Dartmouth College
Chemical Hygiene Plan
2017 (Revision 11)

Office of Environmental Health and Safety

Arts and Sciences
Geisel School of Medicine
Thayer School of Engineering

This document is available to all Dartmouth laboratories using hazardous chemicals

Policy	Chemical Hygiene Plan	**Page:**	1
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Dartmouth College Chemical Hygiene Plan

Table of Contents

Introduction:

Hazardous chemicals are a vital tool in teaching and research. The risks of exposure, fire/explosion and injury can be managed with training, planning and the proper equipment. This plan is intended for experienced scientists and will help them mentor new researchers. Competency in the lab can be achieved through training, observation and supervision. This guide is a reference to that end.

What do you need to do?

1- Register your hazardous chemical work with EHS: https://dartmouth.bioraft.com
2- Train and supervise staff and students on an ongoing basis. Laboratory safety training is available from EHS.
3- Develop written procedures for high hazard work to minimize risks.
4- Review your lab space on a routine basis and talk to your lab group about safety!
5- Most importantly – ask EHS for help!

Selected Definitions

Chemical Hygiene Plan (CHP): must be a written document which establishes procedures and policies to protect laboratory personnel and other support staff from the potential adverse health effects associated with exposure to hazardous chemicals.

Chemical Hygiene Officer (CHO): a qualified individual who provides technical guidance in developing and implementing a chemical hygiene plan. At Dartmouth College the CHO is a member of EHS, reporting to the Director. Individual departments or faculty groups should also designate a CHO for their own specific laboratories.

Designated Area: a pre-determined and labeled area in which potentially hazardous chemicals are used and stored. For simplicity, any laboratory at Dartmouth that uses or stores potentially hazardous chemicals is considered a designated area and must be labeled with an EHS provided door sign.

Laboratory Personnel: any person working in a Dartmouth College teaching or research laboratory who handles or uses potentially hazardous chemicals. At Dartmouth, visiting scientists, guest researchers, special volunteers, support staff, students and other similar personnel are included in the scope of the Chemical Hygiene Plan.

Laboratory/Laboratory Scale/Laboratory Use: a workplace in which relatively small quantities of hazardous chemicals (usually several) are used in a non-production basis and which the tasks performed are generally managed by one person.

Basic Chemical Hazards and Toxicology Terminology

Chemical hazards can be broadly broken into four categories defined as follows:

1) Flammable and Combustible Liquids

Liquids with a flash point at or below 140°F are considered flammable, those with a flash point below 200°F are combustible (see table below). The local fire departments set and enforce flammable storage limits. Always store flammable liquids in rated cabinets when not in use and never store them on the floor or near heat or ignition. Extremely flammable liquids are those that flash below 73° F, these have stricter limits. Contact EHS for assistance in determining your flammable liquid storage limits and options to ensure safety.

Flashpoint	<73°F	73 - 140° F	140 - 200° F
Description	Extremely Flammable	Flammable Liquids	Combustible Liquids
Storage limits with rated cabinet	1 Gal/4 Liters	20 Gal/80 Liters	40 Gal/160 Liters

2) Corrosives

This includes solids and liquids at the pH extremes and those that can damage intact skin or mucous membranes on contact. Contact with corrosives must be eliminated by minimizing volumes/use and continuous use of protective equipment (gloves and chemical splash goggles). The federal hazardous waste laws go further to define corrosive wastes as any liquid with a pH <2 (acid) or >12.5 (base). These wastes must be collected for disposal by EHS and cannot be neutralized without a permit from the state of New Hampshire.

3) Reactives

Highly unstable compounds or chemicals that react with air (i.e. white phosphorous), water (i.e. sodium metal), heat (azobisisobutyronitrile), friction/shock (picric acid) to explode, decompose violently, ignite/burn, give off toxic gasses (i.e. sodium cyanide or sulfide) or polymerize/self heat (monomers). Additional considerations must be given for compounds that if combined with other compounds in a procedure, will explode or become uncontrollable. In general these are materials that may undergo chemical or physical changes during routine use to generate by-products that may overcome standard control measures or penetrate available personal protective equipment to cause severe acute or lethal injuries.

4) Toxic Materials

Toxic materials can harm humans or the environment and can be measured in a variety of ways. Toxicity is broken into acute (single or one time exposures with immediate effects) and chronic hazards (lower, long term exposures and/or delayed effects). In reality many toxic materials can produce both acute and chronic health risks with effects that are duration and dose dependent. More importantly, the toxic effects of many research chemicals have not yet been thoroughly identified. With that said the following terms are important in evaluating toxicity:

Extremely Toxic Chemicals: generally substances with lethal dose values of 5mg/kg or lower are considered extremely or super toxic. This is equivalent to as little as 7 drops or even a taste of the pure substance causing death in a 150-lb. person. Lethal dose information can be found on MSDS/SDS sheets and from online and printed resources, always use the lowest published LD or LD_{50} data irrespective of the route of entry or organism tested.

Particularly Hazardous Substances: these include "select carcinogens", reproductive toxins and substances that have a high degree of acute toxicity. A substance is considered to be “Particularly Hazardous” if it has an $LD_{50} \leq 50$ mg/kg (approximately one teaspoon for a 150 lb. person) or carries a “skin” designation.

Permissible Exposure Limit (PELs): OSHA's legally enforceable exposure limit for a hazardous chemical (also see TLV's or threshold limit values – both can be found on MSDS/SDS sheets).

Potentially Hazardous Chemical: a substance which is recognized to have a measurable potential for adverse (acute or chronic) health effects in humans. The Federal Hazard Communication Standard provides additional guidance in determining the extent of the hazard presented by a chemical.

Reproductive Toxins/Teratogens: chemicals that affect an individual's reproductive ability including chromosomal damage (mutations) and/or have an adverse effect on an embryo/fetus (teratogenesis).

"*Select Carcinogen*": a substance regulated by OSHA as such, as designated by the National Toxicity Program (NTP) or the International Agency for Research on Cancer (IARC) as having a moderate to high potential for causing cancer in humans or in animal models. The most current "Report on Carcinogens" is available from the National Toxicology Program (http://ntp-server.niehs.nih.gov/).

"Skin" Designation: The American Conference of Governmental Industrial Hygienists (ACGIH) designation for chemicals with potentially significant contributions to exposure via skin contact (including eyes and mucous membranes).

Threshold Limit Values (TLVs): occupational exposure limits established by the American Conference of Governmental Industrial Hygienists (ACGIH). At Dartmouth we rely on TLV's, which generally reflect current exposure research for determining occupational exposures.

Acute Toxicity Table:
Items in red denote particularly hazardous substances where additional care is required.

Toxicity Classes per. Gosselin, Smith and Hodge		
Probable Oral Lethal Dose (Human)		
Toxicity Rating	Dose	For 70-kg Person (150 lbs)
6 Super Toxic	< 5 mg/kg	1 grain (a taste - less than 7 drops)
5 Extremely Toxic	5-50 mg/kg	4 ml (between 7 drops and 1 tsp)
4 Very Toxic	50-500 mg/kg	30 ml (between 1 tsp and 1 fl ounce)
3 Moderately Toxic	0.5-5 g/kg	30-600 ml (between 1 fl oz and 1 pint)
2 Slightly Toxic	5-15 g/kg	600-1200 ml (between 1 pint -1 quart)
1 Practically Non-Toxic	Above 15 g/kg	More than 1200 ml (more than 1 quart)

Regulatory Background:

This plan outlines the minimum standards for hazardous chemical use in laboratories at Dartmouth College. The Occupational Health and Safety Administration (OSHA) Laboratory Standard (29 CFR 1910.1450) requires the development and implementation of a “Chemical Hygiene Plan”. Specifically this must be a formal, written and employee-accessible program that is "capable of protecting employees from health hazards associated with hazardous chemicals used in the laboratory". The Dartmouth College Chemical Hygiene Plan applies to laboratory work areas while the Dartmouth College Hazard Communication Program applies to non-laboratory chemical use on campus.

Scope:

This plan applies to all laboratories and laboratory personnel at Dartmouth College that use, store or handle hazardous chemicals. All laboratory personnel who work with or around hazardous chemicals must have access to and be familiar with this plan.

Responsibilities:

- Principal Investigator/Course Professor is responsible for the implementation and oversight of this policy in his/her laboratory or course. This includes providing students and staff with specific information and training beyond this plan on the unique hazards of their lab work and documenting this activity. The Principal Investigator/Course Professor is responsible for the day-to-day health and safety management of their laboratories and ensuring compliance with EHS waste disposal requirements.

- All laboratory personnel who use, store and handle hazardous chemicals are required to abide by the minimum requirements set forth in the Dartmouth Chemical Hygiene Plan and any requirements specific to their school or department. All laboratory personnel must follow the waste disposal requirements set forth by EHS.

- EHS is responsible for ensuring the effectiveness and evaluation of the Dartmouth College Chemical Hygiene Plan. EHS provides support and technical assistance in the safe use, storage and disposal of hazardous chemicals.

- The Dartmouth College Laboratory Safety Advisory Committee (LSAC) is made up of faculty representatives from the different schools and departments and is responsible for general oversight of the Colleges chemical safety program. The committee serves as a peer review mechanism for faculty who wish to use high hazard chemicals or procedures.

Minors and volunteers working in laboratories:

Enabling volunteers, visitors and undergraduate students to work in our research laboratories is an important part of research and teachign. Additional insurance and legal responsibilities apply when welcoming inexperienced personnel into your lab.

- Children 14 years of age and under are prohibited from entering (including working) in hazardous materials use labs unless special arrangements are made with the office of risk management and EHS.
- Children ages 15-17 are allowed to enter or work in hazardous materials labs provided they are under constant supervision of a responsible lab member. This lab member is accountable for the activities in the lab and may be a faculty member/principal investigator, lab manager or senior lab staff. The responsible lab member must ensure that all visitors/workers have the appropriate training, protective equipment and are informed of potential hazards in the space.
- Contact Human Resources for children 15-17 who are compensated for any work in a laboratory.
- The safety of all laboratory workers (undergraduates, visitors or others) is ultimately the responsibility of the Principal Investigator (PI).
- The PI (or designee) must inform undergraduates, visitors/volunteers or high school students of the hazards of their work and provide appropriate training and personal protective equipment **before** work begins. This training should be specific to the chemicals used (review MSDS/SDS etc.) and the processes employed (heat, pressure, glassware handling etc.).
- Document all training with the date, location, trainee signature and outline of material covered. Keep these records in the laboratory for audit or review.
- All work with hazardous materials or processes must be adequately supervised. Students and others must never work alone or without detailed procedures and instructions.
- In addition to training and supervision provided by the principal investigator, all new researchers should complete appropriate EHS training programs in basic laboratory safety and waste management.
- Work with ionizing radiation or biological hazards must comply with Radiation Safety Committee and Institutional Biosafety Committee requirements and limitations.

Registration of hazardous chemical work with EHS

All work with hazardous chemicals needs to be registered with EHS. PI's, faculty, instructors and supervisors are responsible for notifying EHS of planned work involving hazardous materials. EHS has developed a registration process available through Bioraft at: https://dartmouth.bioraft.com. More information on Bioraft is available on the site, if you don't have a lab set up in Bioraft simply contact EHS to get started.

Minimum Requirements in Dartmouth College Laboratories:

Administrative Controls:

- Each PI/laboratory supervisor must ensure that all laboratory personnel under their direction possess the requisite knowledge, training and education to safely handle hazardous chemicals in the laboratory.
- All laboratory personnel are responsible for following appropriate work practices when using hazardous chemicals.
- Hazardous chemical work in laboratories must be registered with the EHS department through Bioraft. This information should be updated as research and chemical inventories change.
- Avoid work with hazardous chemicals alone or at night when assistance and emergency response capabilities are limited. Use a partner system and work only with the approval of the PI or faculty member directing the research

"Designated Area" and Facility Controls:

- Laboratories where hazardous chemicals, infectious materials, radioactive materials/sources or physical hazards exist must have provisions for restricting access by unauthorized persons.
- Food, drinks, cosmetics and medication for consumption or use are prohibited inside laboratories where hazardous chemicals are used or stored.
- Hazardous chemicals may only be used in laboratory facilities specifically designed and engineered for such work. They may not be used in areas not intended for such use; including (but not limited to) offices, storage rooms, shared equipment areas, cold rooms and other areas lacking the appropriate infrastructure and a proper means of ventilation.
- Use an uncluttered chemical fume hood when opening, pouring or handling chemicals or substances that would otherwise enter the atmosphere without containment. Minimize all chemical exposures and avoid an underestimation of the risk - never deliberately taste or smell chemicals and absolutely never mouth pipette.
- Containment and ventilation should be the primary method to prevent inhalation and control flammable vapors, respirators are only appropriate as a secondary control. Respirator use requires training from EHS. It is your responsibility to report ventilation needs or problems (malfunctions, alarms or evidence of failure) to facilities maintenance personnel.
- Keep all doors to the laboratory closed when using the fume hood to ensure proper hood operation. Open laboratory doors can adversely effect hood performance.
- Ensure unrestricted access to a suitable eyewash station and drench shower. A person with compromised vision should be able to reach the eyewash or drench shower in less than 10 seconds. In the event of a hazardous chemical exposure or spill, move to a safe location and flush exposed area with water.

Personnel Controls

- Always select and wear the right personal protective equipment when handling hazardous chemicals. That may include chemically resistant gloves, chemical splash goggles, face shields, safety glasses, lab coats, fire resistant clothing, aprons or chemically resistant coveralls depending on the hazards posed by your work. Assistance in selecting protective equipment is always available from EHS.
- Protect your clothes and exposed skin through the use of laboratory coats or gowns. Open toed shoes, sandals, shorts and other apparel that leave exposed skin are prohibited when handling hazardous chemicals. Lab coats must not be worn outside of research areas--such as to the library, outside of the building, etc.
- Keep all containers tightly closed when not in use. All waste collection containers must also be kept closed. Evaporation of hazardous chemicals is not an approved disposal method.
- Good housekeeping is mandatory in all laboratories using or storing hazardous chemicals. Ensure that all chemical spills are cleaned up promptly and safely. Dispose of old chemicals, mixtures and solutions routinely (after each term). Keep exit routes, emergency eyewash and safety shower access clear. Keep clutter to a minimum in fume hoods, workbenches and on the floor. Ensure trash, recycling, sharps and chemical wastes are promptly and properly disposed of.
- If you need to ship or transport hazardous chemicals contact EHS for training and assistance. Never put chemicals in the mail, in your personal vehicle, college vehicles or allow movers or contractors to handle or move them unless arranged through EHS. Concealing hazardous chemicals in the mail or shipment via air is forbidden and may result in federal penalties.
- Hazardous chemicals can be safely transported within and between buildings using bottle carriers and suitable carts. Avoid riding elevators with cryogens, toxic compressed gasses, air or water reactive chemicals and highly toxic or volatile materials.
- After working with laboratory chemicals, carefully remove your gloves and thoroughly wash your hands and forearms. In all circumstances, wash your hands before leaving the laboratory. Remove gloves before leaving the lab or touching commonly used surfaces like doorknobs, telephones, etc.
- Never dispose of hazardous chemicals down the drain, in the trash or via evaporation, it is a violation of federal, state and local regulations.

Information and Training:

EHS provides basic laboratory safety training that covers the safe handling and disposal of hazardous materials through the Bioraft web site and in person. The PI and/or laboratory supervisor are responsible for providing health and safety information to his or her staff on the specific hazards found in their laboratory on an on-going basis. Documentation of this activity should be kept in the lab (See Appendix E for a sample training sign in).

The hazard communication training module on the EHS web site is designed to provide support staff (Facilities, Operations and Management (FO&M) and DMS facilities) with training on basic chemical hazards, MSDS/SDS sheets, selection of personal protective equipment and emergency response initiation (awareness level training) for work in and around lab facilities. The academic and research community has an obligation to communicate potential health hazards to any individual working in your area. Specific tasks are evaluated by facilities supervisors and may require additional training or specialized contract personnel.

Safety Data Sheets:

The Occupational Safety and Health Administration (OSHA) requires that information on the physical and health effects of hazardous chemicals be readily available to employees who must work with or potentially be exposed to such substances (29 CFR 1910.1200 and 29 CFR 1910.1450). The required form of this information are fact sheets--known commonly as Safety Data Sheets—formally known as MSDS. According to OSHA, these sheets must be readily available to employees during working hours in an easily accessible location.

At Dartmouth, an on-line SDS database is available through Bioraft, in addition most SDS sheets can be found through a Google search. SDS sheets are a good starting point for safety and handling information, they can be supplemented by literature searches and use of safety databases (i.e. National Toxicology Program, EPA Integrated Risk Information System)

In addition to the online system, laboratories must keep copies of current MSDS/SDS sheets for any commercial products used in the lab (mixtures, experimental compounds, proprietary compounds etc.) and any MSDS/SDS sheets not available through online sources.

Labeling Containers in the Laboratory

Container labels are an essential form of hazard communication in the lab and are required by law. They provide information to you, your co-workers and even regulatory inspectors or emergency response personnel. It is essential that all containers in the lab have, at a minimum a legible label to identify the contents – even if it is water or benign material.

Hazardous chemical containers must have the following:

- Original manufacturer label with the date received written on it – OR-
- Printed label identifying the contents, concentration, primary hazards, owner and date prepared.

Personal Protective Equipment:

Personal protective equipment (PPE) is a vital means of worker protection, but it should be used in combination with fume hoods, safety shields and work enclosures. Additional guidance on the use of PPE can be found in OSHA 29 CFR 1910.132 and in the Dartmouth College Personal Protective Equipment Policy.

Eye/Face Protection: Minimum protection for chemical work is impact resistant safety glasses, splash Goggles are required for handling toxic or corrosive liquids in larger quantities (>100ml) or in high risk systems (pressurized or aerosolized). Face shields may be used in conjunction with goggles or glasses for additional impact and splash protection. Contact EHS for help with specialty eyewear for UV light, lasers or welding. Look for the ANZI Z87 stamp on all protective eyewear.

Hand Protection: Minimum protection for lab scale chemical work is available from disposable nitrile gloves (4 mil thick). These gloves provide a barrier to exposure and are disposable (single use). High-risk work (toxics or high probability exposure scenarios) may require impervious reusable gloves, consult permeation guides to select the best glove. Specialty gloves (for handling cryogenic material/high heat applications, or cut protection) can be ordered. Contact EHS if you need assistance in selecting the proper type of gloves for the chemicals you handle.

Protective Clothing: Flame resistant lab coats for work with solvents, basic lab coats, chemically resistant aprons, coveralls and shoe covers are available in a variety of styles, both disposable and reusable. Contact EHS for help selecting the proper type and check out the stockrooms to see what they have.

Respiratory Protection: Respirators should not be used in the laboratory without prior approval of EHS. Laboratory supervisors are not authorized to select or recommend the use of respiratory protection, **regardless of the type.** Call EHS if you feel that you need respiratory protection. (The selection, fitting and use of respirators is referenced in OSHA standard 29 CFR 1910.134)

Lab Coats

Policy: Lab coats are required at Dartmouth when working with hazardous materials including work with hazardous chemicals, unsealed radioactive materials, and biological agents at BL2 or greater. In some cases, through a hazard assessment, laboratory supervisors may identify situations (a task, experiment, or area) where alternative or more protective apparel must be worn.

When properly used, lab coats:

- Provide protection of skin and personal clothing from incidental contact and small splashes.
- Prevent the spread of contamination outside the lab (provided they are not worn outside the lab).
- Provide a removable barrier in the event of an incident involving a spill or splash of hazardous substances.

Limitations of Lab Coats

In general, protective clothing, including lab coats, should not be used as a substitute for engineering controls such as a fume hood, a glove box, process enclosure, etc., or as a substitute for good work practices and personal hygiene. For significant chemical handling, it will be necessary to supplement lab coat use with additional protective clothing, for example, a rubber or vinyl apron for handling large quantities of corrosives or hydrofluoric acid, or it may be preferable to use chemical resistant coveralls for full body protection. Conversely, use of engineering controls such as fume hoods do not preclude the need for wearing the proper PPE, including lab coats.

Some known limitations of lab coats include:

- Lab coats are not designed to be the equivalent of chemical protection suits for major chemical handling or emergencies.
- There are no design or test criteria specified in regulations or guidelines specific to lab coats. What this means is that:
    - Lab coats are not tested for typical conditions that might be encountered in a research lab with respect to chemical use, or combined research activities.
    - There is little or no information provided by manufacturers or distributors about the capability of a lab coat for a combination of hazards. A coat that is described as “flame resistant”, such as treated cotton, may not be chemical resistant or acid resistant.
    - A coat that is advertised as flame resistant has not been tested using criteria involving flammable chemicals on the coat. The term “flame resistant” refers to the characteristic of a fabric that causes it not to burn in air. The testing criteria involves applying an open flame to the bottom edge of a strip of fabric in a test chamber for 12 seconds and then looking at char length, after flame, and after glow, testing the self extinguishing properties of the fabric. The flame resistance test criteria were intended to

simulate circumstances of a flash fire, or electric arc flash, not a chemical fire.

Selection - Hazard Assessment

With the limitations above in mind, lab coats are made of different materials, and it is important to select a coat or coats of appropriate material for the types of hazards in the lab. The first step in this selection process is to determine the types of hazards that exist in your lab and the reasons for the lab coats. Some questions to consider are the following:

- Does your lab work primarily with chemicals, biological agents, radioisotopes, or a mix of things?
- Are the lab workers undergraduates or graduate students and professional techs.
- Does your lab work involve animal handling?
- Are there large quantities of flammable materials (>4 liters) used in a process or experiment?
- Are there water reactive or pyrophoric materials used in the open air, e.g. in a fume hood instead of a glove box?
- Are there open flames or hot processes along with a significant amount of flammables?
- How are hazardous chemicals used and what engineering controls are available, e.g. a fume hood or glove box?
- Is there a significant risk of spill, splash or splatter for the tasks being done?
- What is the toxicity of chemicals used and is there concern about inadvertent spread of contamination?

Choosing the Right Lab Coat - While there are many different style features, from a protection standpoint the best coats have the following characteristics:

- Tight cuffs (knitted or elastic)
- Snap closures on the front for easy removal in case of contamination
- Coats with different properties are easy to tell apart (ex: FR coats should have outer markings clearly identifying them as FR coats and can be ordered in a different color than other coats present in the lab)
- Proper fit
- Appropriate material for hazards to be encountered

One coat may not work for all lab operations. Some people may want to provide a basic poly/cotton blend coat for most operations, but have available lab coats of treated cotton or Nomex for work involving pyrophoric materials, extremely flammable chemicals, large quantities of flammable chemicals, or work around hot processes or operations. If chemical splash is also a concern, use of a rubber apron over the flame resistant lab coat is recommended. Lab coat materials may be made of materials for limited reuse, or disposable one time use.

Flame Resistant (FR) Lab Coats

Work with pyrophoric, spontaneously combustible, or extremely flammable chemicals presents an especially high potential for fire and burn risks to the skin. EHS recommends the use of fire retardant or fire resistant (FR) lab coats to provide additional skin protection where the individual will be working with these chemicals. The primary materials used for FR lab coats are FR-treated cotton or Nomex. Further information is available in the table at the end of this document, as well as from EHS.

Getting a Lab Coat - The Supervisor/PI is responsible for assuring that required PPE, including lab coats, is available, used, and maintained. There are several methods in which a lab can obtain lab coats.

- Rental coats/Laundry Service – there are a number of companies (Cintas, UniFirst) capable of providing lab coats in a rental/laundry system. The benefits of this type of program are that it limits up-front costs for labs and can include free repairs or replacements for coats damaged through normal wear and tear. Contact EHS and procurement for more information.
- Purchase reusable lab coats - Lab coats can be purchased from many sources; the table at the end of this document includes ordering information for a variety of coat styles offered Lab Coat Vendors.
- Purchase disposable lab coats -> Disposable coats can be purchased from companies such as VWR. For environmental and cost reasons this is generally not the best solution. However, in cases where lab coats are rarely needed, or when a type of material not generally available in a reusable style is needed, this can be a viable option.

Lab Coat Use - When lab coats are in use, the following should be observed:
- Wear lab coats that fit properly. Lab coats are available in a variety of sizes. Some lab coat services also offer custom sizes (e.g., extra long sleeves, tall, or woman's fit). Lab coats should fasten close to the collar to provide optimal protection.
- Lab coats should be worn fully buttoned or snapped with sleeves down.
- Wear lab coats only when in the lab or work area. Remove lab coats when leaving the lab/work area to go home, to lunch, to the restroom, or meetings in conference rooms, etc.

Spill or Splash

Laundry services are not equipped to handle significant contamination of lab coats with hazardous materials. In the event of a significant spill of a hazardous material on the lab coat, remove the coat immediately. If skin or personal clothing is impacted, it will be necessary to proceed to an emergency shower. Remove any contaminated clothing, and shower. Generally, significantly contaminated coats and clothing will be considered a hazardous waste, and must be managed based on the type of contamination. If you have questions about significance of contamination from a specific incident, contact the EHS Office.

If your coat becomes contaminated, please notify EHS. If the coat must be discarded, document the loss of the coat, and if the coat is part of a laundry service, notify the lab coat provider.

Lab Coat Cleaning/Rentals -

Personnel are not allowed to launder lab coats at home. Clean non-disposable soiled lab coats routinely by use of a laundry service or work area washers and dryers. Frequency of cleaning will depend on the amount of use and contamination.

Laundry Services - A number of area laundry services provide routine laundering of reusable lab coats. Do not use a local dry cleaner that does not specialize in lab coats as they generally are not familiar with proper handling of potentially contaminated items.

Services available from lab coat preferred vendors include:

- Rent or buy lab coats in a variety of materials (100% cotton, poly/cotton blends, flame resistant cotton, Nomex, etc).
- Perform custom-tailoring of coats
- Repair minor damage (ex. Lost snaps, torn pocket)
- Pick up coats on a weekly, biweekly, monthly, or on-demand schedule
- Provide storage options for clean and soiled coats
- Service individual labs or centralized service areas

In negotiating with a vendor, you should be sure they understand the possible contamination that may be on the lab coat. See the Spill or Splash section for more information on what to do in the event of contamination.

In addition to providing lab coats and laundering them, the lab coat companies can also provide solutions to some of the most common problems encountered when setting up or managing a lab coat system. For example, in many areas space is limited. These companies have experience assessing available space and can provide multiple solutions on how to best store clean and soiled lab coats so they are conveniently located yet do not take up valuable lab space.

Lab Coat Information Table

Material	Vendor and Model Info	Splash Resistance / Chemical Resistance / Flame Resistance	Uses / Comments
Polyester / Cotton Blend.	Suppliers: Cintas - Model:	No flame resist. – burns. May be fluid resistant. Check	Lightweight breathable. The more cotton, the more breathable. Most

80/20 65/35 40/60 (Recommend at least 65/35 for chemical research lab setting.)	59925 VWR	information from manufacturer. Unknown chemical resistance. Anecdotally, better for work with acids than cotton.	common for clinical settings, poly/cotton coats should not be worn for handling flammable or pyrophoric.
100% Cotton	Supplier: Cintas/ White Swan Model: 650 Supplier: North Star Manufacturer: Fashion Seal Model: 420	No flame resistance – burns. Not fluid resistant or fluid proof. Degraded by acids. Anecdotally, more resistant to solvents.	Lightweight breathable
FR treated materials (either 100 % Cotton or primarily cotton treated with flame retardant)	Supplier: Cintas - Red Kap Model: KP72WH Supplier: North Star Manufacturer: Bulwark Model: KEL2LB	Variable flame resistance. Not necessarily fluid resistant. Degraded by acids. More resistant to solvents. Not generally tested for chemical resistance.	For lab settings with significant fire hazard. Supplement with an apron for acid handling. No bleach should be used by the laundry service.
Dupont Nomex	Supplier: Cintas Manufacturer: White Knight Model: OM60 Supplier: North Star Manufacturer: Bulwark Model: KNL6RB	Flame resistant. Unknown splash and chemical resistance. There is a claim for chemical resistance but specific testing information could not be found.	Expensive Breathable. Flame resistance is maintained even with laundering, provided bleach is not used.
Polypro lab	Various models	No flame or fluid	Breathable Intended for

coat.	available from VWR Ex: VWR Cat. #414004-346	resistance.	non-hazardous environment such as animal handling and clean rooms. Burns readily.
VWR Microbreathe Lab Coat	Available from VWR VWR cat. #14001-814	No flame resistance. Fluid resistant for blood and body fluids and chemicals	Breathable Disposable. For clinical and biological lab settings, and some chemical labs. Snap front, so can be readily removed. Not good for settings with significant fire hazard.
Kimberley Clark A65 Lab Coat (Disposable FR Coat)	Available from VWR through ECAT.	Flame resistant. No Information on fluid.	Breathable Product literature mentions lab use.

Safe Storage and Disposal of Hazardous Chemicals:

- Incompatible chemicals must be physically separated during storage. This means segregating chemicals by physical properties – flammables, oxidizers, acids, bases and storing them in appropriate cabinets or containment bins (bins are free from EHS). A segregation chart is available in the laboratory safety calendar and online.

- Fire code requires that flammable liquids be stored in rated storage cabinets when not in use. These are typically double walled metal cabinets stamped with the "FM" rating. They are designed to protect the flammables inside from small potentially self-extinguishing fires in the lab. The total amount of flammable material allowed in any lab is limited by code, never store more than you can fit in your rated cabinets. Small volumes (2 liters or less) can be stored in standard cabinets away from heat or ignition sources.

- Never store hazardous chemicals under sinks, over-head, on countertops or open shelves. Specially designed cabinets are best, but cabinets with doors will do. Use plastic bins (available from EHS) as secondary containment for liquids and to segregate incompatible materials. Contact EHS for assistance.

Emergency Procedures:

When you hear a fire alarm: Shut off all open flames. Safely store hazardous materials if time permits. Leave your work location. Shut all doors behind you as you leave. Evacuate the building through the nearest FIRE EXIT. Do not use elevators.

You must exit your laboratory and the building during all fire alarms. Chemical spills may present insidious hazards you cannot smell or see, so don't rely on your nose – just get out. Failure to do so is illegal and can result in disciplinary action from the Police or the College.

Chemical Spills:

Chemical spills are a simple fact of life in teaching and research laboratories. Controlling the extent of a chemical spill requires planning and a prompt response. Using shatter resistant primary and secondary containers can prevent many chemical spills.

In the Event of A Chemical Spill

Small spills involving chemicals you are familiar with can be safely handled within the laboratory. All spilled material must be collected, labeled and stored for disposal by EHS.

Every lab that uses hazardous chemicals should have a spill kit (contact us to request one). The kits contain inert absorbent pads that work on all spills, solvents, aqueous materials or acids/bases. The kits also contain bags and hazardous waste labels for packaging contaminated spill debris. Safely store spill debris in a chemical fume hood and contact EHS to request a waste pick up. All spills and near misses should be reported to EHS, simply email us and describe the incident so we can all learn from it.

Leave the area, close all doors and call for assistance if any of the following occur…

- For fire or potential for a fire – Pull nearest fire alarm pull station, evacuate the building and go to a safe location to dial 911.
- Serious injury or exposure to a hazardous material -- dial 911.
- Spill is beyond your ability to control.
- Spill has left the immediate area or threatens other areas.
- Unknown materials are involved.

Reporting a Chemical Spill:

Notify everyone in the room (or area) that a spill has occurred.
If needed provide immediate first aid.

Eliminate potential sources of ignition, such as lights, motors or open flames.

Leave the room (or area) immediately and close the door behind you.

Secure the area and prevent others from entering.

If a fire, potential fire or medical emergency is **not** involved, call **646-1762** to report the spill to Dartmouth College EHS. On weekends and after hours follow the paging instructions.

> *Remain near the phone and keep the line clear. Please state your name, exact location, the chemical spilled and any special circumstances. Be ready to provide the telephone number of the location you are calling from to EHS. Remain nearby until help arrives.*

Do not re-enter the area until the appropriate authorities determine that the area is safe.

First Aid for Chemical Contamination:

*Go to the nearest eyewash station or safety shower.

*Flush the contaminated area with large volumes of water.

*While flushing, remove any clothing that may have been contaminated.

*Continue flushing until the fire department arrives.

* Provide the MSDS/SDS(s) of spilled chemical(s) to EMS/emergency room personnel.

Procedures for Power Outages or Service interruptions:

If the power in your lab should be interrupted for any reason immediately stop all work, seal all chemical containers, shut off or unplug equipment and lower all chemical fume hood sashes. Your local ventilation will not work or may be diminished so if there is potential for the generation of toxic airborne contaminants immediately exit the lab and contact EHS. The building should have emergency power for a few essential services but this is not intended to allow continued use of the lab. For your own safety secure all reactions, containers and equipment, close the doors and leave the lab.

Take special care with potentially unstable reactions that require cooling water and with any work involving a glove box, pyrophoric/water reactive or temperature sensitive chemicals. Contact EHS if you have concerns about potentially long term power interruptions and the stability of your chemical inventory or reactions.

Air Monitoring & Exposures to Hazardous Chemicals:

Local exhaust ventilation systems such as chemical fume hoods, engineered enclosures and glove boxes are the preferred and primary method of controlling exposures to hazardous chemicals in the laboratory. Assuming that the fume hoods and other appropriate methods of containment are used properly the need for routine monitoring of airborne contaminates in the laboratory is unnecessary and impractical.

When a concern does arise over potential exposure to a laboratory chemical, assistance is available from EHS. Contact EHS at 646-1762 for assistance. As required by the laboratory standard, exposures to OSHA regulated chemicals in the laboratory must *not* exceed the Permissible Exposure Limits (PELs) or the recommended Threshold Limit Values (TLVs) when there is no PEL.

Special Note on Pregnancy:

Personnel who are pregnant or considering becoming pregnant may have special concerns about working with chemicals that have potential reproductive hazards. Such concerns can be discussed with their supervisor and EHS. All inquiries are confidential. Disclosure of pregnancy is not mandatory but EHS does encourage early consultation with a medical professional, as the first trimester is an important phase in pregnancy.

Medical Consultation:

Medical consultation and evaluation are available to Dartmouth College employees upon request. Contact EHS to discuss potential occupational exposures or to request a consultation with a doctor through the Occupational/Employee Health Program located at Dartmouth-Hitchcock Medical Center (DHMC) or through Alice Peck Day.

In general, medical follow-up is required:

- In the event of a spill or an event that results in an acute chemical exposure.

- When signs or symptoms develop that may be associated with potential exposure(s) to chemicals used in the laboratory.

- When chemical exposure monitoring data reveals an exposure at or above the action level for an OSHA regulated substance.

Services Provided by EHS:

Periodic audits of laboratories are conducted by EHS to ensure compliance with the requirements of the College's Chemical Hygiene Plan. A lab safety checklist for staff and researchers can be found in Appendix B. Training and information are also provided on an on-going basis to promote and increase awareness. Annually, EHS hires a third party to inspect each chemical fume hood to ensure that it is working and being used properly.

Services Provided by Facilities:

- Repair and preventive maintenance of chemical fume hoods and other local exhaust systems.
- Repair of electrical or other physical hazards in your facilities.
- Inspection of fire extinguishers
- Periodic testing of safety showers.

Working With Particularly Hazardous Substances:

These substances include "select" carcinogens, reproductive toxins and chemicals that have a high degree of acute or chronic toxicity. Acute toxicity can be defined with LD^{50} data (the dose which is lethal to 50% of the test population), any substance with a published $LD^{50} < 50$mg/kg (any route of exposure) should be considered highly toxic. Substance specific information is available in Appendix H and through the EHS Office (646-1762).

The laboratory supervisor is responsible for ensuring that appropriate additional precautions are taken when working with such chemicals.

General Procedures for High Hazard Substances

* Maintain an accurate record of who uses these substances and the amounts used and stored in the laboratory.

* In the event that toxicologically significant quantities of a particularly hazardous substance are used on a routine or frequent basis, contact EHS at 646-1762 to determine if medical surveillance may be warranted.

* Particularly hazardous substances must be kept in a secondary container to help prevent breaks and spills. This secondary container should be opened inside a chemical fume hood.

* A suitable label should be attached to this secondary container to alert others of the chemical contained therein and (if required) the need for special precautions. *For example: Warning -- Cancer Hazard or Highly Toxic.* Such labels are available from EHS.

* Access to the laboratory should be controlled by the use of appropriate signs that warn of the hazards and indicate the precautions or approval needed for entry. Doors must be kept closed at all times.

* Additional containment devices (such as, glove boxes, shielding or protective filters) may be needed to safely handle, store or protect equipment when using these chemicals.

Note: Any chemical that carries a “skin” designation warning must be treated with extreme caution. Follow the guidance found on the EHS calendar regarding *Essential Information on the Selection and Use of Chemically Resistant Gloves in the Laboratory* concerning the use of flexible laminate gloves as a permeation resistant liner.

*In addition to the use of the proper gloves, eye/face protection and other protective apparel or equipment may be needed. Examples could include chemically resistant gowns, aprons, gauntlets or other specialized protective equipment.

* Work surfaces should be protected from contamination through the use of disposable, absorbent, plastic backed paper. Replace contaminated paper as necessary and handle as hazardous waste.

* On completion of work and before leaving the laboratory, remove all protective apparel and thoroughly wash hands and forearms.

Regulated Carcinogens

Work with the following carcinogens on high volume and regular basis requires additional care and may include exposure monitoring and medical screening:

2-acetylaminofluorene
acrylonitrile
4-aminodiphenyl
arsenic
asbestos
benzene
benzidine (and salts)
1,3-butadiene
cadmium
bis-chloromethylether
1,2-dibromo-3-chloropropane
3,3'-dichlorobenzidine
4-dimethylaminoazobenzene
ethyleneimine
ethylene dibromide
ethylene oxide
formaldehyde/formalin
lead
methylchloromethylether
methylenebischloroaniline
methylenedianiline
α and β-napthylamine
4-nitrobiphenyl
N-nitrosodimethylamine
β-propiolactone
vinyl chloride

Formaldehyde use in the Lab

The use of formaldehyde in the lab may be subject to the Occupational Safety and Health Administration's (OSHA) Formaldehyde Standard (29 CFR 1910.1048) as well as the OSHA laboratory standard. See Appendix H for an OSHA fact sheet on formaldehyde. These procedures apply to all occupational exposures to formaldehyde.

Background

Formaldehyde is a pungent low molecular weight gas that is easily soluble in water. What we typically think of as formaldehyde is actually a 37% (by weight) solution with methanol added to inhibit polymerization. It is combustible when exposed to heat or flame and can react vigorously with oxidizing materials. Polymerized formaldehyde is known as paraformaldehyde, which when in solution can yield free formaldehyde.

Formaldehyde is a human carcinogen and may cause nasal cancer, lung cancer, and possibly brain cancer and leukemia. Workers who are exposed to airborne concentrations of formaldehyde in excess of 0.1 parts per million may experience irritation of the eyes, nose, and throat, as well as coughing, wheezing, chest pains and bronchitis.

OSHA requires that a range of services and controls be established to limit exposure to formaldehyde.

Safe Work Practices

- Formaldehyde must be used with containment ventilation and certified chemical fume hood should be the first choice. Down draft or perfusion tables can also be effective but may require modified work practices and are generally less effective than containment hoods.
- Chemically resistant gloves must be worn. Heavy-duty nitrile or neoprene is best. Disposable NDEX® gloves may be worn when there is a limited splash hazard but must be changed routinely and whenever they become contaminated. Latex gloves are not acceptable.
- Eye protection must be worn. At a minimum, safety glasses for volumes of 500 ml or less. Splash goggles are required for greater amounts.
- If formaldehyde is used routinely, in large quantity or for perfusions, contact EHS to arrange exposure monitoring. Assuming good laboratory practice is followed, potential exposures should be well controlled. Exposure monitoring provides a useful assessment of chemical handling and practice. Please contact EHS.

Written Program

This program *supplements* but does not replace the College's Chemical Hygiene Plan (29 CFR 1910.1450). All elements of the Chemical Hygiene Plan (CHP) apply to the use of formaldehyde.

Material Safety Data Sheets (MSDS) for hazardous chemicals including formaldehyde are available on the EHS Web Site.

Formaldehyde Container Labeling

All manufacturer container labels for formaldehyde and products that contain formaldehyde must remain affixed and legible. Stock solutions of formaldehyde if not in the original container must be labeled as required by the CHP and must also include the following label:

"**Formaldehyde: Potential Cancer Hazard & Respiratory Sensitizer**"

All boxes or containers of small vials must be labeled as to the preservative used. If the preservative is formaldehyde, it must be labeled as:

"**Formaldehyde: Potential Cancer Hazard & Respiratory Sensitizer**"

These labels are available from EHS.

Concerns over exposure, potential health effects and safe work practices should be discussed with EHS. Through the EHS Exposure Consultation Program, individuals can receive medical evaluation if they have health concerns. A copy of the OSHA Formaldehyde Standard will be provided to the examining health care professional.

No one is to purchase, use or otherwise have available a respirator without permission and training from EHS. Dust or facemasks will provide little or no protection from formaldehyde exposure. Contact EHS if you have any questions.

Formaldehyde Waste Disposal

- Formaldehyde or paraformaldehyde solutions that are less than 1% may be drain disposed with copious amounts of water.

- Formaldehyde or paraformaldehyde solutions that are 1% and greater must be disposed to EHS as hazardous waste. **Dilution as a means of disposal is not acceptable.**

Protocols for Acute Toxins and Potentially Unstable Materials

Prior review is warranted when working with certain hazardous chemicals/procedures and where there is a significant risk of harm as follows:

* The chemical(s) to be used can cause severe acute or lethal effects upon exposure by any route of entry to quantities of 5 mg/kg or less based on available LD_{50} data.

Note: Chemicals of unknown toxicity but having characteristics that can be reasonably anticipated to make them dangerous should be discussed with EHS.

* Highly unstable compounds or chemicals that, if combined with other compounds in the procedure, will explode or become uncontrollable.

* Compounds are used that may undergo chemical or physical changes during routine use, and generate by-products that may overcome standard control measures or penetrate available personal protective equipment to cause severe acute or lethal injuries.

* Specific chemicals and operations are used that have been determined by EHS to require approval above the level of the laboratory supervisor.

When one or more of the aforementioned criteria is met, the project principal investigator must ensure that:

1. A specific written safety protocol is developed and submitted to the Dartmouth College EHS for review **prior to ordering the chemical or beginning work**. See the sample protocol included in Appendix E of the CHP. The safety protocol should include: (1) a thorough description of the chemical(s) used--including the potential physical and health effects, (2) a step-by-step review of the work to be performed, (3) a list of the required engineering controls and personal protective equipment, (4) where the chemical(s) are to be kept and proper labeling, (5) a description of inventory control and security provisions, (6) provisions for proper waste disposal and (7) decontamination procedures.

2. Evidence of employee training on the safety protocol is available (see Appendix E for a sample sign in sheet). This information must include a review of the safety protocol developed above, expected behaviors in the event of an emergency, the date that training was provided and the name(s) of those trained. Assistance in laboratory safety training is available from EHS.

3. The proposed activities are conducted by specifically trained personnel in accordance with the approved protocol.

Standard Operating Procedure for Handling Pyrophoric Materials

Minimum Protective Clothing:

- Fire resistant or “FR” lab coat (look for “FR” on label)
- Long pants with closed toe shoes
- Safety glasses or chemical splash goggles
- Two pair 4 mil nitrile gloves (single use disposable give the best dexterity)
- Face Shield is optional
- Nomex/Leather flight gloves are optional but recommended

Minimum Protective Equipment:

- Functioning chemical fume hood
- Access to a working eyewash and safety shower
- Access to a fire extinguisher
- Portable lexan shield (optional as space allows)

Training and Work Practices

- A principle investigator must authorize trained personnel to work with reactive chemicals.
- Training must include observation and direct supervision of work to gain experience with specialized equipment and chemicals.
- Minimum training prerequisites available via the EHS website (www.dartmouth.edu/~ehs): view “Handling Pyrophoric Materials” video, hands on fire extinguisher training, general lab safety program, hazardous waste management web module.
- Never work alone, a co-worker must be present in the lab during liquid transfer
- Work in fume hood at all times, keep the sash as low as possible, remove all un-needed chemical containers, waste bottles and combustibles (paper etc.)
- Use a portable lexan shield as space allows.
- Work in dry/inert glove box can provide superior protection but additional training and instruction specific to glove box operation is required. No lab coat is required when working in a glove box. An FR lab coat is required when the air lock is opened to transfer hazardous chemicals.

Emergency Procedures

- Spills or releases of small amounts of pyrophoric materials may self extinguish in the container or hood bench. If this happens, secure all reaction containers and stop work. Report all spills/fires to EHS and your PI, consult with PI to identify causes/solutions.
- Larger spills and/or fires must be treated as an emergency. If possible close the hood sash, step away from the fume hood and send co-worker to pull the fire alarm. Only fight a fire if the fire alarm has been activated and you have been trained in hands on fire extinguisher use and have your exit path clear.

Technical Notes:

- Transfers of small volumes (1-25 ml) can be performed with glass Luer-lock syringe using dry nitrogen/argon and mineral oil bubbler. Never use plastic syringes for handling pyrophorics.
- Transfers of larger volumes (>50ml) must be performed using a cannula with a Schlenk line or similar nitrogen/argon purged apparatus with mineral oil bubbler.
- Check the MSDS/SDS for each pyrophoric to find compatible cooling solvents. In a spill/release acetone and 2-propanol will react violently with certain pyrophoric liquids (i.e. organolithiums). Consider hexane or heptane as alternatives.
- Ensure all systems, glassware, reaction/transfer/sample containers are dried and cooled to room temperature before use.
- Dry and pure Nitrogen or Argon should have no more than 5ppm moisture or oxygen content.
- Argon must be used where lithium metal is a reactant to prevent the formation of lithium nitride.
- Pyrophoricity will vary between chemicals and also based on concentration, age and environmental conditions. Evaporation of carrier solvent can CONCENTRATE pyrophoric solutions and increase the hazard. Always titrate your pyrophoric to determine the concentration before use.
- Reactions with pyrophoric liquids are exothermic, always use larger than normal reaction vessels and provide pressure release on inert systems.

Definitions/Notes:

Pyrophoric chemicals are liquids or solids that can ignite spontaneously in air. This includes n-butyl lithium, t-butyl lithium sec-butylithium, methyllithium, dibutylmagnesium and some phosphines and silanes. Pyrophoric materials can ignite in air via reactions with moisture (i.e. organolithiums) or oxygen (i.e. phosphines). Carrier solvents with low flash points will increase the hazard. Lower concentrations of pyrophoric material in solvent may be classified as less hazardous" spontaneously combustible" or "water reactive" materials. Dispersions of water reactive solids in solvents (sodium hydride, borohydrides etc.) and some solid chemicals can exhibit pyrophoric characteristics under humid conditions. "Air reactive" materials may decompose, generate toxic/flammable gases and subsequently ignite. "Water reactive" chemicals may react with liquid water to generate toxic/flammable gasses and heat causing a subsequent fire. "Moisture sensitive" materials are generally least reactive, and may simply decompose or lose desired activity if exposed to moisture.

References:

Sigma Aldrich technical bulletins AL-134 and AL-164
FMClithium "Organometallics and reactive specialty organics safe handling guide"
FMClithum "Butyllithium safe handling guide"

Solvent Purification and Distillation

Dartmouth College has adopted a policy of purifying all solvents through solvent purification columns that do not use heat or drying agents (i.e. potassium or sodium). This avoids the high-risk thermal solvent distillation procedures that may lead to fires, explosion or personnel exposures. Solvent purification columns have proven their ability to provide dry and pure solvent and are now considered state of the art (see Cournoyer, et.al., ACS Journal of Chemical Health and Safety July/August 2003).

The steps outlined below addresses basic procedures for set up and operation of solvent purification columns at Dartmouth College.

COMMON HAZARDOUS CHEMICALS PURIFIED ON SITE:

FLAMMABLE LIQUIDS: Tetrahydrofuran (THF), Diethyl ether, Toluene, Dimethylformamide (DMF), Benzene, Ethyl Acetate and Hexanes.

TOXIC LIQUIDS: Methylene Chloride (MeCl, dichloromethane or DCM))

PERSONAL PROTECTIVE EQUIPMENT

EYE PROTECTION: Chemical Splash Goggles, Face Shield if desired.
PROTECTIVE CLOTHING: Flame resistant lab coat, closed toe shoes, nitrile gloves (5 mil thick single use or 16 mil thickness optional),

ENGINEERING / VENTILATION CONTROL

The solvent purification system must be installed with a rated FM/UL flammable liquid storage cabinet or inside a functioning chemical fume hood.

Ensure that all heat generating equipment has over temperature shut off controls installed.

Ensure a reliable supply of low-pressure (<20 PSI) dry inert gas (i.e. nitrogen or argon) to eliminate the chance of ignition in the systems.

SPECIAL HANDLING PROCEDURES AND STORAGE REQUIREMENTS

Follow all manufacturer/provider guidance on installation and use.

If using glassware inspect for defects before use.

Benzene and methylene chloride are confirmed human carcinogens - avoid inhalation and skin contact. Handle should be handled inside the fume hood. Methylene chloride can pass through nitrile gloves (polyvinyl alcohol rubber is best) and there is no approved respirator for this solvent.

Ensure all storage containers are labeled with the name and any hazard warning (i.e. flammable, toxic). Store the flammables in FM/UL rated flammable storage cabinets before they are transferred into the distillation flask.

The ethers (glyme, THF, ether, dioxane) can form explosive peroxides when exposed to air and stored for a time. They must be tested if over one year old. Contact EHS for assistance.

Use secondary containment carriers whenever transporting hazardous material outside of the lab. Use due care and caution when moving hazardous materials.

SPILL AND ACCIDENT PROCEDURES

EHS provides spill kits for small spills that pose no threat to you or others in the area.

For large spills - isolate the spill if possible, evacuate area, keep people away, and Call for help:

Call 911 in the case of fire or flammable solvent spills outside of ventilation
EH&S (8 AM - 5 PM) – 603-646-1762
After Hours call 911 or Safety and Security

WASTE DISPOSAL

Solvent or silica gel used in these systems is regulated as hazardous waste when disposed. Label and contain wastes properly and contact EHS to request waste pick up.

EXEMPTIONS

Exemptions to this policy may be approved on a case-by-case basis. Requests must be in writing, include specific procedures and approval is be signed by the PI, department chair/dean and EHS.

References:

Cournoyer, M.E., Dare, J.H., *The use of alternative solvent purification techniques*, Americal Chemical Society, Journal of Chemical Health and Safety, July/August 2003

Grubbs, R.H. et. Al, *Safe and convenient procedure for solvent purification*, Oranometallics, 1996, 15, 1518

Nanoparticles in the Laboratory

Nanoparticles are defined those particles with at least one dimension of 100 nanometers (nm) or smaller. Engineered nanoparticles are seeing increase use in consumer products and in the lab. Consumer products contain bound up or incorporated nanoparticles, which are not likely to become airborne in free form. Manufacturing and research materials are more varied in form – these procedures apply only to nanoparticles in the free unbound state.

While health hazards of nanoparticles are not fully understood; current evidence is that nanoparticles do enter the body via inhalation and skin contact. Because of their size and relative surface area to mass ratio increase reactivity is assumed. Results from human and animal studies show inhaled nanoparticles can deposit in the respiratory tract and enter the bloodstream. Nanoparticles pose the greatest risk when they are in the form of individual particles, or particles from nanostructured materials that become airborne or come into contact with the skin.

Exposure Limits

There are currently no published exposure limits for nanoparticles from US regulatory or consensus standard groups. There are a number of proposed standards and industry standards of note:

5 ug/m3	carbon nanotube – Bayer "baytubes" 2010
2.5 ug/m3	carbon nanotube – Nanocyl 2009
1 ug/m3	carbon nanofibers – NIOSH current intelligence bulletin 2013
300 ug/m3	titanium oxide – NIOSH current intelligence bulletin 2013

These limits represent the best intelligence currently and in the case of carbon nanotubes are the lowest levels currently detectable with available sampling tools.

ALARA for nanoparticles

The advised approach to exposures to nanoparticles to maintain exposures as low as reasonably achievable through containment ventilation and protective equipment.

Key points:

- HEPA filtration is effective for capture of nanoparticles in ventilation and respiratory protection
- Chemical fume hoods are effective at containment of nanoparticles. Some type of containment ventilation must be used to control exposure and environmental contamination.
- N95 respirators will provide effective filtration of nanoparticles limited by fit and overall hygiene. N99 or N100 respirators offer significant improvements in capture.

Operations of concern:

The National Institute of Occupational Safety and Health (NIOSH) identified the following tasks that may increase the risk of exposure to nanoparticles:

- Working with nanoparticles in liquid media without adequate protection (e.g., gloves)
- Working with nanoparticles in liquid media during pouring or mixing operations, or where a high degree of agitation is involved, will lead to an increased likelihood of inhalation and respirable droplets being formed.
- Generating nanoparticles in the gas phase in non-enclosed systems will increase the chances of aerosol release to the workplace.
- Handling nanoparticle based powders will lead to the possibility of aerosolization.
- Maintenance on equipment and processes used to produce or generate nanoparticles will pose a potential exposure risk to workers performing these tasks (i.e. vacuum chamber cleanout).
- Cleaning of dust collection systems used to capture nanoparticles will pose a potential for both skin and inhalation exposure (i.e. HEPA filter changeout).

Work Procedures

The same procedures, equipment and work-practices used for handling toxic chemicals apply to nanoparticle work. At Dartmouth College the following engineering, work practice and ventilation controls are required when handling nanoparticles in the pure form, in solution or when exposure risks exist:

- Restrict the handling of nanoparticles to areas well within the lab. Labs that handle nanoparticles must have non-recirculating ventilation systems (100% exhaust air). Lab pressurization must be negative to the hallway.
- Food and drink are restricted in all nanoparticle handling areas.
- Hand washing facilities must be provided in all labs. Hand washing must be performed after handling nano materials.
- Handle dry nanomaterials in a fume hood, glove box or a vented HEPA filtered enclosure. Do not work on the open bench with dry nanoparticles.
- Transport dry nanoparticles in closed containers.
- Aerosol producing activities (such as sonication, vortexing and centrifuging) may not be conducted on the open bench. Perform these activities in a fume hood, biological safety cabinet, glove box or a vented filtered enclosure.
- Clean bench tops using soap and water after each work activity.
- Spills of dry nanoparticles must be cleaned with a HEPA vacuum. Dry sweeping is prohibited. Large spills must be reported to EHS.
- Exhaust from all furnaces used to produce nanoparticles must be trapped and connected to a local exhaust source.

Protective Equipment

- Lab coats must be worn when handling nanomaterials in addition to closed toe shoes and long pants.
- ANSI approved safety glasses are required when working in any lab with hazardous materials. Splash goggles are required when liquid splash hazards exist (i.e. pouring, mixing).
- Gloves (disposable nitrile) must be worn when handling nano materials.
- Local exhaust snorkels or ventilated enclosures should be considered before respirators. All respirator use must be coordinated through EHS per our Respiratory Protection Program.

Nanoparticle Waste Disposal

All solutions and solid materials/contaminated debris must be disposed of as hazardous waste via EHS.

References:

National Institute for Occupational Safety and Health – *Nanomaterial Production and Downstream Handling Processes,* November 2013

NIOSH CIB - http://www.cdc.gov/niosh/docs/2013-145/

CDC/NIOSH Nanotechnology page
http://www.cdc.gov/niosh/topics/nanotech/

3D Printers and Laser Cutters

3D printing refers to various processes used to create or replicate an object by using successive layers of material (usually plastics) to create an object. Objects can be of any shape or geometry are produced from a 3D model or from a design fed into the 3D printer by a computer.

With 3D printing, an object can be made by using the following methods:

- Extruding
- Sintering
- Curing

Extruding involves using continuous filament of a thermoplastic material as the feedstock. Sintering is an additive manufacturing procedure that uses a laser as a power source. Curing uses a liquid resin as the feed material and the object is built layer-by-layer and cured; this process takes place slowly.

Printing and Cutting Emissions: Nanoparticles & Vapors

Studies have indicated that 3D printers can generate potentially harmful concentrations of nanoparticles (ultrafine particles) and chemical vapors during the print process and through processes used following printing to treat the finished product. Laser cutters have been demonstrated to release chemical vapors, partial combustion byproducts (carbon monoxide, formaldehyde) and dusts.

Nanoparticles (ultrafine particles less than 1/10,000 of a millimeter) are one of the by-products emitted during the 3D printing process. Recent studies have shown that 3D printing using a low-temperature Polylactic Acid (PLA) feedstock can release 20 billion particles per minute, while a higher temperature Acrylonitrile Butadiene Styrene (ABS) feedstock can release 200 billion.

Nanoparticles are of concern for the following reasons:

- They are very small,
- They have large surface areas, and
- Can interact with the body’s systems, including the skin, lungs, nerves and the brain.

Exposures to nanoparticles at high concentrations have been associated with adverse health effects, including total and cardio-respiratory mortality, strokes and asthma symptoms. Current research indicates HEPA filter media is at leasd 95% efficient at capture of ultrafine nanoparticles. While PLA feedstock is designed to be biocompatible, the thermal decomposition products of ABS feedstock have been shown to have toxic effects on lab rodents.

Chemical Vapors

Heating of certain substrates and thermoplastic filament can generate toxic vapors and vapors with high volatile organic compounds (VOCs). Some laser cutters and 3D printers do not come with an enclosure, exhaust ventilation specification or any filters. The following should be assessed before purchasing and installing a laser cutter or 3D printer:

- Building/Room where 3D printer will be located
- Placement of the 3D printer in the space itself
- Selection of substrate to be cut and/or printing feedstock

Evaluating feedstock and substrate:

Laser cutters can be used to cut a variety of materials including wood, plastic, paper products and engineered wood or synthetics. Each material will produce a unique set of VOC's and vapors. Do not assume wood or engineered wood product emissions are benign as carbon monoxide and glue byproducts can be hazardous. Consult the manufacturer specification for ventilation and enclosure and review with EHS.

3D printers are designed to use certain types of materials. The most common type of desktop 3D printer technology joins thin strands, or filaments, made of ABS or compostable materials, such as PLA, a biodegradable thermoplastic aliphatic polyester derived from corn starch tapioca.

The materials being fed into the machine (feedstock) can have inherent hazards and may release vapors and gases that may be more hazardous, for example, after they are heated during the 3D printing process.

- Consult the 3D printer manual to be sure you are using the proper feedstock.
- Review safety data sheets for feedstock materials before using.
- Double check what vapors or gases are generated when heating.

Other 3D potential printer hazards include:

- High temperature surfaces or work pieces – lamps, print heads
- High voltage – cases should be UL listed and interlocked but users should not remove protective housing.
- UV radiation – some technologies employ UV curing lamps and may require eye protection or protective shrouds.
- Moving parts – finger pinch or entrapment risks should protective covers be removed.
- Alkaline baths/corrosives used to remove supporting materials (Contact EHS if you use printers like the Stratysus Dimension that require corrosives. Before installing or using an alkaline bath, make sure you have the following: proper lab ventilation, written standard operating procedure, control of access to authorized and trained users only and proper personal protective equipment to handle corrosive liquids.)

- Biological materials such as cells for engineered-tissue generation or scaffolding for lung tissue. (Contact EHS to evaluate potential exposure to the aerosols generated, containment, disinfection of the area and review by the Institutional Biosafety Committee.)

Policy

The laser cutter and 3D Printer policy establishes the minimum requirements necessary to allow for the safe use of these devices located in Dartmouth College buildings. The policy covers all laser cutters and 3D printers including but not limited to those affiliated with the sciences, medicine, arts, performing arts, engineering, libraries and arts and craft studios.

Roles and responsibilities:

Environmental Health and Safety (EH&S)
EH&S provides consultation to review laser cutters or 3D printers, including the size and intensity of the operation, the type of print media to be used and the proposed location of the printer set-up. EH&S may request the modification of proposed location or the addition of improved exhaust ventilation and will specify protective equipment to be used. EH&S has final authority over all safety issues and may immediately halt any operations or procedures it considers unsafe at any time at its discretion.

Construction, design and engineering staff and consultants – Campus Services
Design and construction professionals should use the current industry standard in design of ventilation and facilities for 3D printers and lasers cutters. EHS should be consulted to ensure all potential hazards are addressed during the design phase prior to installation.

Principal Investigators (PI) and Managers with 3D printer oversight
The PI and facility/equipment managers are responsible for enforcing the provisions of this policy including compliance with the training requirements. PI's and supervisors are responsible for providing required personal protective equipment (PPE) and enforcing its correct use. Programs and users groups areresponsible for the cost of equipment, protective equipment and modifications of facilities to allow use.

Users of cutters and 3D printers (Faculty, staff, students)
Individuals will receive training in the correct and safe operation of the 3D printer including Hazard Communication (HAZCOM) training relevant to the media and other chemical products used in the printing process. Required personal protective equipment shall be provided and used. No eating or drinking is allowed in areas where 3D printers are present.

Procedures:

Ventilation, Enclosures and Engineering Controls

Use 3D printers and Laser Cutters ONLY in properly ventilated areas. ABS print media is thought to represent a greater health and safety risk than PLA media. EHS and Campus Services Engineering will evaluate the program and determine the appropriate enclosures, ventilation and engineering controls. Some important considerations:

- 3D printers using PLA media exclusively are generally acceptable for use in spaces with at least 4 air changes per hour.
- The number of PLA printers in one location should be limited by the size of the space. Requests for the placement of multiple PLA printers in any space should be reviewed by EH&S before proceeding.
- 3D printers using ABS media, including printers designed and set-up to use both PLA and ABS may only be used in work areas having a dedicated exhaust system meeting current engineering and safety standards (i.e. single pass air, negatively pressurized direct exhaust enclosure or fume hood).
- 3D printers using other types of media, including but not limited to thermoplastics, photopolymers, nylon, high impact polystyrene, high density polyethylene, powdered metals, biological media or other uncommon media shall be reviewed on a case by case basis with specific precautions required based on the hazards unique to the printing process.

General Safety

- Choose low-emitting printers and feed materials/filament when possible.
- Wear proper personal protective equipment. Have a risk assessment to determine what is required.
- Purchase and use the manufacturer's supplied controls, such as an interlocked enclosure. (Enclosures appear to be more effective at controlling emissions than just a machine cover.)
- Safety interlock switches must be enabled and working properly during printer operation.
- Operators must be protected from hot surfaces associated with the printers.
- If UV light is used in the curing process, personal protective equipment and/or shielding must be utilized to protect personnel.
- Maintain a safe distance from the printer to minimize the inhalation of emitted particles.
- Turn off the printer if the printer nozzle jams, and allow the printer to ventilate before removing the cover.
- All printers must be installed according to the manufacturer's requirements and according to NFPA 72 National Electric Code.
- Safety Data Sheets (SDS) must be provided for all print media and for any other chemical product used in the printing process. SDS must be readily accessible for review in the event of an emergency.

Training Requirements

All users working directly with a 3D printer and associated media are required to have hazard communication (HAZCOM) training covering any hazardous materials used in the process. Completion of the training must be documented in writing with the records maintained by the manager of the printing operation.

Personal Protective Equipment (PPE) Requirements

- Follow all PPE recommendations found in the Safety Data Sheet (SDS) for the specific printer media used.
- Eye protection is required during any activity where airborne projectiles may be present (i.e. cutting off rough edges of a printed item).
- For print processes using an alkaline bath to dissolve support material, an emergency eyewash will be required in the immediate vicinity of the work.
- A spill kit capable of neutralizing the caustic components of the alkaline bath shall also be provided.

References:

NIOSH Research Rounds
Volume 1, Number 12 (June 2016)
Control Measures Critical for 3D Printers
https://www.cdc.gov/niosh/research-rounds/resroundsv1n12.html#a

Emissions of Nanoparticles and Gaseous Material from 3D Printer Operation
Yuna Kim[†], **Chungsik Yoon** [*†‡], **Seunghon Ham**[†‡], **Jihoon Park**[†], **Songha Kim**[†], **Ohhun Kwon**[†], **and Perng-Jy Tsai**[§]
Environ. Sci. Technol., **2015**, *49* (20), pp 12044–12053
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Select Agent Toxin and Biological Toxin Work

Some toxins are subject to additional controls through the CDC and Department of Agriculture. These laws and policies are intended to: (1) safeguard the use, disposal, transport and storage of these agents, (2) collect and provide information on the location and movement of select agents, and (3) establish a procedure to alert authorities if unauthorized access to these agents occurs or is attempted.

At Dartmouth College, all Select Agent (including work with exempt quantities of toxins) work must be authorized by the Institutional Biosafety Committee (IBC). All requests to obtain, use and dispose of Select Agents must go through the Director of Environmental Health and Safety (EHS) who serves as the Responsible Facility Official (RFO) and is coordinated through the Biosafety Officer in EHS.

What Are Select Agents and who regulates them?

The select agent list and relevant regulatory program information are maintained by the CDC and can be found on the select agent web site http://www.selectagents.gov/. The regulations covering select agents include Code of Federal Regulations, *Title 7, Part 331 (agriculture), Title 9, Part 121 (animals and animal products), Title 42, Part 73 (public health).*

Permissible toxin amounts:

The following toxins are exempt from the full scope of the Select Agent rules provided they are under the control of a principal investigator, treating physician or veterinarian and the aggregate amount does not, at any time, exceed the following amounts:

Abrin 100 mg
Botulinum neurotoxins 0.5 mg
Conotoxin 100 mg
Diacetoxyscirpenol (DAS) 1000 mg
Ricin 100 mg
Saxitoxin 100 mg
Staphylococcal enterotoxins (A, B, C, D and E subtypes) 5.0 mg
T-2 toxin 1000 mg
Tetrodotoxin 100 mg

Use of these toxins requires and number of steps for compliance including

- Receive IBC approval before possession
- Inventory tracking and security, log each use, keep toxin locked and secure
- Document destruction or depletion, disposal must be approved and witnessed
- Develop specific procedures, train staff and document your work
- Report all exposures, spills or theft/suspicious activity

There are a number of other toxins of biological origin which exhibit similar toxicity and risk (i.e. – Bungarotoxin, Digitoxin, Pertussis Toxin, Cholera Toxin, Diptheria Toxin), but are NOT on the select agent list (see Appendix G for a more comprehensive list of biological toxins). These toxins should be handled with similar precautions as outlined in this policy (security, inventory control, training, documented disposal etc.)

Controlled Substances:

The Federal Drug Enforcement Administration (DEA) requires that research personnel must have their own DEA license. At Dartmouth, the principal investigator is the responsible individual. Special inventory, security and recordkeeping requirements apply For more information on obtaining a DEA license, contact EHS (646-1762).

TSCA – the Toxic Substances Control Act

TSCA, or the Toxic Substances Control Act (1976), regulates new and existing chemicals for potential environmental and public health effects prior to production or transportation. This law requires a basic hazard assessment for all new chemicals offered for transport or sale and requires documentation and communication of this hazard assessment.

Laboratories engaged in research must consider the applicability of the Toxic Substances Control Act (TSCA) on their operation. Most chemicals in our labs are on the TSCA inventory already (referred to as "existing" chemicals) but specialty chemicals or materials synthesized in our labs are likely not on the inventory and are thus "new chemicals". Documentation and evaluation of adverse health effects is required for both existing and new chemicals. In addition new chemicals must be registered with TSCA or used under the research and development exemption.

You become subject to TSCA when you:

- **Bring chemicals not on the TSCA Inventory (i.e., "new chemicals") on campus or into the country.**
- **Purchase a "new" chemical, either from a domestic or foreign vendor.**
- **Synthesize a new chemical for use, transfer, shipment or export.**
- **Transfer or ship a new chemical to another lab or institution, in the US or overseas.**
- **Observe an adverse health or environmental effect associated with a new chemical, or a new health effect associated with an existing chemical.**

As EPA becomes aware of activities at colleges and universities, it becomes increasingly important for Dartmouth College to demonstrate that a TSCA compliance program is in place. Most activities at Dartmouth College should be exempt from TSCA provided certain conditions are met but you will need to document that your work meets this exclusion. In rare cases you may need to document your TSCA registration information.

Overview of Research and Development (R&D) Exemption Requirements:

A chemical substance can be exempted from many TSCA requirements when it is imported, manufactured or used in small quantities, solely for purposes of *non-commercial* scientific experimentation, analysis or research and used under the supervision of a technically qualified individual.

- **Laboratory work involving new chemicals must be overseen by a technically qualified individual (such as the Principal Investigator) and be laboratory scale, non-production work.**

- **New chemicals must be appropriately labeled with the chemical name, a statement that the chemical is to be used for research and development purposes only, and information regarding the potential hazards. If you create your own label you must document this. An example label might read: "*chemical name*, for laboratory research and development purposes only, for use by technically qualified individuals only, liver toxin and suspect carcinogen, the physical, chemical and toxicological properties have not been fully investigated, this product is not on the TSCA inventory".**

- **New chemicals can be shipped to offsite locations (i.e. – for identification, analysis or collaboration) provided that a hazard assessment is performed (toxicology research) and documented, the container is labeled as above and an MSDS/SDS sheet is developed. You will also need to document the names/addresses of those you distribute the material to, and the date, amount distributed and notices provided to them (container labels, warnings, MSDS/SDS etc.).**

- **All documentation needs to be kept on file in your lab for 5 years minimum.**

Note that laboratories synthesizing, storing or using new chemicals that do not meet the requirements of the R&D exemption are subject to significant additional TSCA requirements. See Appendix D for additional clarification and definitions associated with TSCA. If you suspect that your operation does not meet the R&D exemption; please contact the EH&S office at 646-1762 for assistance.

The US Environmental Protection Agency (EPA) administers TSCA by 1) creating a list of chemicals that are widely available (i.e., "TSCA Inventory"); 2) regulating chemical imports and exports; 3) collecting information on adverse environmental and health effects for new and existing chemicals; 4) screening new chemicals intended for broad manufacture; and 5) banning chemicals with unacceptable environmental and/or health risk from broad circulation in commerce (e.g., PCBs and asbestos).

Chemical Hygiene Plan Evaluation and Recordkeeping:

The Dartmouth College Chemical Hygiene Plan will be evaluated and updated as needed by EHS. Comments and suggestions on the improvement of this document should be directed to the Director of EHS (646-1762).

Training and chemical exposure monitoring records are maintained by EHS. Individuals may request their records by contacting the Director of EHS (646-1762).

Appendix A: OSHA Fact Sheet, *Occupational Exposure to Hazardous Chemicals in Laboratories*

OSHA® FactSheet

Laboratory Safety OSHA Laboratory Standard

OSHA's Occupational Exposure to Hazardous Chemicals in Laboratories standard (29 CFR 1910.1450), referred to as the Laboratory standard, covers laboratories where chemical manipulation generally involves small amounts of a limited variety of chemicals. This standard applies to all hazardous chemicals meeting the definition of "laboratory use" and having the potential for worker exposure.

Hazardous chemicals present physical and/or health threats to workers in clinical, industrial, and academic laboratories. Hazardous laboratory chemicals include cancer-causing agents (carcinogens), toxins that may affect the liver, kidney, or nervous system, irritants, corrosives, and sensitizers, as well as agents that act on the blood system or damage the lungs, skin, eyes, or mucous membranes. OSHA rules limit all industry exposures to approximately 400 substances.

Elements of the Laboratory Standard

This standard applies to employers engaged in laboratory use of hazardous chemicals.[1]

- "Laboratory" means a facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.
- "Laboratory use of hazardous chemicals" means handling or use of such chemicals in which all of the following conditions are met:
  - Chemical manipulations are carried out on a "laboratory scale" (i.e., work with substances in which the containers used for reactions, transfers, and other handling of substances is designed to be easily handled by one person);
  - Multiple chemical procedures or chemicals are used;
  - The procedures involved are not part of a production process, nor do they in any way simulate a production process; and
  - "Protective laboratory practices and equipment" are available and in common use to minimize the potential for worker exposure to hazardous chemicals.
- Any hazardous chemical use which does not meet this definition is regulated under other standards. This includes other hazardous chemical use within a laboratory. For instance:
  - Chemicals used in building maintenance of a laboratory are not covered under the Laboratory standard.
  - The production of a chemical for commercial sale, even in small quantities, is not covered by the Laboratory standard.
  - Quality control testing of a product is not covered under the Laboratory standard.
- If the Laboratory standard applies, employers must develop a Chemical Hygiene Plan (CHP). A CHP is the laboratory's program which addresses all aspects of the Laboratory standard.
  - The employer is required to develop and carry out the provisions of a written CHP.
  - A CHP must address virtually every aspect of the procurement, storage, handling, and disposal of chemicals in use in a facility.
- Primary elements of a CHP include the following:
  - Minimizing exposure to chemicals by establishing standard operating procedures, requirements for personal protective equipment, engineering controls (e.g., chemical fume hoods, air handlers, etc.) and waste disposal procedures.
  - For some chemicals, the work environment must be monitored for levels that require action or medical attention.
  - Procedures to obtain free medical care for work-related exposures must be stated.

- The means to administer the plan must be specified.
- Responsible persons must be designated for procurement and handling of Material Safety Data Sheets, organizing training sessions, monitoring employee work practices, and annual revision of the CHP.

Additional Information

The following OSHA Interpretations of the Laboratory standard provide additional information:

- Labeling Requirements under the HAZCOM and Laboratory standards; use of safe needle devices. (2001, January 11). Available at: www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=23781. Also, for labeling information, refer to the Laboratory Safety QuickCard.
- Coverage of various types of laboratories by the Laboratory standard. (1991, February 8). Available at: www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=20190.
- The Laboratory standard does not apply to a pharmacy operation mixing cytotoxic drugs. (1990, June 22). Available at: www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=20025.

OSHA's Safety and Health Topics Page entitled Laboratories, provides more detailed information about the Laboratory standard and is available at: www.osha.gov/SLTC/laboratories/index.html.

[1] **Note:** The scope of the Formaldehyde standard (29 CFR 1910.1048) is not affected in most cases by the Laboratory standard. The Laboratory standard specifically does not apply to formaldehyde use in histology, pathology, and human or animal anatomy laboratories; however, if formaldehyde is used in other types of laboratories which are covered by the Laboratory standard, the employer must comply with 29 CFR 1910.1450.

This is one in a series of informational fact sheets highlighting OSHA programs, policies or standards. It does not impose any new compliance requirements. For a comprehensive list of compliance requirements of OSHA standards or regulations, refer to Title 29 of the Code of Federal Regulations. This information will be made available to sensory-impaired individuals upon request. The voice phone is (202) 693-1999; the teletypewriter (TTY) number is (877) 889-5627.

For assistance, contact us. We can help. It's confidential.

OSHA®
Occupational Safety
and Health Administration
www.osha.gov 1-800-321-6742

OSHA FS-3464 8/2011
DSG

Appendix B: Laboratory Safety Inspection Checklist

Dartmouth College
ENVIRONMENTAL HEALTH & SAFETY
Laboratory Safety Program

Lab Safety Inspection Form

Principle Investigator: **Contact Person:**

Building/Room: **Date:**

Inspected By: ____________________________________

Training Requirements:	**Acceptable**	
Bio-Raft Training Registration Audit		☐ **Concern:**

Posting Requirements:	**Acceptable**	
EHS Door sign up to date: Rad Warning Sign? BSL2 Door Sign?		☐ **Concern:**
Emergency Numbers posted		☐ **Concern:**
Compliance Calendar		☐ **Concern:**

Safety Equipment:

Fume hood cert < than 1 year		☐ **Concern:**
BSC cert < than 1 year		
Clean bench not used w/ hazards		☐ **Concern:**
Vacuum traps labeled and disinfected		☐ **Concern:**
Eyewash access/operational/ labeled		☐ **Concern:**
Fire Ext. present/inspected/ posted		☐ **Concern:**
Spill kit available		☐ **Concern:**

PPE:

Lab coats, gloves, eye protection avail.		☐ **Concern:**
Lab coats worn in BSL2/Rab/Chem labs when working with hazards		☐ **Concern:**
Gloves worn with hazards		☐ **Concern:**
Proper attire (no shorts, sandals)		☐ **Concern:**

Chemical Storage:

Chemicals sealed and labeled		☐ **Concern:**
Chemical inventory acceptable (no old, no duplicates, volume OK)		☐ **Concern:**
Liquids in secondary containment		☐ **Concern:**

Peroxide forming chemicals dated/tested		☐**Concern:**
Flammables stored away from ignition sources		☐**Concern:**

Chemical Waste:

Hazardous Waste label affixed/completed/ legible		☐**Concern:**
Waste segregated/in secondary containment/compatible		☐**Concern:**
< 10 gallons in SAA		☐**Concern:**
Containers sealed/clean/non-leaking		☐**Concern:**

Bio-Safety:

Povidone iodine at sink in BSL2		☐**Concern:**
BSCs, centrifuges, incubators, shakers, etc. clean/maintained		☐**Concern:**
Orange bags contained/no sharps		☐**Concern:**
No biohazards in regular trash or glass box		☐**Concern:**
Waste containers emptied promptly		☐**Concern:**
Needles not recapped		☐**Concern:**

Rad-Safety:

Locks on rad. material inc. freezer		☐**Concern:**
Containment sealed and labeled		☐**Concern:**
Appropriate use of labels		☐**Concern:**

General Lab Safety:

No evidence of food/drink		☐**Concern:**
Gas cylinders upright/restrained		☐**Concern:**
Ergo, electrical or trip hazards		☐**Concern:**
Routes of egress, fire sprinklers unobstructed (3 ft access)		☐**Concern:**
No mold growth in cold room		☐**Concern:**
Hand washing (soap & sink)		☐**Concern:**
Work surfaces clean?		☐**Concern:**
Bench paper use appropriate??		☐**Concern:**
General Housekeeping		☐**Concern:**

Appendix C: Additional information and definitions under TSCA

Additional Requirements for import, export and shipping chemicals:

· **Imports:** Any chemicals imported from outside the US Customs Territory must be certified as TSCA compliant or not regulated by TSCA at the time of import.
· **Exports:** Any chemicals exported outside the US Customs Territory must be screened against certain EPA chemical lists. Some particular chemicals may require additional actions required by EPA prior to or within several days of export.
· **Shipments:** New chemicals shipped to other institutions or entities must be shipped for R&D purposes only. Containers of these chemicals and shipping documentation must be labeled. The environmental and health risks of these chemicals must also be evaluated and communicated to the receivers by preparing and shipping an MSDS/SDS and/or shipment form with the substance.
· **Reporting:** ALLEGATIONS OF ADVERSE REACTIONS - Create and maintain records and report any allegations of adverse effects to human health or the environment potentially caused by R&D substances. DISCOVERY OF SUBSTANTIAL RISK - Document and report any significant risks to human health or the environment potentially associated with R&D substances.

TSCA Definitions/Clarifications:

Chemical substances ***regulated*** by TSCA include:
"Any organic or inorganic substances of a particular molecular identity including any combination of such substances occurring, in whole or in part, as a result of chemical reaction or occurring in nature and any element or uncombined radical."

Chemical substance means any organic or inorganic substance of a particular molecular identity, including any combination of such substances occurring in whole or in part as a result of a chemical reaction or occurring in nature, and any chemical element or uncombined radical, except that “chemical substance” does not include:
(1) Any mixture *(individual components are chemical substances).*
(2) Any pesticide when manufactured, processed, or distributed in commerce for use as a pesticide.
(3) Tobacco or any tobacco product.
(4) Any source material, special nuclear material, or byproduct material.
(5) Any pistol, firearm, revolver, shells, or cartridges.
(6) Any food, food additive, drug, cosmetic, or device, when manufactured, processed, or distributed in commerce for use as a food, food additive, drug, cosmetic, or device.

Commercial Activities
Activities whose results are directly intended to produce commercial gain for those involved in the oversight or performance of the activity.

Laboratory is a contained research facility where relatively small quantities of chemical substances are used on a non-production basis, and where activities involve the use of containers for reactions, transfers, and other handling of substances designed to be easily manipulated by a single individual.

Prudent and safe handling practices means the implementation of safe chemical handling practices as delineated in the Chemical Hygiene Plan.

Small quantities solely for research and development (or ‘small quantities solely for purposes of scientific experimentation or analysis or chemical research on, or analysis of, such substance or another substance, including such research or analysis for the development of a product”) means quantities of a chemical substance manufactured, imported, or processed or proposed to be manufactured, imported, or processed solely for research and development that are not greater than reasonably necessary for such purposes.

Technically qualified individual means a person or persons (1) who, because of education, training, or experience, or a combination of these factors, is capable of understanding the health and environmental risks associated with the chemical substance which is used under his or her supervision, (2) who is responsible for enforcing appropriate methods of conducting scientific experimentation, analysis, or chemical research to minimize such risks, and (3) who is responsible for the safety assessments and clearances related to the procurement, storage, use, and disposal of the chemical substance as may be appropriate or required within the scope of conducting a research and development activity.

Chemicals or Activities not Regulated by TSCA:

Foods, food additives, drugs, cosmetics **or** devices regulated by the Food and Drug Administration.

Radioactive materials regulated by the Nuclear Regulatory Commission .
Tobacco, tobacco products and ammunition regulated by Alcohol Tobacco and Firearms

Pesticides regulated by **FIFRA (Federal Insecticide, Fungicide and Rodenticide Act**)--pesticides officially recognized as pesticides through an experimental use permit or otherwise. FIFRA regulated pesticides.

Individual components of a given pesticide <u>are</u> regulated by TSCA.

Appendix D: Documentation of training, the sign in sheet

Laboratory Safety Training Documentation

Date:_______ **Principle Investigator(s):____________________**

Topic(s):____

Presenter(s):____

Printed Name	**Signature**	**PI/Supervisor**

Topics covered by training:

- ☐ **Review of CHP**
- ☐ **Health hazards of chemicals used**
- ☐ **Physical hazards of lab operations**
- ☐ **The SOPs for the laboratory**
- ☐ **MSDS/SDS Location and interpretation**
- ☐ **Emergency response (spills, fire or service interruptions)**
- ☐ **PPE selection and use**
- ☐ **Use of fume hood**
- ☐ **Other engineering controls**
- ☐ **Chemical inventory control**
- ☐ **Chemical exposure symptoms**
- ☐ **Other ____________________**
  ____

Remember: Include a brief description of the curriculm or topics covered in the section above or attach a description of the material covered. Photocopy the title of any videos shown or include literature references for material covered.

Appendix E: Template for high hazard chemical work

HIGH HAZARD LAB OPERATIONS

WORK REQUIRING PRIOR APPROVAL AS DEFINED IN THE OSHA LAB STANDARD AND THE CHEMICAL HYGIENE PLAN

Principle Investigator: ________ Department: ___________________

Project Title:_________________________________

Work Location(s) Building and room #: ___________________

Name and Titles of Personnel Approved/Trained for Procedure:

Describe the proposed work, be sure to include the following:

Use:
TTX is used to characterize sodium channels in excitable membranes and to study the role of sodium channels in normal physiology and disease. To inhibit voltage-gated sodium channels action potentials generated in mouse brain slices or cultured primary cell lines.

Hazard:
It is a neurotoxin, a selective sodium(Na) channel blocker that blocks propagation of impulses in excitable membranes. Reversible, selective blocker of Na^+channels; blocks propagation of impulses in excitable membranes.

Synonyms	Fugu poison
	TTX
	Maculotoxin
	Tarichatoxin
Molecular Formula	$C_{11}H_{17}N_3O_8$
Molecular Weight	319.27
CAS Number	4368-28-9
Beilstein Registry Number	49176
EG/EC Number	2244588
MDL number	MFCD00213719

Routes of Entry:

Very toxic by inhalation, in contact with skin and if swallowed.

Target organ(s): Nerves. Skeletal muscle.

HMIS RATING

HEALTH: 4* Ingestion: May be fatal if swallowed.

TARGET ORGAN(S) OR SYSTEM(S)

Nerves. Skeletal muscle. Tetrodotoxin is among the most toxic substances known to man.

Death can occur within 30 minutes. It is extremely dangerous by ingestion, inhalation and skin absorption, or if it enters the bloodstream in any manner. Symptoms of poisoning which include numbness, tingling of the lips and inner mouth surfaces, weakness, paralysis of the limbs and chest muscles, and a drop in blood pressure have been reported within as little as 10 minutes after exposure. To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Color: White

Form: Powder

Hazardous Decomposition Products: Carbon monoxide, Carbon/Nitrogen oxides.

Label Precautionary Statements:
Highly Toxic (USA) Very Toxic (EU).

Quantity and Concentration Purchased:
Manufacturer/Vendor or Source:
Ordering Information and Chain of Custody, and Storage
Vendor Information:
SigmaAldrich, P.O Box 14508, St. Louis, MO 63178 USA, 800-325-5832,

An order can be placed online from Sigma/Aldrich Chemicals. T5651-1mg Tetrodotoxin with Citrate Buffer is usually ordered at 5 of 1mg size per shipment in this laboratory. A Declaration of Aggregate Quantities Form is required to be signed by the principle investigator before an order is processed. A maximum of 100mg aggregated quantities is allowed per order. Inventory control is paramount, all orders must be approved by the PI so that at no time the lab exceeds 10mg of tetrodotoxin aggregate. The item is shipped via fedex overnight. The tetrodotoxin package is opened in a chemical hood with the personnel wearing safety goggle, laboratory coat & latex gloves. Then, the person who receives the package records the material onto the inventory sheet & store unopened packages in a locked refrigerator located inside the laboratory(Borwell/750E).

Typical Amount Used per Experiment:
A stock vial is prepared and shared with all users. 1mM concentration stock is prepared for use in electrophysiology patch clamping recording. One to one hundred microliters volume range of TTX is used per experiment, dependent upon total volume of the perfusion solution required for an acute slice preparation. A final concentration of 1uM is dissolved in saline or ACSF. A dedicated container is used to prepare TTX in perfusion

solution(ACSF). The waste perfusion solution is then collected into a large flask, which contains 10% Clorox solution. All the washes from the reservoir and slice chamber are collected into the labeled waste container. A log sheet is kept to track usage by approved and trained users.

Dose that causes adverse effects/symptoms:
0.32 µg/kg if administered subcutaneously (which is 24 µg in a 75 kg human)

Lethal dose
0.334 mg/kg in mouse via oral administration
8.0 µg/kg in mouse via subcutaneous administration
14.0 µg/kg in frogs via intraperitoneal administration

Symptoms of Exposure –
It is extremely dangerous by ingestion, inhalation and skin absorption, or if it enters the bloodstream in any manner. Symptoms of poisoning which include numbness, tingling of the lips and inner mouth surfaces, weakness, paralysis of the limbs and chest muscles, and a drop in blood pressure have been reported within as little as 10 minutes after exposure.

First Aid – What to do if exposed – Provide the MSDS/SDS or other first aid info to the EMT's/Medical care staff.
ORAL EXPOSURE
If swallowed, wash out mouth with water provided person is conscious. Call a physician immediately. Call 911
INHALATION EXPOSURE. Call 911.
If inhaled, remove to fresh air. If not breathing give artificial respiration. If breathing is difficult, give oxygen. Call 911.
DERMAL EXPOSURE
In case of skin contact, flush with copious amounts of water for at least 15 minutes. Remove contaminated clothing and shoes. Call a physician. 911
EYE EXPOSURE
In case of contact with eyes, flush with copious amounts of water for at least 15 minutes. Assure adequate flushing by separating the eyelids with fingers. Call a physician. Call 911.

Inspect the room immediately by a supervisor following spill & assess the degree of emergency.

Procedures for Use:

Safety precautions required when diluting TTX in the laboratory chemical fume hood, PPE - chemical resistant nitrile rubber gloves , goggles & lab coat.
-Researcher wears chemical resistant nitrile rubber gloves and chemical safety goggles and laboratory coats.

-Dissolve powder with saline in chemical fume hood, to avoid aerosolization of powder saline will be introduced to sealed vial, extract with a blunt cannula or hypodermic needle.
-Make small aliquots.
- Aliquots stored in container labeled highly toxic and stored in a locked refrigerator.
- Remove contaminated gloves or debris and place in hazardous waste or decontaminate by soaking in 10%   bleach.
-Wash hands

Storage
We plan to store the TTX stock at 1mM in a dedicated container and in a designated area in the locked refrigerator in Borwell, 750E. Aliquots will be taken from the stock and diluted to the desired concentration immediately before each experiment.

Disposal
All excess ttx or stock solutions must be disposed via EHS. All waste materials will be properly labeled and safely stored inside a chemical hood until pickup.
After use, untensils(pipette tips, glass recording pipettes) should be soaked overnight or boiled for 20 minutes in an excess amount of 2% sodium hydroxide solution or sodium hypochlorite(1% available chlorine) solution in a hood. Also, observe all federal, state, and local environmental regulations.

Security and Restricted Access
The toxin is stored in a locked refrigerator in 750E laboratory. The key will be locked in a locked drawer within the laboratory. Only the trained users know where the key to the locked drawer is stored. There is an emergency contacts list posted outside of the laboratory. NO TRANSFER OR SHIPMENT OF TOXIN ALLOWED

Spill Clean-up – Contact EHS to report or for assistance 646-1762
Evacuate area. Only personnel on the emergency contact list can remain to assist in clean up. Spilled material should be carefully wiped or moistened with water and removed. Decontaminate any spill with 10% caustic solution Ventilate area and wash spill site after material pickup is complete. Remove contaminated clothing to be decontaminated by rinsing & washing thoroughly. The date & amount of spill & who was exposed should be documented on Toxin Inventory sheet. Also, report incident to supervisor & complete Incident Report form.

Emergency Contact Personnel and Telephone Numbers:

Review MSDS/SDS prior to handling of TTX. The MSDS/SDS is available from the supplier and/or on the EHS web site.

PI:
EHS:606-646-1762
DHMC Occupational Medicine: 603-653-3850
Safety and Security:603-646-2234

==

Reccomended Special Practices

1) Identify the hazards that will be encountered under normal work conditions, and those that could be encountered in case of a spill, loss of containment or other accident.
2) Specify the policies and practices to be used to minimize risks (e.g., containment and personal protective equipment, management of spills, management of accidental exposures, medical surveillance).
3) Training specific to the hazards/chemicals used should be required and documented for all laboratory personnel working with these hazards, before starting work and at intervals thereafter.
4) An inventory control system for highly hazardous chemicals/substances should be in place and they should stored in locked storage rooms, cabinets, or freezers when not in use.
5) Access to areas containing high hazard materials should be restricted to those whose work assignments require access.
6) Preparation of primary containers of stock solutions and manipulations of primary containers of pure chemicals/toxins should be conducted in a chemical fume hood, a glove box, or a biological safety cabinet or equivalent containment system. HEPA and/or charcoal filtration of the exhaust air may be required, depending on the material.
7) The user should verify inward airflow of the hood or biological safety cabinet before initiating work.
8) All work should be done within the operationally effective zone (6-8” inside the hood face) of the hood or biological safety cabinet.
9) When high risk operations are underway, the room should be posted to indicate this "______ in Use Authorized Personnel Only." Any special entry requirements should be posted on the entrance(s) to the room. Only personnel whose presence is required should be permitted in the room while high risk operations are ongoing.
10) All high risk operations should be conducted with two knowledgeable individuals present. Each must be familiar with the applicable procedures, maintain visual contact with the other, and be ready to assist in the event of an accident.
11) Before containers are removed from the hood, cabinet, or glove box, the exterior of the closed primary container should be decontaminated and placed in a clean secondary container. Hazardous materials should be transported only in leak/spill-proof secondary containers.
12) Contaminated and potentially contaminated protective clothing and equipment should be decontaminated using methods known to be effective against the material before removal from the laboratory for disposal, cleaning or repair. If decontamination is not possible/practical, materials (e.g. used gloves) should be disposed of as hazardous waste.
13. The interior of the hood, glove box, or cabinet should be decontaminated periodically, for example, at the end of a series of related experiments. Until decontaminated, the hood, box, or cabinet should be posted to indicate that hazards
are in use, and access to the equipment and apparatus restricted to necessary, authorized personnel.

Safety Equipment

1. When using an open-fronted fume hood or biological safety cabinet, impervious protective clothing, including gloves and a disposable long-sleeved body covering (gown, laboratory coat, smock, coverall, or similar garment) should be worn so that hands and arms are completely covered.
2. Eye protection should be worn if an open-fronted containment system is used.
3. Other protective equipment may be required, depending on the hazards posed and and the containment system used.
4. When handling dry forms of hazardous materials that are electrostatic:

a. Do not wear gloves (such as latex) that help to generate static electricity
b. Use glove bag within a hood or biological safety cabinet, a glove box, or a class III biological safety cabinet.

5. When handling materials that are percutaneous hazards (irritants, necrotic to tissue, or extremely toxic from dermal exposure), select gloves that are known to be impervious to the chemical and any solvent carrier(s). This will often mean double gloving with silver shield laminate glove liners and heavy duty outer gloves.

Additional Information/Definitions:

Hazards: Describe the primary hazards posed by this work including chemical hazards (fire, explosion, water/air reactivity, high toxicity, corrosiveness or ability to generate toxic gasses) and physical hazards (high/low pressure or temperature, compressed gasses, UV or other harmful radiation).
Description of Safety Precautions and Equipment: Discuss location of work with attention to exposure control equipment as the primary method of protection. Note if you will be working iin a certified chemical fume hood or biological safety cabinet Class II type B2 or B3. Hood performance must be assessed before each use via a hood monitor or use of smoke/telltale to verify flow. Glove boxes or other advanced engineering controls may be required for significant hazards. Personal protective equipment (PPE) includes gloves, eye/face protection and other items including hearing protection. Engineering controls must be the primary method of protection but PPE also needs to be evaluated.
Security: Describe the inventory control, labeling and tracking methods for high hazard chemicals. Include provisions for securing storage locations and controlling access during work periods and off-hours.
Description of decontamination and waste disposal procedures: Provide specific information on types of waste generated and collection and disposal methods. Include provisions for contaminated debris, disposal of pure materials and stock solutions. If materials or spills are to be decontaminated for disposal in the trash describe the decontamination method to be used and provide references.
Description of emergency response and first aid requirements: Include information on any unique first aid treatments or provisions and emergency procedures for isolation/evacuation of the area.

Appendix F: DHS CFAT – Chemicals of Interest (COI) list

COMMON LABORATORY CHEMICALS ARE HIGHLITED IN YELLOW - COMMERCIAL GRADE REFERS TO THE COMMONLY AVAILABLE CONCENTRATION, THIS INCLUDES REAGENT, LABORATORY AND ULTRAPURE OR HIGHER GRADES

Note: This list excludes chemicals under the laboratory and R+D reporting exemption.

Aluminum (powder) ≥ commercial grade	7429-90-5	Explosive
Ammonium nitrate, solid [nitrogen concentration >23%] ≥ 33%	6484-52-2	Explosive
Ammonium perchlorate ≥ commercial grade	7790-98-9	Explosive
Hydrogen peroxide ≥ 35%	7722-84-1	Explosive
Magnesium (powder) ≥ commercial grade	7439-95-4	Explosive
Nitric acid ≥ 68%	7697-37-2	Explosive
Nitromethane ≥ commercial grade	75-52-5	Explosive
Phosphorus ≥ commercial grade	7723-14-0	Explosive
Potassium chlorate ≥ commercial grade	3811-04-9	Explosive
Potassium nitrate ≥ commercial grade	7757-79-1	Explosive
Potassium perchlorate ≥ commercial grade	7778-74-7	Explosive
Potassium permanganate ≥ commercial grade	7722-64-7	Explosive
Sodium azide ≥ commercial grade	26628-22-8	Explosive
Sodium chlorate ≥ commercial grade	7775-09-9	Explosive
Sodium nitrate ≥ commercial grade	7631-99-4	Explosive
Triethanolamine ≥ 80%	102-71-6	Chemical Weapon/Precursor
CHEMICAL WEAPON/PRECURSORS		
1,3-Bis(2-chloroethylthio)-n-propane	63905-10-2	Chemical Weapon/Precursor
1,4-Bis(2-chloroethylthio)-n-butane	142868-93-7	Chemical Weapon/Precursor
1,5-Bis(2-chloroethylthio)-n-pentane	142868-94-8	Chemical Weapon/Precursor
2-Chloroethylchloro-methylsulfide	2625-76-5	Chemical Weapon/Precursor
Arsenic trichloride (synonym: [Arsenous trichloride]) ≥ 30%	7784-34-1	Chemical Weapon/Precursor
Bis(2-chloroethylthio)methane	63869-13-6	Chemical Weapon/Precursor

Bis(2-chloroethylthiomethyl)ether	63918-90-1	Chemical Weapon/Precursor
Chlorosarin (synonym: [o-Isopropyl methylphosphonochloridate])	1445-76-7	Chemical Weapon/Precursor
Chlorosoman (synonym: [o-Pinacolyl methylphosphonochloridate])	7040-57-5	Chemical Weapon/Precursor
DF (synonym: [Methyl phosphonyl difluoride])	676-99-3	Chemical Weapon/Precursor
Diethyl methylphosphonite ≥ 30%	15715-41-0	Chemical Weapon/Precursor
Ethyl phosphonyl difluoride	753-98-0	Chemical Weapon/Precursor
Ethyldiethanolamine ≥ 80%	139-87-7	Chemical Weapon/Precursor
Ethylphosphonothioic dichloride ≥ 30%	993-43-1	Chemical Weapon/Precursor
HN1 (nitrogen mustard-1) (synonym: [Bis(2-chloroethyl)ethylamine])	538-07-8	Chemical Weapon/Precursor
HN2 (nitrogen mustard-2) (synonym: [Bis(2-chloroethyl)methylamine])	51-75-2	Chemical Weapon/Precursor
HN3 (nitrogen mustard-3) (synonym: [Tris(2-chloroethyl)amine])	555-77-1	Chemical Weapon/Precursor
Isopropylphosphonothioic dichloride ≥ 30%	1498-60-8	Chemical Weapon/Precursor
Isopropylphosphonyl difluoride	677-42-9	Chemical Weapon/Precursor
Lewisite 1 (synonym: [2-Chlorovinyldichloroarsine])	541-25-3	Chemical Weapon/Precursor
Lewisite 2 (synonym: [Bis(2-chlorovinyl)chloroarsine])	40334-69-8	Chemical Weapon/Precursor
Lewisite 3 (synonym: [Tris(2-chlorovinyl)arsine])	40334-70-1	Chemical Weapon/Precursor

MDEA (synonym: [Methyldiethanolamine]) ≥ 80%	105-59-9	Chemical Weapon/Precursor
Methylphosphonothioic dichloride ≥ 30%	676-98-2	Chemical Weapon/Precursor
N,N-(2-diethylamino)ethanethiol (synonym: [2-(Diethylamino)ethanethiol]) ≥ 30%	100-38-9	Chemical Weapon/Precursor
N,N-(2-diisopropylamino)ethanethiol (synonym: [N,N-diisopropyl-(beta)-aminoethane thiol]) ≥ 30%	5842-07-9	Chemical Weapon/Precursor
N,N-(2-dimethylamino)ethanethiol ≥ 30%	108-02-1	Chemical Weapon/Precursor
N,N-(2-dipropylamino)ethanethiol ≥ 30%	5842-06-8	Chemical Weapon/Precursor
N,N-Diethyl phosphoramidic dichloride ≥ 30%	1498-54-0	Chemical Weapon/Precursor
N,N-Diisopropyl phosphoramidic dichloride ≥ 30%	23306-80-1	Chemical Weapon/Precursor
N,N-Dimethyl phosphoramidic dichloride (synonym: [Dimethylphosphoramido-dichloridate]) ≥ 30%	677-43-0	Chemical Weapon/Precursor
N,N-Dipropyl phosphoramidic dichloride ≥ 30%	40881-98-9	Chemical Weapon/Precursor
Nitrogen mustard hydrochloride (synonym: [Bis(2-chloroethyl)methylamine hydrochloride]) ≥ 30%	55-86-7	Chemical Weapon/Precursor
o,o-Diethyl S-[2-(diethylamino)ethyl] phosphorothiolate ≥ 30%	78-53-5	Chemical Weapon/Precursor
O-Mustard (T) (synonym: [Bis(2-chloroethylthioethyl)ether])	63918-89-8	Chemical Weapon/Precursor
Phosphorus oxychloride (synonym: [Phosphoryl chloride]) ≥ 80%	10025-87-3	Chemical Weapon/Precursor
Propylphosphonothioic dichloride ≥ 30%	2524-01-8	Chemical Weapon/Precursor
Propylphosphonyl difluoride	690-14-2	Chemical Weapon/Precursor

QL (synonym: [o-Ethyl-o-2-diisopropylaminoethyl methylphosphonite])	57856-11-8	Chemical Weapon/Precursor
Sarin (synonym: [o-Isopropyl methylphosphonofluoridate])	107-44-8	Chemical Weapon/Precursor
Sesquimustard (synonym: [1,2-Bis(2-chloroethylthio)ethane])	3563-36-8	Chemical Weapon/Precursor
Soman (synonym: [o-Pinacolyl methylphosphonofluoridate])	96-64-0	Chemical Weapon/Precursor
Sulfur mustard (Mustard gas (H)) (synonym: [Bis(2-chloroethyl)sulfide])	505-60-2	Chemical Weapon/Precursor
Tabun (synonym: [o-Ethyl-N,N-dimethylphosphoramido-cyanidate])	77-81-6	Chemical Weapon/Precursor
Thiodiglycol (synonym: [Bis(2-hydroxyethyl)sulfide]) ≥ 30%	111-48-8	Chemical Weapon/Precursor
Triethanolamine hydrochloride ≥ 80%	637-39-8	Chemical Weapon/Precursor
Triethyl phosphite ≥ 80%	122-52-1	Chemical Weapon/Precursor
Trimethyl phosphite ≥ 80%	121-45-9	Chemical Weapon/Precursor
VX (synonym: [o-Ethyl-S-2-diisopropylaminoethyl methyl phosphonothiolate])	50782-69-9	Chemical Weapon/Precursor
EXPLOSIVES		
1H-Tetrazole ≥ commercial grade	288-94-8	Explosive
5-Nitrobenzotriazol ≥ commercial grade	2338-12-7	Explosive
Ammonium nitrate, [with >0.2 percent combustible substances, including any organic substance calculated as carbon, to the exclusion of any other added substance] ≥ commercial grade	6484-52-2	Explosive
Ammonium picrate ≥ commercial grade	131-74-8	Explosive
Barium azide ≥ commercial grade	18810-58-7	Explosive
Diazodinitrophenol (synonym: [DDNP]) ≥ commercial grade	87-31-0	Explosive
Diethyleneglycol dinitrate ≥ commercial grade	693-21-0	Explosive
Dingu (synonym: [Dinitroglycoluril]) ≥ commercial grade	55510-04-8	Explosive
Dinitrophenol ≥ commercial grade	25550-58-7	Explosive
Dinitroresorcinol ≥ commercial grade	519-44-8	Explosive
Dipicryl sulfide ≥ commercial grade	2217-06-3	Explosive

Dipicrylamine [or] Hexyl (synonym: [Hexanitrodiphenylamine]) ≥ commercial grade	131-73-7	Explosive
Guanyl nitrosaminoguanylidene hydrazine ≥ commercial grade		Explosive
Hexanitrostilbene ≥ commercial grade	20062-22-0	Explosive
Hexolite (synonym: [Hexotol]) ≥ commercial grade	121-82-4	Explosive
HMX (synonym: [Cyclotetramethylene-tetranitramine]) ≥ commercial grade	2691-41-0	Explosive
Lead azide ≥ commercial grade	13424-46-9	Explosive
Lead styphnate (synonym: [Lead trinitroresorcinate]) ≥ commercial grade	15245-44-0	Explosive
Mercury fulminate ≥ commercial grade	628-86-4	Explosive
Nitrobenzene ≥ commercial grade	98-95-3	Explosive
Nitrocellulose ≥ commercial grade	9004-70-0	Explosive
Nitroglycerine ≥ commercial grade	55-63-0	Explosive
Nitromannite (synonym: [Mannitol hexanitrate, wetted]) ≥ commercial grade	15825-70-4	Explosive
Nitrostarch ≥ commercial grade	9056-38-6	Explosive
Nitrotriazolone ≥ commercial grade	932-64-9	Explosive
Octolite ≥ commercial grade	57607-37-1	Explosive
Octonal ≥ commercial grade	78413-87-3	Explosive
Pentolite ≥ commercial grade	8066-33-9	Explosive
PETN (synonym: [Pentaerythritol tetranitrate]) ≥ commercial grade	78-11-5	Explosive
Picrite (synonym: [Nitroguanidine]) ≥ commercial grade	556-88-7	Explosive
RDX (synonym: [Cyclotrimethylenetrinitramine]) ≥ commercial grade	121-82-4	Explosive
RDX and HMX mixtures ≥ commercial grade	121-82-4	Explosive
Tetranitroaniline ≥ commercial grade	53014-37-2	Explosive
Tetrazene (synonym: [Guanyl nitrosaminoguanyltetrazene]) ≥ commercial grade	109-27-3	Explosive
TNT (synonym: [Trinitrotoluene]) ≥ commercial grade	118-96-7	Explosive
Torpex (synonym: [Hexotonal]) ≥ commercial grade	67713-16-0	Explosive
Trinitroaniline (synonym: [Picramide]) ≥ commercial grade	26952-42-1	Explosive
Trinitroanisole ≥ commercial grade	606-35-9	Explosive
Trinitrobenzene ≥ commercial grade	99-35-4	Explosive
Trinitrobenzenesulfonic acid (synonym: [Picrylsulfonic acid]) ≥ commercial grade	2508-19-2	Explosive
Trinitrobenzoic acid ≥ commercial grade	129-66-8	Explosive
Trinitrochlorobenzene ≥ commercial grade	88-88-0	Explosive
Trinitrofluorenone ≥ commercial grade	129-79-3	Explosive
Trinitro-meta-cresol ≥ commercial grade	602-99-3	Explosive
Trinitronaphthalene ≥ commercial grade	55810-17-8	Explosive
Trinitrophenetole ≥ commercial grade	4732-14-3	Explosive
Trinitrophenol (synonym: [Picric acid]) ≥ commercial grade	88-89-1	Explosive
Trinitroresorcinol ≥ commercial grade	82-71-3	Explosive
Tritonal ≥ commercial grade	54413-15-9	Explosive
GASSES (please estimate amount of product remaining or use maximum cylinder capacity/amount purchased)		

Arsine ≥ 0.67%	7784-42-1	Toxic Gas
Boron tribromide ≥ 12.67%	10294-33-4	Toxic Gas
Boron trichloride (synonym: [Borane, trichloro]) ≥ 84.7%	10294-34-5	Toxic Gas
Boron trifluoride (synonym: [Borane, trifluoro]) ≥ 26.87%	7637-07-2	Toxic Gas
Bromine chloride (synonym: [Bromine monochloride]) ≥ 9.67%	13863-41-7	Toxic Gas
Bromine trifluoride ≥ 6%	7787-71-5	Toxic Gas
Carbonyl fluoride (synonym: [Carbonyl oxyfluoride]) ≥ 12%	353-50-4	Toxic Gas
Carbonyl sulfide (synonym: [Carbon oxysulfide]) ≥ 56.67%	463-58-1	Toxic Gas
Chlorine ≥ 9.77%	7782-50-5	Toxic Gas
Chlorine pentafluoride ≥ 4.07%	13637-63-3	Toxic Gas
Chlorine trifluoride ≥ 9.97%	7790-91-2	Toxic Gas
Cyanogen (synonym: [Ethanedinitrile]) ≥ 11.67%	460-19-5	Toxic Gas
Cyanogen chloride ≥ 2.67%	506-77-4	Toxic Gas
Diborane ≥ 2.67%	19287-45-7	Toxic Gas
Dichlorosilane (synonym: [Silane, dichloro-]) ≥ 10.47%	4109-96-0	Toxic Gas
Dinitrogen tetroxide ≥ 3.8%	10544-72-6	Toxic Gas
Fluorine ≥ 6.17%	7782-41-4	Toxic Gas
Germane ≥ 20.73%	7782-65-2	Toxic Gas
Germanium tetrafluoride ≥ 2.11%	7783-58-6	Toxic Gas
Hexaethyl tetraphosphate and compressed gas mixtures ≥ 33.37%	757-58-4	Toxic Gas
Hexafluoroacetone ≥ 15.67%	684-16-2	Toxic Gas
Hydrogen bromide (anhydrous) ≥ 95.33%	10035-10-6	Toxic Gas
Hydrogen chloride (anhydrous) ≥ commercial grade	7647-01-0	Toxic Gas
Hydrogen cyanide (synonym: [Hydrocyanic acid]) ≥ 4.67%	74-90-8	Toxic Gas
Hydrogen fluoride (anhydrous) ≥ 42.53%	7664-39-3	Toxic Gas
Hydrogen iodide, anhydrous ≥ 95.33%	10034-85-2	Toxic Gas
Hydrogen selenide ≥ 0.07%	7783-07-5	Toxic Gas
Hydrogen sulfide ≥ 23.73%	7783-06-4	Toxic Gas
Methyl mercaptan (synonym: [Methanethiol]) ≥ 45%	74-93-1	Toxic Gas
Methylchlorosilane ≥ 20%	993-00-0	Toxic Gas
Nitric oxide (synonym: [Nitrogen oxide (NO)]) ≥ 3.83%	10102-43-9	Toxic Gas
Nitrogen trioxide ≥ 3.83%	10544-73-7	Toxic Gas
Nitrosyl chloride ≥ 1.17%	2696-92-6	Toxic Gas
Oxygen difluoride ≥ 0.09%	7783-41-7	Toxic Gas
Perchloryl fluoride ≥ 25.67%	7616-94-6	Toxic Gas
Phosgene (synonym: [Carbonic dichloride] or [Carbonyldichloride]) ≥ 0.17%	75-44-5	Toxic Gas
Phosphine ≥ 0.67%	7803-51-2	Toxic Gas
Phosphorus trichloride ≥ 3.48%	7719-12-2	Toxic Gas
Selenium hexafluoride ≥ 1.67%	7783-79-1	Toxic Gas
Silicon tetrafluoride ≥ 15%	7783-61-1	Toxic Gas
Stibine ≥ 0.67%	7803-52-3	Toxic Gas
Sulfur dioxide (anhydrous) ≥ 84%	7446-09-5	Toxic Gas
Sulfur tetrafluoride (synonym: [Sulfur fluoride (SF4), (T-4)-]) ≥ 1.33%	7783-60-0	Toxic Gas
Tellurium hexafluoride ≥ 0.83%	7783-80-4	Toxic Gas

Titanium tetrachloride (synonym: [Titanium chloride (TiCl4) (T-4)-]) ≥ 13.33%	7550-45-0	Toxic Gas
Trifluoroacetyl chloride ≥ 6.93%	354-32-5	Toxic Gas
Trifluorochloroethylene (synonym: [Ethene, chlorotrifluoro]) ≥ 66.67%	79-38-9	Toxic Gas
Tungsten hexafluoride ≥ 7.1%	7783-82-6	Toxic Gas

Appendix G: High Hazard Chemicals

Section 1: Carcinogens, Reproductive Toxins or Highly Toxic Chemicals used in Biomedical Research

The chemicals listed below are extremely hazardous due to their toxic effects. This is not an exclusive list. Workers must have knowledge of the dangers of these chemicals prior to use, and documentation of training in safe working procedures.

Biologically active compounds:

DNA synthesis inhibitors (e.g. hydroxyurea, nucleotide analogs, dideoxy nucleotides, actinomycin D, acidicolin)
kinase inhibitors (e.g. NaF)
mitogenic compounds (e.g. concanavalin A)
mitogenic inhibitors (e.g. colcemid)
phosphatase inhibitors (e.g. okadaic acid)
protease inhibitors (e.g. PMSF, Aprotin, Pepstatin A, Leopeptin – use safer alternatives like Pefabloc™)
protein synthesis inhibitors (e.g. cycloheximide, Puromycin)
respiratory chain inhibitors (e.g. sodium azide)
transcriptional inhibitors (e.g. a-amanitin and actinomycin D)

BRDU, 5- bromo–2'–deoxyuridine (CAS# 59-14-3) – mutagen, reproductive toxin, potential carcinogen, used as an alternative to tritium (H3) in labeling replicating cells/DNA.

Diisopropyl fluorophosphate: highly toxic cholinesterase inhibitor; the antidote, atropine sulfate and 2-PAM (2-pyridinealdoxime methiodide) must be readily available

MPTP, 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridne hydrochloride (CAS# 23007-85-4) – potent neurotoxin at low doses, producing irreversible parkinsons like symptoms, lethal at high doses

N-methyl-N'-nitro-N-nitrosoguanidine: carcinogen (this chemical also forms explosive compounds upon degradation)
Phalloidin from Amanita Phalloides: used for staining actin filaments
Retinoids: potential human teratogens
Streptozotocin: potential human carcinogen
Urethane (ethyl carbamate): an anesthetic agent, potent carcinogen and strong teratogen, volatile at room temperature

Other compounds used in biomedical research:

5-fluoracil
alpha-Ammanatin
Ethylene Oxide
Hydrofluoric Acid

Osmium Tetroxide
Perchloric Acid
Thimerosol (organic mercury compound)

Section 2: Toxins of Biological Origin
(adapted from the University of Florida website)

Biological toxins are produced by certain bacteria, fungi, protozoa, plants, reptiles, amphibians, fish, echinoderma (spiny urchins and starfish), mollusks, and insects.

Biological toxins with a mammalian LD_{50} of ≤ 100 ug/kg body weight are called "Acute Toxins". Additional precautions, training and supervision are required for work with these materials

The following table lists LD_{50} values for some biological toxins.

Toxin	LD50 (ug/kg)*
Abrin	0.7
Aerolysin	7.0
Botulinin toxin A	0.0012
Botulinin toxin B	0.0012
Botulinin toxin C1	0.0011
Botulinin toxin C2	0.0012
Botulinin toxin D	0.0004
Botulinin toxin E	0.0011
Botulinin toxin F	0.0025
b-bungarotoxin	14.0
Caeruleotoxin	53
Cereolysin	40-80
Cholera toxin	250
Clostridium difficile enterotoxin A	0.5
Clostridium difficile cytotoxin B	220
Clostridium perfringens lecithinase	3
Clostridium perfringens kappa toxin	1500
Clostridium perfringens perfringolysin O	13-16
Clostridium perfringens enterotoxin	81
Clostridium perfringens beta toxin	0.4
Clostridium perfringens delta toxin	5
Clostridium perfringens epsilon toxin	0.1
Conotoxin	12-30
Crotoxin	82
Diphtheria toxin	0.1
Listeriolysin	3-12

Leucocidin	50
Modeccin	1-10
Nematocyst toxins	33-70
Notexin	25
Pertussis toxin	15
Pneumolysin	1.5
Pseudomonas aeruginosa toxin A	3
Ricin	2.7
Saxitoxin	8
Shiga toxin	20
Shigella dysenteriae neurotoxin	1.3
Streptolysin O	8
Staphylococcus enterotoxin B	25
Staphylococcus enterotoxin F	2-10
Streptolysin S	25
Taipoxin	2
Tetanus toxin	0.001
Tetrodotoxin	8
Viscumin	2.4-80
Volkensin	1.4
Yersinia pestis murine toxin	10

*Please note that the LD50 values are from a number of sources. For specifics on route of application (i.v., i.p., s.c.), animal used, and variations on the listed toxins, please go to the references listed below.

Reference:
1. Gill, D. Michael; 1982; Bacterial toxins: a table of lethal amounts; Microbiological Reviews; 46: 86-94
2. Stirpe, F.; Luigi Barbieri; Maria Giulia Battelli, Marco Soria and Douglas A. Lappi; 1992; Ribosome-inactivating proteins from plants: present status and future prospects; Biotechnology; 10: 405-412
3. Registry of toxic effects of chemical substances (RTECS): comprehensive guide to the RTECS. 1997. Doris V. Sweet, ed., U.S. Dept of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; Cincinnati, Ohio

Other Biological Toxins:

Aflatoxins
Amanitin
Amphibian venoms
Anatoxin A
Anthrax toxin
Aspergillus sp toxins
Bacillus sp. toxins - all
Bordetella sp. toxins
Botulinum toxins - all
Brevetoxins
Bungarotoxins
Cardiotoxin
Charybdotoxin
Cholera toxins - all
Ciguatera toxin
Clostridia species toxins - all
Cluepeotoxins
Cobra venous and all derived toxins
Cobratoxin
Conotoxins - all
Crotamine
Dendrodotoxins
Dinoflagellate neurotoxins
Diphtheria toxins
Domoic acid
DTX-1 (Dinophysistoxin-1)
Echinoderm venoms - all
Endotoxins - all
Enterobacteriaciae toxins - all
Enterotoxins - all
Escherichia coli toxins - all
Exotoxin A
Fish venoms - all
Fusarium sp. toxins
Gliotoxin
Joco Spider Toxin JSTX-3
Lappaconitines
Leiurotoxins
Lipid A - all types
Lipopolysaccharides from all species
Maitotoxin
Medamine
Microcystins
Mojave toxin
Mycotoxins - all
Myotoxins
Neurotoxins - all
Notexin
Nodularin
Ochratoxin
Palytoxin
Paradoxin
Pertussis toxins - all
Phalloidin
Psilocybine
Pseudomonas sp. toxins
Reptile venoms - all
Resiniferatoxin
Ricin toxins - all
Sapintoxin
Sarafotoxin
Saxitoxin
Short Neurotoxins
Snake venoms - all
Stable toxins
Staphylococcus sp. toxins
Streptonigrin
Taipoxin
Tetanus toxins - all
Tetrodotoxins - all
Textilotoxin
Thymeleatoxin
Tinyatoxin
Toxin II - all types

Section 3: Working with and Disposing of Biological Toxins

Adapted from the University of Pennsylvania EH&S website

Because they can be extremely hazardous, even in minute quantities, biological toxins require strict safeguards against their inhalation, absorption through skin or mucous membranes (typically due to a splash), ingestion, or percutaneous injury.

Key points of the guidelines are:

1. Written safety **protocols** to cover the use of the specific toxin(s) in use
2. **Security measures** in place to protect against unauthorized access to toxin(s)
3. **Inventory control** system in place; all entries in a hardbound book, in ink
4. Written **plan for** toxin-related **emergencies** (spill, exposure, etc) posted
5. **BSL-2 or BSL-3** containment and practices in use

Some toxins are quite resistant to conventional methods of inactivation. **These agents cannot be simply placed in the biomedical or hazardous waste that is picked up by EH&S**.

Toxins may be destroyed by several methods as shown in the table below. Some toxins are inactivated by autoclaving for one hour at 121°C. Others are inactivated by exposure to sodium hypochlorite and/or sodium hydroxide.

Chemical destruction of toxins:

When using sodium hypochlorite and / or sodium hydroxide to destroy toxin, the procedure(s) must be performed in a laboratory fume hood or a biological safety cabinet. At a minimum, personal protective equipment for all procedures should include:

Long sleeved protective clothing (lab coat, gown)
Gloves and eye protection

1. If the toxin is classified as a select agent, even in exempt amounts, document destruction of the toxin and notify EHS.

2. Work in a fume hood or biosafety cabinet with the sash at the lowest reasonable sash height for safe and effective work.

3. Place plastic backed absorbent paper (bench diaper) on the work surface of the fume hood or biosafety cabinet.

4. CAREFULLY put the Select Agent toxin into solution in the primary container. DO NOT USE A GLASS CONTAINER.

5. Place the primary container in a secondary container, such as a beaker or rack.

6. Slowly dispense an equal volume of the concentrations of sodium hypochlorite and/or sodium hydroxide designated in table 1 below into the primary container of toxin solution to be destroyed.

7. Do not replace the cap on primary container.

8. Place a “WARNING / DO NOT USE” sign on the hood/cabinet.

9. Allow a minimum 60 minutes exposure time. (See table 1 below for additional exposure time recommendations.)

10. Document the destruction of the toxin in the laboratory inventory logbook.

11. Secure the cap on the primary container. DOUBLE BAG the material in zip-lock plastic bags and label it “Inactivated/denatured (TOXIN NAME)”.

12. Contact EH&S for disposal

Steam Sterilization (Autoclaving) of Toxins

If acceptable as a method in table 1 below, destroy toxins by autoclaving them using the procedure outlined below:

1. If the toxin is classified as a select agent, even in exempt amounts, notify EH&S prior to destruction of the agent.

2. In a fume hood or biological safety cabinet, loosen the cap of the primary toxin container to allow steam penetration.

3. Place the primary container into a secondary biohazard sharps container.

4. Place the sharps container in a loosely closed biohazard bag.

5. Place the bag in a autoclavable pan.

6. Autoclave at 121° C for 1 hour on liquid cycle (slow exhaust).

7. Document the destruction of the toxin the laboratory inventory logbook.

8. After autoclaving, allow time for materials to cool before handling.

9. Discard the biobag and its containers as biological waste.

DO NOT use steam sterilization for destruction of any of the low molecular weight toxins (i.e. mycotoxins, marine and reptile venoms).

All waste from toxins that is not disposed as infectious waste must be collected by EH&S for disposal as hazardous waste.

Toxins classified as select agents, even if in exempt amounts, require documentation of destruction with witnesses. Contact EHS and refer to the Select Agent policy.

Table 1 - Inactivation Procedures for Selected Toxins

Allow at least a 60-minute chemical contact time for complete inactivation of toxin. Any procedure labeled "yes" is an approved procedure for inactivation of the toxin specified.

Toxin	**Autoclave** (**1 hour** @ 121° C, liquid exhaust)	**2.5% NaOCL + 0.25 N NaOH**	**1.0% NaOCl**	**2.5% NaOCl**
Abrin (1)(8)	Yes	N/A	N/A	N/A
Botulinum Neurotoxin (1) (7)	Yes	Yes	Yes	Yes
Clostridium perfringens epsilon toxin (2)	Yes	N/A	N/A	N/A
Conotoxin(3)	**CALL EH&S**			
Diacetoxyscirpenol(5)	No	Yes	No	Yes (3-5%)
Ricin (1)(7)	Yes	Yes	Yes	Yes
Saxitoxin (1)(7)	No	Yes	Yes	Yes
Shigatoxin & Shiga-like ribosome inactivating proteins(4)	Yes	Yes	Yes	Yes
Staphylococcal Enterotoxins (1)(7)	Yes	Yes	Yes	Yes
Tetrodotoxin (1)(7)	No	Yes	Yes	Yes
T-2 Toxin (1)(6)(5)	No	Yes	No	No

1. Wannemacher R.W. 1989. Procedures for Inactivation and Safety Containment of Toxins. Proc. Symposium on Agents of Biological Origin, U.S. Army Research, Dev. and Engineering Center, Aberdeen proving Ground, MD. pp. 115-122

2. Factsheets on Chemical and Biological Warfare, http://www.cbwinfo.com/Biological/Toxins/Cper.html

3. Factsheets on Chemical and Biological Warfare, http://www.cbwinfo.com/Biological/Toxins/Conotox.html

4. Factsheets on Chemical and Biological Warfare, http://www.cbwinfo.com/Biological/Toxins/Verotox.html

5. Factsheets on Chemical and Biological Warfare, http://www.cbwinfo.com/Biological/Toxins/mycotoxins.html

6. For complete inactivation of T-2 mycotoxin extend exposure time for liquid samples, spills, and non-burnable waste in 2.5% sodium hypoclorite and 0.25 N sodium hydroxide to 4 hr. Expose cages/bedding from animals exposed to T-2 mycotoxin to 0.25% sodium hypochlorite and 0.025 N sodium hydroxide for 4 hrs.

7. For inactivation of saxitoxin, tetrodotoxin, ricin, botulinum toxin, or staphylococcal enterotoxins, expose work surfaces, solutions, equipment, animal cages, spills to 10% sodium hypochlorite for 60 minutes.

8. http://www.inchem.org/documents/pims/plant/abruspre.htm

Section 4: Poisonous Gasses and Compressed Liquids

Arsine
Boron Trichloride
Bromine Pentafluoride
Chlorine Trifluoride
Cyanogen
Diborane
Dinitrogen tetroxide
Fluorine
Germane
Hydrogen Selenide
Nitric Oxide
Nitrogen Dioxide
Nitrogen Trioxide
Nitrosyl Chloride
Oxygen Difluoride
Phosgene
Phosphine
Phosphorous Pentafluoride
Selenium Hexafluoride
Stibine
Sulfur Tetrafluoride
Tellurium Hexafluoride
Tetraethyldithiopyrophosphate
Tetraethylpyrophosphate

Other unique compressed gas hazards:
Hydrogen Fluoride (cylinders can fail over time due to corrosion and/or overpressurization from HF degradation)
Tetrafluoroethylene (flammable and unstable over time due to peroxide formation)

Section 5: OSHA regulated carcinogens

These chemicals, with their unique Chemical Abstract Service (CAS) numbers in parentheses, are:

- Acrylonitirle (107-13-1)
- Arsenic (7440-38-2) and inorganic arsenic compounds
- Asbestos (1332-21-4), including Amosite (12172-73-5),
- Chrysotile (12001-29-5), and Crocidolite (12001-28-4)
- Benzene (71-43-2)
- Cadmium (7440-43-9) and cadmium compounds
- Coal tar pitch volatiles (8007-4-2)
- Coke oven emissions
- 1,2-Dibromo-3-chloropropane (96-12-8)
- Ethylene dibromide (106-93-4)
- Ethylene oxide (75-21-8)
- Formaldehyde (50-00-0) (including paraformaldehyde [30525-89-41])
- 4,4'-Methylenebis(2-chloroaniline) (101-14-4)
- 4,4'-Methylenedianiline (107-77-9)
- Vinyl chloride (75-01-4)
- Carcinogens with specific laboratory activity regulations:
  - 2-Acetylaminofluorene (53-96-3)
  - 2-Aminodiphenyl (92-67-1)
  - Benzidine (92-87-2) (and its salts)
  - bis-Chloromethyl ether (542-88-1)
  - 3,3'-Dichlorobenzidine (91-94-1) (and its salts)
  - 4-Dimethylaminoazobenzene (60-11-7)
  - Ethyeneimine (151-56-4)
  - Methyl chloromethyl ether (107-30-2)
  - alpha-Naphthylamine (134-32-7)
  - beta-Naphthylamine (91-59-8)
  - 4-Nitrobiphenyl (92-93-3)
  - N-Nitrosodimethylamine (62-75-9)
  - beta-Propiolactone (57-57-8)

Section 6: Shock Sensitive and Peroxide forming Chemicals

(From Sigma Aldrich http://www.sigmaaldrich.com/chemistry/solvents/learning-center/peroxide-formation.html accessed on 5/2/2012)

Peroxide Forming Solvents

A significant number of laboratory solvents can undergo autoxidation under normal storage conditions to form unstable and potentially dangerous peroxide by-products. This process is catalyzed by light and heat and occurs when susceptible materials are exposed to atmospheric oxygen. Molecular structure is the primary factor relating to a material's potential for hazardous peroxide formation.

Most overviews of potential peroxide-forming chemicals classify various materials into three categories, on the basis of peroxide formation susceptibility, each with general handling and use guidelines.1 The two categories relevant to solvents are defined as solvents that pose a peroxide related safety risk without having to be pre-concentration (see Group A, next section) and solvents that necessitate pre-concentration in order to form peroxides (see Group B, next section). Storage time guidelines for perviously opened containers is provided in the section following this paragraph (Potential Peroxide-Forming Solvents*). Please note that the storage time indicated below are based on these solvents continually being stored in opaque containers and under inert atmospheric gases.

Potential Peroxide-Forming Solvents*

Group A: Chemicals that form explosive levels of peroxides without concentration

Severe peroxide hazard after prolonged storage, especially after exposure to air.
Test for peroxide formation before using or discard after 3 months.

Isopropyl ether

Group B: Peroxide hazards on concentration

Test for peroxide formation before distillation or evaporation. Test for peroxide formation or discard after 1 year.

Acetal

Acetaldehyde

Benzyl Alcohol

2-Butanol

Dioxanes

Chlorofluoroethylene

Cumene(isopropylbenzene)

Cyclohexene

2-Cyclohexen-1-ol

Cyclopentene

Decahydronapthalene(decalin)

Diacetylene(butadiyne)

Dicyclopentadiene

Diglyme

Diethyl ether

Ethylene glycol ether acetates

Furan

4-Heptanol

2-Hexanol

Methyl Acetylene

3-Methyl-1-butanol

Methyl-isobutyl ketone

4-Methyl-2-pentanol

2-Pentanol

4-Penten-1-ol

1-Phenylethanol

Tetrahydrofuran

Tetrahydronapthalene

Vinyl Ethers

Sec. Alcohols

* Materials other than those listed may form peroxides. Applies only to pure materials.

Use and Storage of Peroxide-Forming Solvents

The solvents most commonly used in the laboratory solvents, such as diethyl ether, tetrahydrofuran, cyclohexene, glycol ethers, decalin and 2-propanol are shown in Group B of the previous section. These compounds produce organic peroxides that are significantly less volatile than the solvent in which they are formed, as a result, evaporative concentration or distillation can produce dangerous levels of peroxides. In fact, most Group B solvents are sufficiently volatile that multiple openings of a single container can result in significant and dangerous peroxide concentration. The next section contains a list of key aspects to consider when handling peroxide-forming solvents.

General Handling Considerations for Peroxidizeable Solvents:

- All peroxide-forming solvents should be checked for the presence of any peroxides prior to distillation or evaporation.
- Solvents containing low levels of free radical scavengers such as BHT should be used whenever the presence of the stabilizing species does not interfere with intended application.
- Uninhibited materials should be stored with care and frequently checked for peroxide formation.
- Peroxide-forming solvents should be purchased in limited quantities and older material in inventory should be preferentially selected for use.
- Materials should be stored away from light and heat with tightly secured caps and labeled with dates of receipt and opening.
- Periodic testing to detect peroxides should be performed and recorded on previously opened material. For more information, it is recommended that the reader review the articles referenced below by Kelly2 and/or Clark3

Peroxide Detection

A variety of methods are available to test for the presence of peroxides in organic solvents with the two most common tests described below. At present, 100 ppm is widely used as a general control point with respect to minimum hazardous peroxide concentration in a solvent, however, this value lacks scientific validation and is likely too liberal or conservative depending on the solvent in question and intended application.2 If there are visible crystals, visible precipitate or an oily viscous layer present in the material, these are visual indicators of dangerous high peroxide levels, immediately contact your company's EH&S (Environmental, Health and Safety) department or its equivalent, to manage this hazardous situation and to dispose of this material.

Quantofix® Peroxide Test Strips (Sigma-Aldrich Part # 37206)

In the presence of hydrogen peroxide the test paper turns blue. Quantofix® Peroxide test sticks can also be used for the determination of peracetic acid and other organic and inorganic hydroperoxides. To test for hydroperoxides in organic solvents, the test zone is wetted with one drop of water after evaporation of the solvent.

Interferences: In the pH range of 2-9, the accuracy of the determination is independent of the pH of the test solution. Buffer strongly acidic solutions with sodium acetate and adjust alkaline solutions to about pH 5-7 with citric acid. Falsely positive results can only be caused by strong oxidizing agents.

Storage: Avoid exposing the sticks to sunlight and moisture. Store unopened packs in refrigerator (+2 °C to +8 °C). Opened packs: store container in a cool and dry place.

Potassium Iodide Indicator

Add 0.5-1.0 ml of the sample solvent to an equal volume of glacial acetic acid containing about 0.1 g of sodium iodide or potassium iodide crystals. A yellow color indicates iodine formation via iodide oxidation by sample peroxide; a brown color indicates high concentration. A blank determination should be made particularly when color development is faint since iodide/acetic acid mixtures will, over time, turn a yellow - brown color due to air oxidation.

A more sensitive variation of the above method adds one drop of a saturated, aqueous starch solution to the sample solution. Starch and iodine combine to form a bright blue complex that is more easily visualized than the yellow color generated by iodine alone. Dark blue solution color would be indicative of high peroxide concentrations.

References

Jackson, H.L., McCormack, W.B., Rondestvedt, C.S., Smeltz, K.C., and Viele, I.E. Control of Peroxidizable Compounds, J. Chem. Educ., 1970, 46 (3), A175.

Kelly, R.J, Review of Safety Guidelines for Peroxidizable Organic Compounds, Chemical Health and Safety, 1996, 3 (5), 28-36.

Clark, D.E., Peroxides and Peroxide - Forming Compounds, Chemical Health and Safety, 2001, 8 (5), 12-21.

B. Shock, Temperature or Friction Sensitive

Acetyl acetone peroxide with more than 9% wt active oxygen
Acetyl benzoyl peroxide (solid or more than 40% in solution)
Acetyl cyclohexanesulphonyl peroxide (> 82% with <12% water)
Acetyl peroxide, solid, or more than 27% in solution
Aceytlene (liquid), Ethyne (liquid) acetylene
Acetylene silver nitrate
Aluminum dross, wet or hot
Ammonium azide
Ammonium bromate
Ammonium chlorate
Ammonium fulminate
Ammonium nitrite
Ammonium permanganate
Antimony sulfide and a chlorate, mixture of
Arsenic sulfide and a chlorate, mixtures of
Ascaridole (organic peroxide) epidioxy-2-p-menthene
Azaurolic acid (salt of) (dry)
3-Azido guanidine picrate (dry)
Azido-1,2-propylene glycol dinitrate
Azidodithiocarbonic acid
Azidoethyl nitrate
Azotetrazole (dry)
Benzene tirozonide
Benzenediazonium chloride (dry)
Benzenediazonium nitrate (dry)
Benzoxidiazoles (dry)
Benzoyl azide
Benzazide, benzoic acid azide
Biphenyl triozonide
Bromine azide
4-Bromo-1,2-dinitrobenzene
Bromo silane
Butanetriol trinitrate
tert-butoxycarbonyl azide
Butyl azidoformate
tert-Butyl hydroperoxide, more than 90% with water

    Hydroperoxide, 1,1-dimethylethyl (more than 90% with water)
tert-Butyl peroxyisobutyrate, 77% or more
Chlorine azide
Chlorine dioxide (not hydrated)
Chloroprene, uninhibited
Copper amine azide
Copper tetramine nitrate
Cyanuric triazide
Cyclotetramethylene tetranitramine (dry)
    Octogen (dry)
    HMX (dry)
Di(beta-nitroxyethyl)ammonium nitrate
A,A-Di(nitroxy)methyl ether
Di(1-hydroxy tetrazole) (dry)
Di(1-naphthoyl) peroxide
Diacetone alcohol peroxide >57% in solution, >9% hydrogen peroxide,<26% diacetone alcohol, <9% water; total active
Diazidobenzene
1,2-Diazidoethane
1,1-Diazoaminonaphthalene
Diazoaminotetrazole (dry)
Diazodinitrophenol (dry)
    Dinol (dry)
    Diazol (dry)
    DDNP (dry)
    Diazo-4,6-dinitrobenzene-1-oxide (dry)
    Dinitro-1,2,3-benzoxadiazole (dry)
Diazodiphenyl methane
Diazomethane
Azimethylene
Diazonium nitrates (dry)
Diazonium perchlorates (dry)
Diazopropane
Dibenzyl peroxydicarbonate, >87% with water
Dibromoacetylene
Dibromomethyne
N,N'-dichlorazodicarbonamidine (salts of) (dry)
    Chloroazodin (salts of) (dry)
    Azochloramide (salts of) (dry)
Dichloroacetylene
    Dichloroethyne
2,4 dichlorobenzoyl peroxide (>77% with water)
Diethanol nitrosamine dinitrate
Diethyl peroxydicarbonate more than 27% in solution
Diethylene glycol dinitrate
    DEGN

  Digylcol nitrate
  Dinitroglycol
Diethylgold bromide
1,8-dihydroxy-2,4,5,7-tetranitroanthraquinone
  chrysamminic acid
Diiodoacetylene
  Diiodoethyne
Diisopropylbenzene hydroperoxide (>72% in solution)
  Isopropylcumyl hydroperoxide (>72% in solution)
2,5-dimethyl-2,5-dihydroperoxy hexane, more than 82% with water
Dimethylhexane dihydroperoxide (dry)
1,4-dinitro-1,14,4-tetramethylolbutanetetranitrate (dry)
2,4-dinitro-1,3,5-trimethylbenzene
1,3-dinitro-4,5-dinitrosobenzene
1,3-dinitro-5,5-dimethylhydantoin
Dinitor-7,8-dimethylglycouril (dry)
1,2-dinitroethane
1,1-dinitroethane (dry)
Dinitroethane
Dinitropropyleneglycol
4,6-dinitroresorcinol (heavy metal salts of) (dry)
2,4-dinitroresorcinol (heavy metal salts of) (dry)
3,5-dinitrosalicylic acid (lead salt) (dry)
Dinitrosobenxylamide and salts of (dry)
2,2-Dinitrostilbene
1,9-dinitroxypentanamethylene-2,4,6,8-tetramine (dry)
t-butyl peroxyacetate, >77% in solution
Ethanolamine dinitrate
Ethyl hydroperoxide
Ethyl perchlorate
Ethylene diamine diperchlorate
Ethylene glycol dinitrate
  EGDN
  Nitrogylcol
Fulminating gold
Fulminating platinum
Fulminating silver
Fulminic acid
Galactsan trinitrate
Glycerol monogluconate trinitrate
Glycerol monolactate trinitrate
Glycerol-1,3-dinitrate
Guanyl nitrosaminoguanylidine hydrazine (dry)
Hexamethylene triperoxide diamine (dry)
  HMTD (dry)
Hexamethylol benzene hexanitrate

- 2,2,4,4,6-Hexanitro-3,3'-dihydroxyazobenzene (dry)
- Hexanitroazoxy benzene
- 2,3,4,4,6-Hexanitrophenyl ether
  - Hexanitrodiphenyloxide
- N,N'-Hexanitrodiphenyl ethylene dinitramine (dry)
- Hexanitrodiphenyl urea
- 2,2,3,4,4-Hexanitrodiphenylamine (2,2,3,4,4,6)
- Hexanitroethane
- Hexanitoroxanilide
- Hydrazine azide
- Hydrazine chlorate
- Hydrazine dicarbonic acid diazide
- Hydrazine perchlorate
- Hydrazine selenate
- Hydrocyanic acid (prussic), unstabilized
- Hydroxylamine iodide
- Hyponitrous acid
- Lead nitroresorcinate (dry)
- Lead monoresorcinate (dry)
- Guanyl nitrosamineogyanyltetrazene (dry)
  - Tetrazene (dry)
- Lead styphnate (dry)
  - Lead trinitroresorcinate (dry)
- Inositol hexanitrate (dry)
- Inulin trinitrate (dry)
- Iodide Azide (dry)
- Iodoxy compounds (dry)
- Iridium nitratopentamine iridium nitrate
- Isothiocyanic acid (polymerization hazard)
  - Thiocyanic acid (polymerization hazard)
  - Hydrogen thiocyanate (polymerization hazard)
- Lead azide (dry)
- Lead picrate (dry)
- Magnesium dross (wet or dry)
- Mannitan tetranitrate
- Mercurous azide
- Mercury acetylide
- Mercury fulminate (dry)
- Mercuric cyanate (dry)
  - Fulminic acid, mercury(2+) salt (dry)
  - Fulminate of mercury (dry)
  - Fulminating mercury (dry)
- Mercury iodide aquabasic ammonbasic
  - Iodide of millon's base
- Mercury nitride
- Di-n-Butyl peroxydicarbonate, >52% in solution

- Metal salts of methyl nitramine (dry)
- Methazoic acid
- Methyl ethyl ketone peroxide, in solution with >9% by weight active oxygen
- Methyl isobutyl ketone peroxide, in solution with >9% by weight active oxygen
- Methyl nitrate
  - Nitric acid methyl ester (less than 10% with ethanol)
- Methyl picric acid (heavy metal salts of)
- Methyl trimethylol methane trinitrate
- Methylamine dinitramine and drys salts of
- Methylamine nitroform
- Methylamine perchlorate (dry)
- Methylene glycol dinitrate
- alpha-methylglucoside tetranitrate
- alpha-methylglycerol trinitrate
- Chloroacetone, unstabilized
  - Chloro-2-propanone, unstabilized
- Naphthalene diozonide
- Naphthyl amineperchlorate
- Nickel picrate
- Nitrated paper (unstable)
- Nitrates of diazonium compounds
- Nitrohydantoin
- Nitro isobutane triol trinitrate
- Nitro-n-methylglycolamide nitrate
- 2-Nitro-2-methylpropanol nitrate
- 6-Nitro-4-diazotoluene-3-sulfonic acid (dry)
- M-Nitrobenzene diazonium perchlorate
- Nitroethyl nitrate
- Nitroethylene polymer
- Nitrogen trichloride
- Nitrogen triiodide
- Nitrogen triiodide monoamine
- Nitroguanidine nitrate
- Mannitol hexanitrate (dry)
- Cabazide
- Nitrophenyldinitro methane
- Nitrosugars (dry)
- 1,7-octadiene-3,5-diyne-1,8-dimethoxy-9-octadecynoic acid
- Pentaerythrite tetranitrate (dry)
- Pentaerythritol tetranitrate (dry)
  - PETN (dry)
  - Baritrate (dry)
  - Angicap (dry)
  - Angitet (dry)
  - Antora (dry)
  - Arcotrate (dry)

  - Duotrate (dry)
  - Erinit (dry)
  - Hasethrol (dry)
  - Martrate-45 (dry)
  - Methranil (dry)
  - Mycardol (dry)
  - Niperyt (dry)
  - Niperyth (dry)
  - Nitropenta (dry)
  - Pencard (dry)
  - Pentafin (dry)
  - Pentestan-80 (dry)
  - Pentrate (dry)
  - Pentriol (dry)
  - Peritrate (dry)
- Pentanitroaniline (dry)
- Perchloric acid, exceeding 72% strength
- Peroxyacetic acid >43% and with more than 6% hydrogen peroxide
- Phenylene diaminediperchlorate (dry)
- Phosphorous (white or red) and a chlorate mix
- Pyridine perchlorate
- Quebrachitol pentanitrate
- Selenium nitride
- Silver acetylide (dry)
- Silver azide (dry)
- Silver chlorite (dry)
- Silver fulminate (dry)
- Silver oxalate (dry)
- Silver picrate (dry)
- Sodium picryl peroxide
- Sodium tetranitride
- Sucrose octanitrate (dry)
- Sulfur and chlorate (loose mixtures of)
- Tetraazido benzene quinone
- Tetraethylammonium perchlorate (dry)
- Tetramethylene diperoxide dicarbimide
- Tetranitrodiglycerin
- 2,3,4,6-Tetranitrophenol
- 2,3,4,6-Tetranitrophenyl methyl nitramine
- 2,3,4,6-Tetranitrophenylnitramine
- Tetranitroresorcinol (dry)
- 2,3,5,6-Tetranitroso nitrobenzene (dry)
- 2,3,5,6-tetranitroso-1,4-dinitrobenzene
- Tetrazine (dry)
- Tetrazoyl azide (dry)
- Tri-(B-nitroxyethyl)ammonium nitrate

Trichloromethyl perchlorate
Triformoxine trinitrate
Trimethylene glycol diperchlorate
Trimethylol nitromethane trinitrate
Trinitro-1,3-diazobenzene
Trinitroacetic acid
Trinitroacetonitrile
Trinitroamine cobalt
Trinitroethanol
Trinitroethyl nitrate
Trinitromethane
Nitroform
1,3,5-Trinitronaphthalene (alpha)
2,4,6-Trinitrophenyl guanidine (dry)
2,4,6-Tirnitrophenyl nitramine
2,4,6-Trinitrophenyl trimethylol methylnitramine trinitrate (dry)
2,4,6-Trinitroso-3-methyl nitraminoanisole
Trinitrotetramine cobalt nitrate
Vinyl nitrate polymer
1-Bromo-3-nitrobenzene
n-Butyl peroxydicarbonate >52%
2,2-Di-(tert-butylperoxy) butane, >55% in solution
Di-(tert-butylperoxy) phthalate, >55% in solution
2,2-Di-(4,4-di-tert-butylperoxycyclohexyl)propane, >42% with inert solid
Di-2,4-dichlorobenzoyl peroxide, >72% with water
Di(chlorethyl) sulfide
Mustard gas
    Dichlorodiethylsulfide
    Bis(2-chloroethyl) sulfide
Dichlorovinylchloroarsine
Dipropionyl peroxide, >28% in solution
Methyl nitramine
Methyl nitrite
Nitroglycerin, liquid not desensitized
P-Xylyl diazide
Dess-Martin periodinane
    Periodinane
5-Azido-1-hydroxy tetrazole
Azido hydroxy tetrazole (mercury and silver salts)

Appendix H: OSHA Fact Sheet, *Formaldehyde*

OSHA® FactSheet

Formaldehyde

Formaldehyde is a colorless, strong-smelling gas often found in aqueous (water-based) solutions. Commonly used as a preservative in medical laboratories and mortuaries, formaldehyde is also found in many products such as chemicals, particle board, household products, glues, permanent press fabrics, paper product coatings, fiberboard, and plywood. It is also widely used as an industrial fungicide, germicide and disinfectant.

Although the term formaldehyde describes various mixtures of formaldehyde, water, and alcohol, the term "formalin" is used to describe a saturated solution of formaldehyde dissolved in water, typically with another agent, most commonly methanol, added to stabilize the solution. Formalin is typically 37% formaldehyde by weight (40% by volume) and 6-13% methanol by volume in water. The formaldehyde component provides the disinfectant effects of formalin.

What Employers Should Know

The OSHA Formaldehyde standard (29 CFR 1910.1048) and equivalent regulations in states with OSHA-approved state plans protects workers exposed to formaldehyde and apply to all occupational exposures to formaldehyde from formaldehyde gas, its solutions, and materials that release formaldehyde.

- The permissible exposure limit (PEL) for formaldehyde in the workplace is 0.75 parts formaldehyde per million parts of air (0.75 ppm) measured as an 8-hour time-weighted average (TWA).
- The standard includes a second PEL in the form of a short-term exposure limit (STEL) of 2 ppm which is the maximum exposure allowed during a 15-minute period.
- The action level – which is the standard's trigger for increased industrial hygiene monitoring and initiation of worker medical surveillance – is 0.5 ppm when calculated as an 8-hour TWA.

Harmful Effects on Workers

Formaldehyde is a sensitizing agent that can cause an immune system response upon initial exposure. It is also a cancer hazard. Acute exposure is highly irritating to the eyes, nose, and throat and can make anyone exposed cough and wheeze. Subsequent exposure may cause severe allergic reactions of the skin, eyes and respiratory tract. Ingestion of formaldehyde can be fatal, and long-term exposure to low levels in the air or on the skin can cause asthma-like respiratory problems and skin irritation such as dermatitis and itching. Concentrations of 100 ppm are immediately dangerous to life and health (IDLH).

Note: The National Institute for Occupational Safety and Health (NIOSH) considers 20 ppm of formaldehyde to be IDLH.

Routes of Exposure

Workers can inhale formaldehyde as a gas or vapor or absorb it through the skin as a liquid. They can be exposed during the treatment of textiles and the production of resins. In addition to healthcare professionals and medical lab technicians, groups at potentially high risk include mortuary workers as well as teachers and students who handle biological specimens preserved with formaldehyde or formalin.

How Employers Can Protect Workers

Airborne concentrations of formaldehyde above 0.1 ppm can cause irritation of the respiratory tract. The severity of irritation intensifies as concentrations increase.

Provisions of the OSHA standard require employers to do the following:

- Identify all workers who may be exposed to formaldehyde at or above the action level or STEL through initial monitoring and determine their exposure.

- Reassign workers who suffer significant adverse effects from formaldehyde exposure to jobs with significantly less or no exposure until their condition improves. Reassignment may continue for up to 6 months until the worker is determined to be able to return to the original job or to be unable to return to work – whichever comes first.
- Implement feasible engineering and work practice controls to reduce and maintain worker exposure to formaldehyde at or below the 8-hour TWA and the STEL. If these controls cannot reduce exposure to or below the PELs, employers must provide workers with respirators.
- Label all mixtures or solutions composed of greater than 0.1 percent formaldehyde and materials capable of releasing formaldehyde into the air at concentrations reaching or exceeding 0.1 ppm. For all materials capable of releasing formaldehyde at levels above 0.5 ppm during normal use, the label must contain the words "potential cancer hazard."
- Train all workers exposed to formaldehyde concentrations of 0.1 ppm or greater at the time of initial job assignment and whenever a new exposure to formaldehyde is introduced into the work area. Repeat training annually.
- Select, provide and maintain appropriate personal protective equipment (PPE). Ensure that workers use PPE such as impervious clothing, gloves, aprons, and chemical splash goggles to prevent skin and eye contact with formaldehyde.
- Provide showers and eyewash stations if splashing is likely.
- Provide medical surveillance for all workers exposed to formaldehyde at concentrations at or above the action level or exceeding the STEL, for those who develop signs and symptoms of overexposure, and for all workers exposed to formaldehyde in emergencies.

Recordkeeping Requirements

Employers are required to do the following regarding worker exposure records:

- Retain exposure records for 30 years.
- Retain medical records for 30 years after employment ends.
- Allow access to medical and exposure records to current and former workers or their designated representatives upon request.

Additional Information

For more information on this, and other health-related issues affecting workers, visit OSHA's web site at www.osha.gov.

This is one in a series of informational fact sheets highlighting OSHA programs, policies or standards. It does not impose any new compliance requirements. For a comprehensive list of compliance requirements of OSHA standards or regulations, refer to Title 29 of the Code of Federal Regulations. This information will be made available to sensory-impaired individuals upon request. The voice phone is (202) 693-1999; the teletypewriter (TTY) number is (877) 889-5627.

For assistance, contact us. We can help. It's confidential.

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