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Chemical Hygiene Plan (CHP)

Compiled by Leslie S York-Hubbard

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14. ABSTRACT

The US Army Combat Capabilities Development Command Army Research Laboratory's Safety Office has updated the Chemical Hygiene Plan (CHP) that provides guidance on the management of occupational exposures to hazardous chemicals in the laboratories. The CHP applies to all laboratories and areas that use hazardous chemicals in accordance with the definition of laboratory use and scale provided in the plan. Generally, where this standard applies it supersedes provisions of all other standards in 29 CFR Part 1910 Subpart Z, except in specific instances identified by the OSHA 29 CFR 1910.1450 standard. Laboratories covered by the standard are obligated to maintain employee exposures at or below Permissible Exposure Limits specified in 29 CFR Part 1910 Subpart Z, but the manner in which it is achieved will be determined through formulation and implementation of a CHP.

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1. Introduction

1.1 Chemical Hygiene Plan (CHP)

The Occupational Safety and Health Administration's (OSHA's) laboratory health standard 29 CFR 1910.1450 *Occupational Exposure to Hazardous Chemicals in Laboratories*[1] requires employers to apprise laboratory employees of the hazards of chemicals in their work area and to establish appropriate work practices, procedures, and controls to protect employees from chemical health and safety hazards. The 29 CFR 1910.1450 is commonly known as the "Laboratory Standard".

The US Army Combat Capabilities Development Command (CCDC) Army Research Laboratory (ARL) is committed to providing a safe and healthful environment for all persons associated with the institution, including employees, contractors, subcontractors, and guests/visitors. The diverse mission at ARL requires work with a variety of hazardous chemicals, some of which pose significant health and safety risks. The operating procedures set forth in this document identify the safeguards that should be taken when working with hazardous chemicals in laboratory settings. Cooperation of all employees is expected to ensure these safeguards are implemented in a way that reflects safety as a core value for ARL.

This CHP details the manner in which ARL complies with the elements of OSHA's Laboratory Standard. It identifies responsibilities and establishes procedures for the identification, evaluation, and control of hazardous chemicals used in the laboratory setting.

The ARL CHP is posted on ARL's Intranet to which all employees have access. Hard copies are available from the ARL Safety Office upon request.

1.2 Scope and Application

This plan applies to all employees and guests/visitors working in ARL laboratories using hazardous chemicals in activities that fit the term "laboratory use." See Appendix A for its definition.

This CHP describes ARL's safety programs, including but not limited to personal protective equipment (PPE) used, engineering controls and operations (such as vented hoods), employee training programs, health and physical hazards of chemicals, and medical surveillance programs. The CHP is designed as a tool to

coordinate safety procedures. Every employee in the laboratory must be trained in the details of this plan.

OSHA's *29 CFR 1910.1200 Hazard Communication* standard,[2] also known as "HAZCOM", applies to employees in labs, industrial, and office settings.

This CHP has a variety of additional information and useful aids in five appendixes:

- Appendix A. Definitions
- Appendix B. Partial List of Carcinogens and Reproductive Toxins
- Appendix C. Cryogens
- Appendix D. Job Hazard Analysis–DD Form 2977
- Appendix E. 'Designated Area' Posting
- Appendix F. Organic Peroxide-Forming Chemical Groups—Storage Times

1.3 Responsibilities

1.3.1 Safety Office

The Safety Office has a fundamental role in the development and maintenance of the CHP:

- Appoints a Chemical Hygiene Officer to provide technical guidance in the development, implementation, and maintenance of the provisions of the CHP and overall lab safety.
- Ensures the CHP is reviewed and updated as necessary on an annual basis.
- Provides guidance to laboratory management toward CHP implementation.
- Supports line management in the implementation of the CHP including, but not limited to, providing guidance for establishing work practices, PPE, and engineering controls to minimize and control exposure to chemicals.
- Investigates and completes a report for all accidents and near misses that result in or may be a result of a potential exposure to hazardous chemicals or toxins.
- Participates in the review, recommendations, and finalization of standard operating procedures (SOPs) for all hazardous operations.
- Conducts preoperational surveys and participates in the hazard analysis of all new laboratory operations using hazardous chemicals.

- Assists with the annual review of SOPs and updates that are necessary any time there are changes to laboratory work practices or personnel.
- Reviews plans and specifications for all laboratory construction or renovation projects to ensure appropriate laboratory design criteria are incorporated.
- Ensures ventilation-hood certifications are conducted as required and according to written procedures in order to evaluate hood performance.
- Develops and provides training on the CHP and any other chemical-safety-related training requested by personnel in support of educating workers about chemical hazards and best management practices.
- Provides guidance for all chemical-related purchases.

1.3.2 Environmental Office

The Environmental Office likewise has several responsibilities under ARL's CHP:

- Establishes policy and procedures for chemical/hazardous waste handling and disposal.
- Reviews and approves hazardous-waste tracking systems' requests for turn-in of chemical/hazardous waste from laboratories.
- Provides assistance visits on a periodic basis to all laboratories where hazardous waste is generated or stored.
- Reviews, comments on, and signs final copies of SOPs for new hazardous operations when applicable.
- Participates in preoperational surveys and the completion of hazard analyses/SOPs of all laboratory operations if applicable.

1.3.3 Branch Chiefs and Team Leaders

The following actions also apply to supervisors and those who oversee and manage individuals working in laboratories:

- Appoint a Branch Chemical Hygiene Officer (BCHO) who will serve as the Branch's point of contact (POC) and facilitate the requirements of the CHP. Other individuals may be appointed to assist the BCHO with implementation of the CHP.
- Ensure the development of and adherence to SOPs and the associated hazard analysis for all hazardous operations, and sign final copies of SOPs.

- Conduct preoperational surveys and participate in the hazard analysis of all new laboratory operations using hazardous chemicals.
- Review SOPs and hazard analysis at least annually or as changes in process and/or personnel dictate a need.
- Complete a thorough hazard evaluation of hazardous chemicals including a review of the Safety Data Sheet (SDS) and other references (see Appendix A) prior to ordering the material to ensure preparations have been made to safely handle, store, and dispose of the material.
- Ensure an SDS is obtained from the manufacturer of the hazardous chemical prior to receiving the material.
- Ensure an SDS is developed for all chemicals synthesized in laboratories for research and developmental work.
- Ensure all employees for whom they are responsible do the following:
    - Receive job-related medical surveillance as necessary.
    - Read, sign, and receive training to conduct operations under approved SOPs and the associated hazard analysis, which they must execute.
    - Review and understand the SDS or other related references for the hazardous chemicals they work with or around in the laboratory and are aware of signs and symptoms associated with exposures to the chemicals and methods to protect from exposure.
    - Handle, store, and dispose of hazardous chemicals appropriately.
    - Are aware of the location and availability of this CHP and SDSs.
    - Complete training on the CHP and HAZCOM and any other safety training deemed necessary by the supervisor and SO.
- Document and maintain training records for laboratory-specific safety training.
- Provide personnel the appropriate protective clothing and equipment necessary and ensure they receive training on their use.
- Conduct periodic inspections of laboratory operations to ensure employees are adhering to safe work practices and conditions are safe in the laboratories. Also, check for compliance with SOPs, the CHP, and other applicable policies or regulations.

- Ensure that those who handle or manage hazardous waste receive initial hazardous-waste training and annual refresher classes thereafter.
- Ensure compliance with hazardous-chemical storage and distribution requirements.
- Ensure annual certification is provided for laboratory ventilation systems (chemical fume hoods and local exhaust systems).
- Identify and mitigate any unsafe conditions present in the lab or unsafe acts conducted by laboratory operators.
- Establish and monitor compliance with requirements and policies for the use of PPE in the laboratory in accordance with the hazards present.
- Ensure all chemical containers are properly labeled.
- Substitute materials of lower hazard when practical.
- Limit the amount of hazardous chemicals procured, used, and stored to the minimum required.
- Maintain a current inventory of the hazardous materials used or stored in their work area.
- Be aware of and approve the procurement of hazardous materials for use in the work area.
- Ensure corrective action is taken to address any issues identified during laboratory surveys/assessments.
- Audit the performance of the supervisors and POCs with respect to safety issues and address deficiencies as appropriate.
- Appoint an alternate supervisor or POC whenever the primary supervisor/POC is out of the laboratory for an extended period of time (e.g., sabbatical, vacation**,** or protracted illness) to oversee their laboratory operations with respect to safety procedures and requirements. The person selected must be 1) an ARL employee, 2) familiar with the hazards of the operations occurring in the lab, and 3) empowered to address concerns as they arise. The supervisor/POC must notify their branch chief of who will be assuming responsibility for all safety aspects of their laboratory operations in their absence. The branch chief and the supervisor/POC must agree the selected person has the experience, knowledge, and background to assume the responsibilities. Notify all affected personnel, to include the

Safety Office and BCHO, of the appointment and provide the name along with the contact information of the responsible individual.

1.3.4 Employees

For purposes of safety, ARL does not distinguish among military, civil-servant, contracted, exchange-program, collaborative, and internship personnel working at ARL facilities. All of these are considered employees who have the right and responsibility to be informed about the known physical and health hazards of the chemical substances in their work areas. They can accomplish this by reviewing SDSs and/or other references so they are aware of signs and symptoms associated with exposure to the chemicals, methods of exposure mitigate ion, and how to work safely with these substances. All ARL personnel* are required to follow the provisions set forth herein:

- Attend training seminars as recommended or dictated by the CHP, ARL SO, BCHO, and/or Army, state, or federal regulation.
- Inform their supervisors of accidents and conditions or work practices they believe to be a hazard to their health or to the health of others.
- Plan and conduct laboratory operations using hazardous chemicals in accordance with approved SOPs (and the associated hazard analysis) and the CHP.
- Report to the local medical authority, as directed by the installation's industrial hygienist and supervisor, for job-related medical surveillance such as annual physicals required for those working with specific chemical hazards or physicals required for the use of respiratory protection.
- Review and sign SOPs for operations they must execute on an annual basis and ensure they fully understand how to safely execute the SOP, including the use of any hazardous chemicals.
- Upon request by the Team Leader, participate in the development of SOPs, the completion of preoperational surveys, or the completion of the associated hazard analysis of all new laboratory operations using hazardous chemicals and toxins.

* **Visitors** will comply with all provisions of the Chemical Hygiene Plan as appropriate for their destinations and durations at ARL.

- Assist with the completion of the required SOP and associated hazard assessment. Ensure the required review and signatures processes are complete prior to initiating any hazardous operations.
- Handle, store, and dispose of hazardous chemicals appropriately.
- Know the location of the CHP and SDSs.
- Remain informed about the chemicals used in their work areas. Use the protective clothing and equipment necessary to conduct lab operations in a safe manner and adhere to requirements for use of PPE in the laboratory as set by laboratory management.
- Report hazardous conditions, chemical exposures, or abnormal circumstances associated with a hazardous chemical to their team leader, supervisor, and Safety Office.

1.3.5 Branch, Division, or Directorate Chemical Hygiene Officers

At each of these echelons, implementation of ARL's CHP will ensure compliance with the regulatory requirements and help maintain a safe work environment. To those ends, the Branch, Division, or Directorate Chemical Hygiene Officer has the following duties:

- Provide reports at that echelon's Safety Committee meetings on chemical-hygiene activities performed.
- Work with supervisors and lab POCs to develop, review, and approve job hazard analyses and SOPs detailing all aspects of proposed research activities that involve hazardous materials.
- Work with supervisors and lab POCs on the approval process for the purchase of highly toxic, reactive, carcinogenic, or other inherently hazardous materials.
- Work as a liaison with the installation and ARL Safety Office to ensure compliance with the Chemical Hygiene Plan.
- Disseminate chemical-safety information throughout their jurisdiction through emails, postings, and other forms of communications.
- Provide general chemical-safety guidance to branch researchers, staff, and any visiting students/personnel.

1.3.6 Local Medical Authority, Preventive Medicine Services

These entities will provide preventative medicine services in accordance with (IAW) the established Inter-Service Support Agreement and/or Memorandum of Understanding with ARL and Army Regulation (AR) 40–5.[3]

2. Chemical Procurement, Inventory, SDS, Labeling, Transport, Storage, and Disposal

2.1 Procurement and Inventories

ARL personnel shall order the smallest quantity of chemical(s) possible to complete the planned experiments/work.

Before a new substance that is known or suspected to be hazardous is received, those individuals who will handle it should have information on proper handling, storage, and disposal; health and physical hazards; and protection from exposure.

All chemical purchases must be approved by the Safety Office prior to buying. Any inbound chemicals involved in collaboration with outside entities must be approved prior to shipping by the SO.

It is the responsibility of the principal investigator, team leader, and lab manager to ensure the laboratory facilities in which the substance will be handled and stored are adequate and that those who will work with or around the substance receive proper training and the training is documented.

References in addition to the SDS should be consulted when researching the hazards associated with the use of a chemical, especially for particularly hazardous materials. (Refer to Appendix A for references on chemical hazards that can be consulted in addition to the SDS.)

Personnel shall inspect chemical containers upon receipt to ensure they are intact, not leaking, and the label is intact and legible. Leaking containers should not be accepted from deliverer and, if necessary, the local emergency number should be dialed to report a chemical spill.

Laboratory personnel, team leaders, or supervisors initiating and approving the procurement of chemicals are responsible to ensure each new item is entered into the local chemical-tracking system and any other chemical inventory maintained by the laboratory.

Laboratory managers and team leaders shall ensure chemical inventories are maintained for each room where chemicals are stored or used, and they shall ensure

accurate inventory information is maintained in the local chemical-tracking system. They will also be responsible for proper labeling and correct storage; also, they will ensure turn-in before the expiration date or when the chemical is no longer needed.

2.2 Safety Data Sheet

An SDS provides chemical–specific, health- and safety-related information such as known hazards, physical and chemical properties, exposure limits, appropriate protective measures, and emergency and first-aid procedures. Any person using hazardous materials must first review and be trained on the SDS by their supervisor to comprehend the associated hazards and necessary protective measures required to work safely with each constituent. Also, the timing of review is important:

- The review will be used in the development of an SOP and/or job hazard analysis (JHA).
- An annual review of all SDSs should be included as part of the annual SOP/JHA review or chemical-safety training refresher to ensure they remain current and pertinent to the process.

A SDS for each hazardous chemical must be available and readily accessible to all laboratory personnel. SDS's must be updated continually.

2.2.1 SDS from Manufacturer/Distributor

Chemical manufacturers and distributors must provide the purchasers of hazardous chemicals with an appropriate SDS for each hazardous chemical/product purchased. If an SDS was not provided with the shipment of a hazardous chemical, one must be requested from the manufacturer or distributor in a timely manner.

- Any person ordering hazardous materials is responsible for requesting that the buyer, ordering activity, and/or procurement agency notify the vendors that shipments of hazardous materials are to be accompanied by an applicable SDS.
- Each buyer, ordering activity, and/or procurement agency is responsible for ensuring the user's request for the SDS is relayed to the vendor.

All sample materials received by an outside manufacturer or agency must have an accompanying SDS. Ensure the sample is entered into the local chemical-tracking system and any other chemical inventory maintained by the laboratory when received.

2.2.2 SDS for Chemical Produced In-house

Pertaining to chemical substances developed in the laboratory:

- If the composition of a chemical substance produced in-house for laboratory use is known, the researcher, supervisor, or lab POC shall identify the hazards, establish controls, label the container, and provide training to the users.
- If the chemical produced is a by-product whose composition is not known, the researcher, supervisor, or lab POC shall assume it is hazardous, establish controls, label the container, and provide training to the users.
- If the chemical substance is produced for another user outside the laboratory where the material was synthesized, the supervisor or lab POC shall comply with the federal HAZCOM standard (29 CFR 1910.1200)[2] including the requirements for the preparation of an SDS and labeling.

2.2.3 Management of SDSs

SDS's may be maintained in one of the following ways:

Printed hard copies—SDSs may be managed as printed hard copies. Laboratories are strongly urged to print the SDS sheets for their chemicals from the manufacturer that produced them and keep them in a clearly marked, three-ring binder in the laboratory where they will be visible to all researchers and personnel. These printed SDSs must be updated and current and compliant with the Globally Harmonized System (GHS).

Electronic file—SDSs may be stored as an electronic file. If this method is used, the following are required:

- All lab personnel must have access to the electronic file on a functioning computer and printer.
- Each person in the lab who uses chemicals must be trained on the location of the computer file, how to access the file, and how to print a SDS's.
- Desktop icons or shortcuts must be used on the computer or posted in a conspicuous location to facilitate easy access.
- Provisions must be in place for dealing with long-term interruptions to power, the network, or the server that would make electronic versions unavailable. Contact the local SO for available facility options.

2.3 Labels

Labels are required for all primary and secondary containers of hazardous materials. Primary containers are the original containers received from the manufacturer; secondary containers are cans, squeeze bottles, and other vessels into which an employee transfers hazardous chemicals.

All containers must be clearly labeled in accordance with the HAZCOM (GHS) including product identifier, pictogram, hazard statement, signal word, and precautionary statements as well as the supplier's name and address. All secondary containers must be labeled in a manner that conveys all of the HAZCOM information on the primary label.

Labels on incoming containers shall not be removed or damaged unless they are emptied of the original material. All site-specific labels must also not be removed. If they become damaged or destroyed contact the SO for guidance.

Small tubes or vials may pose difficulties with adequate labeling. You may store the tubes/vials in appropriate storage holders and label the entire group, provided they contain the same chemistry and have the same associated hazards and concentrations. Each individual tube must have a symbol or number that corresponds to the storage holder.

Supervisors shall ensure labels on hazardous chemicals are not removed or defaced.

Labeling Chemicals with unknown toxicity

Chemicals whose toxic properties are unknown are defined as *a chemical for which there is no known statistically significant study conducted in accordance with established scientific principles that establishes its toxicity*. In the absences of peer-reviewed scientific toxicity data, a researcher must assume the material is toxic and follow prudent practices to include the information on the label and in the SDS.

- Researchers can present the "unknown acute toxicity" information on labels either as a single statement or as multiple statements where routes of exposure (oral, dermal, and inhalation) are differentiated. If there is an unknown acute toxicity by more than one route, and the researchers chooses to provide one statement in order to save space on the label or SDS, then the route with the *highest* percentage of unknown toxicity will be used in the statement. The single statement on the label or SDS would state that
    - x % of the mixture consists of ingredient(s) of unknown acute toxicity.

- Because it is possible to have ingredients with unknown toxicity for more than one route (e.g., oral, dermal, and inhalation), differentiating the unknown toxicity statement by route is recommended.[2] As such, researchers may also communicate the information from among the following:
    - x % of the mixture consists of ingredient(s) of unknown acute oral toxicity.
    - x % of the mixture consists of ingredient(s) of unknown acute dermal toxicity.
    - x % of the mixture consists of ingredient(s) of unknown acute inhalation toxicity.

2.4 Transportation of Hazardous Materials

Hazardous materials are to be transported in vehicles only by employees appropriately trained according to the US Department of Transportation (DOT) in accordance with Paragraph 2.2 of AR 600–55,[4] which specifies the Army's driver/operator standards.

All shipments to and from ARL must have proper DOT-approved packaging, markings/labeling, and shipping papers and an accompanying SDS. Researchers are responsible for constructing a SDS that is GHS compliant for all synthesized materials being shipping to or from ARL. Refer to Appendix A: Health Hazard Criteria (Mandatory) of 29 CFR 1910.1200[2] at

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10100.

Transporting hazardous materials by employees in private vehicles is not permitted. This is to minimize risk to employees and the public.

Laboratory employees may move small quantities (1 gal or 100 grams) of hazardous materials for short distances within a building or between adjacent buildings, provided it can be done safely. Toxic, flammable, or corrosive chemicals should be placed in a carrying bucket or other unbreakable container when moved between rooms or through the laboratory corridors. Use handcarts and drip trays to transport larger quantities of materials (to contain any spilled material). Use standard cylinder dollies to transport compressed-gas cylinders. While dollies are preferred, cylinders weighing 11 kg (25 lb) or less may be hand carried. Never move a cylinder with a regulator connected to it. Cylinder-valve protection caps and valve-opening caps must be in place when moving cylinders. Lecture bottles

and other cylinders that are not normally equipped with valve-protection caps should be transported in either the original DOT-specified package or an equivalent container.

2.5 Chemical Storage

2.5.1. Best Storage Practices

The first step in the storage of any chemical at ARL is to refer to its SDS and other source references for guidance. The following must be applied:

- Chemical storage inside the laboratory shall be limited to those chemicals necessary to complete mission requirements.
- Avoid storing chemicals on countertops except for those being currently used.
- Avoid using chemical fume hoods for storage of chemicals unless the hood is a dedicated space. Contact the Safety Office for exceptions and guidance regarding highly toxic or corrosive materials.
- Flammables must be stored in an Underwriters Laboratories (UL)-listed flammable cabinet.
- Corrosives must be stored in a corrosives cabinet designed specifically for that purpose.
- Open shelves should be designed with a restraining device or lip to prevent containers from creeping or tipping over.
- Use spill trays to reduce commingling of chemicals in the event of spills or leaks.
- Provide a definite storage place for each chemical and return the chemical to that location after each use.
- Do not expose stored chemicals to heat or direct sunlight.

2.5.2 Chemical-Inventory Best Practices

Although the barcodes/inventories on chemicals are monitored though the Pharmacy, it is still good practice to inspect chemical containers and labels at least semiannually.

- Determine their condition and to ensure they will not be stored beyond their shelf life if the stability of the chemical is of concern.

- Corroded or leaking containers shall be overpacked and turned in according to applicable local, state, and federal guidelines.
- Clean and ensure an inventory each laboratory storage unit, refrigerator, freezer, and shelf is conducted at least annually.

2.5.3 Chemical Storage Compatibility

Certain hazardous chemicals should not be mixed or stored with other chemicals because a severe reaction can take place or an extremely toxic reaction product can result.

Chemical storage based solely on an alphabetical arrangement of chemicals may inadvertently place incompatible materials in close proximity. Therefore, separate chemicals into compatible groups *prior* to storing alphabetically.

There are published methods available to ensure the compatibility of stored chemicals. One authoritative reference is *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards* published by the National Research Council.[5] A 361-page PDF can be downloaded (for electronic storage) at

https://sols.asu.edu/sites/default/files/safety/Prudent%20Practices%20in%20the%20Lab%202011.pdf.

Lab personnel must be knowledgeable of the processes and procedures used to store chemicals in the lab.

2.6 Chemical Compatibility Chart

Table 1 is a chemical-storage compatibility chart adapted from the *CRC Handbook of Laboratory Safety*.[6] It lists chemicals in 23 different groups with examples and incompatibles listed for each. This chart is by no means complete, but will aid in making decisions concerning chemical storage. For more information, please refer to SDSs or contact the ARL Safety office.

Table 1 Chemical-storage compatibility chart

Group #	Group name	Example	Incompatible groups #s
#1	Inorganic Acids	Hydrofluoric acid Hydrochloric acid Nitric acid Sulfuric acid Phosphoric acid	2,3,4,5,6,7,8,10,11,13,14, 16,17,18,19,21,22,23
#2	Organic Acids	Acetic acid Butyric Formic propionic	1,3,4,7,14,16,17,18,19,22
#3	Caustics	Sodium hydroxide Ammonium hydroxide solution	1,2,5,7,8,13,14,15,16,17, 18,20,22,23
#4	Amines and Alkanolamines	Aminoethylethanolamine Aniline Diethanolamine Dimethylamine Ethyllenediamine 2-methyl-5-ethylpyridine Monoethanolamine Pyridine Triethanolamine Tryethylamine Triethylenetetramine	1,2,5,7,8,13,14,15,16,17, 18,23
#5	Halogenated Compounds	Allyl Chloride Carbon tetrachloride Chlorobenzene Methylene Chloride Monochlorodifluoromehtane 1,2,4-Trichlorobenzene 1,1,1-Trichloroethane Trichloroethylene Trichlorofluoromethane	1,3,4,11,14,17
#6	Alcohols Glycols Glycol Ether	1,4-Butanediol Butanol (iso,n,sec,tert) Diethylene glycol Ethyl alcohol Ethyl butanol Ethylene glycol Furfuryl alcohol Isoamyl alcohol Methyl alcohol Propylene glycol	1,7,14,16,20,23
#7	Aldehydes	Acrolein Acetaldehyde Ethanal Butyraldehyde Crotonaldehyde Formaldehyde Furfural Paraformaldehyde Propionaldehyde	1,2,3,4,6,8,15,16,17,19, 20,23

Table 1 Chemical-storage compatibility chart (continued)

Group #	Group name	Example	Incompatible groups #s
#8	Ketones	Acetone Acetophenone Diisobutyl Ketone Methyl ethyl ketone	1,3,4,7,19,20
#9	Saturated Hydrocarbons	Butane Cyclohexane Ethane Heptane Paraffins Paraffin Wax Pentane Petroleum Ether	20
#10	Aromatic Hydrocarbons	Benzene Cumene Ethyl benzene Naphtha Naphthalene Toluene Styrene Xylene	1,20
#11	Olefins	Butylene 1-Decene 1-Dodecene Ethylene Turpentine	1,5,20
#12	Petroleum Oils	Gasoline Mineral oil	20
#13	Esters	Amyl acetate Butyl acetates Caster oil Dimethyl sulfate Ethyl acetate	1,3,4,19,20
#14	Monomers Polymerizable Esters	Acrylic acid Acrylonitrile Butadiene Acrylates	1,2,3,4,5,6,15,16,19,20, 21,23
#15	Phenols	Carbolic acid Cresote Cresols Phenol	3,4,7,14,16,19,20
#16	Alkylene oxides	Ethylene oxide Propylene oxide	1,2,3,4,6,7,14,15,17,18, 19,23
#17	Cyanohydrins	Acetone cyanohydrins Ethylene cyanohydrins	1,2,3,4,5,7,16,19,23
#18	Nitriles	Acetonitrile Adiponitrile	1,2,3,4,16,23
#19	Ammonia	Ammonium hydroxide Ammonia gas	1,2,7,8,13,14,15,16,17,20 ,23
#20	Halogens	Chlorine Fluorine Bromine	3,6,7,8,9,10,11,12,13,14, 15,19,21,22

Table 1 Chemical-storage compatibility chart (continued)

Group #	Group name	Example	Incompatible groups #s
#21	Ethers	Diethyl ether THF Methyl ethyl ether	1,14,20
#22	Phosphorus	Phosphorus, elemental	1,2,3,20
#23	Acid anhydrides	Acetic Anhydride Propionic anhydride	1,3,4,6,7,14,16,17,18,19

The following list is of incompatibility among chemical groups:

- Acids **and** alkaline
- Spontaneously combustible **and** acidic
- Acid **and** flammable
- Acid **and** cyanides
- Acid **and** reactive sulfides
- Oxidizers **and** organics
- Nitrates **and** Acids
- Ammoniated compounds **and** hypochloites and bleach
- Organic nitrates/perchlorates **and** other oxidizers or metals
- Azides **and** metals, metal salts, acids, strong oxidizers halogens
- Perchloric acid **and** metals, metal salts, charcoal, ethers, organics, combustibles, acids

2.7 Chemical Disposal

Laboratory wastes shall be handled and disposed of according to applicable federal, state, and local environmental regulations and policies. In order to meet this goal, ARL personnel involved in the generation, identification, characterization, storage, handling, and transportation of hazardous waste—and their supervisors—will receive the appropriate training that complies with each site's regulatory permitting requirements.

Where applicable, each SOP/JHA identifies waste(s) generated during the operation and describes how the waste(s) will be handled prior to disposal.

No chemicals are permitted to be flushed down a drain without prior approval from the Safety and Environmental Branch Office. No chemicals are to be placed in a fume hood to evaporate.

3. General Lab Controls

In a lab, a *control measure* is an action intended to eliminate a hazard completely. Selecting your controls is a key part of the process of identifying and evaluating hazards in the lab. If the identified hazard cannot be eliminated, follow the hierarchy of controls to select the next-best control measure to mitigate the risk of an accident/incident or injury in the lab. There are many different types of control measures, all of which fall into four main categories (in order of priority and effectiveness):

1) Elimination or Substitution
2) Engineering
3) Administrative
4) Personal Protective Equipment

3.1 Elimination or Substitution

Elimination is the process of removing the hazard from the workplace. It is the most effective way to control a risk and the preferred way to control a hazard. This control should be used whenever possible.

Substitution occurs when a new chemical or substance that is less hazardous is used in place of the original (more hazardous) chemical. Another type of substitution includes using the same chemical but in a different form. For example, a powder may be a significant inhalation hazard, but if this material can be purchased and used in a pellet or crystal form, there may be significantly less dust generated and therefore less exposure.

Elimination and substitution, while most effective at reducing hazards, also tends to be the most difficult to implement in an existing process. If a process is still at the design or developmental stage, this is a viable hazard-control option. However, for an existing process, major changes in equipment and procedures may be required to eliminate or substitute for a hazard.

3.2 Engineering Controls

A major component to any Occupational Health and Safety Program is controlling employee exposure by designing a process that reduces the degree of hazard. Engineering controls are methods of controlling employee exposure by reducing or eliminating the quantity of contaminants released into the workspace.

Although engineering controls are often considered synonymous to ventilation design, there are many other types such as interlock mechanisms, protective heat or radiation barriers, automated systems, fabrication of closed assemblies, or wet collectors and scrubber devices. Isolation of the operator or the process is a key consideration in the discipline of engineering controls. The use of protective barriers and remote controls when handling explosives or the application of a glove box to completely enclose a toxic agent are two examples. When integrated into a process design, these engineering controls reduce or eliminate exposures to various hazards.

3.2.1 Ventilation, Types of

Ventilation design can basically be subdivided into by two categories: general and local exhaust ventilation. Note: The selection, procurement, installation, and balancing of all ventilation systems must be coordinated with and reviewed by the ARL Safety Office.

General Ventilation—While general ventilation is a broad term that refers to dilution or comfort criteria, local ventilation is typically intended to capture or isolate a contaminant and provide a suitable pathway for evacuation.

Local Exhaust Ventilation—There are a number of different designs for local exhaust ventilation, each with a unique construction to optimize a safe and healthy work environment.

- **Chemical fume hoods** are designed to contain and evacuate a contaminant and to prevent contaminant migration to the process operator and into the work space. There are a number of different applications for chemical fume hoods, each providing various degrees of protection and energy efficiency. For example, the design of a perchloric-acid hood contrasted with a ductless hood not only shows variability of construction parameters but also process applications.
- **Canopy hoods** are designed for use with constituents of low toxicity and generally, with hot operations to take advantage of thermal drafts generated from the production of high-conduction and convection heat.

- **Snorkel exhausts** are used for point-source removal, such as in welding and soldering operations. These exhaust systems are typically designed with flexible trunks that can be moved to reach various locations within immediate proximity.
- **Drop branches**, which are typically stationary, are also used to capture contaminates at the point source. Capture velocity improves as distance is reduced.
- **Slotted hoods** are defined as hoods with an opening width-to-length ratio of 0.2 or less. This design is most commonly used to provide uniform exhaust air flow and capture velocity over a finite length. By properly sizing the slot width and plenum depth, the velocity of air flow through the slot is much higher than in the plenum, making it compatible for open surface tanks or filling operations.
- **Glove box** design can isolate process exposure by enclosing an operation that may incorporate highly toxic or radioactive constituents, requires a particular environmental condition such as an inert atmosphere, or—depending on the path of the air flow, as with a clean bench—is intended to protect the product. Glove-box pressures range from mostly negative- (for confinement) to positive-pressure environments (for process protection). Failure to maintain correct operational pressures or to follow established operational procedures could render a glove box both ineffective and unsafe.

  Positive-pressure glove boxes: For research samples' protection from the outside environment, a closed-system glove box shall be maintained at a positive pressure relative to outside the glove box of at least +0.25 water gauge (w.g.), and should be monitored through the aid of a manometer or differential pressure gauge.

  Negative-pressure glove boxes: For worker protection, a closed-system glove box shall be maintained at a negative pressure relative to outside the glove box of at least –0.25 w.g., and should be monitored through the aid of a manometer or differential pressure gauge.

  Glove boxes without an airlock shall also have an airflow of at least 50 $ft^3/min/ft^2$ of open-door area, and where the formation of explosive conditions could occur; the quantity of makeup air may need to be greater.

  Inspect the glove box prior to each use:

  - Conduct a visual check of the gloves to ensure material integrity.

- Ensure interior atmosphere settings indicate correct condition.
- Ensure compressed gas feeding the glove has a sufficient amount of gas.

- **Biological safety cabinets** are recommended when small quantities of volatile, flammable, or toxic chemicals must be used in conjunction with items requiring biological precautions. These cabinets are not to be used in place of a chemical fume hood when larger quantities of hazardous chemicals are used. Refer to the Biosafety Manual for more information on engineering controls for biological materials at https://arl.apgea.army.mil/labops/lof/SitePages/biosafety.aspx or Army Pamphlet 385–69 *Safety Standards for Microbiological and Biomedical Laboratories*.[7]
- **Gas cabinets** shall be ventilated at a minimum rate of 250 ft/min at the face plane of the intake. Performance is tested annually and after any repairs or modification. The outcome of the annual performance survey is conveyed using the sticker method as with the chemical fume hoods.

Filtration, scrubber, or vacuum systems shall be incorporated as engineering controls prior to the discharge of an effluent from test equipment or a process if 1) there is a potential for an air contaminant to be released or 2) contamination to mechanical equipment or in-house supply lines could occur. Vacuum pumps shall also be vented into a chemical fume hood or local exhaust-ventilation system if used with hazardous chemicals.

The following conditions mandate the use of local exhaust ventilation:

- Volatile or acutely toxic substances.
- Hazardous materials, including carcinogens and reproductive toxins; procedures that generate airborne particulates or liquid aerosols; chemicals listed in Appendix B; or radiological materials.
- Odoriferous compounds.
- When conducting chemical process and reactions, diluting concentrated acids and caustics, or discharging hazardous gases or vapors.
- When working with materials that need to be isolated from either atmospheric moisture or oxygen.

Operations involving *perchloric acid*, , must be evaluated by an industrial hygienist to determine what special controls are necessary; that is, use of an acid fume hood

with a wash-down system to prevent the accumulation of explosive perchlorate crystals or special ductwork design, ductwork materials, and so on.

3.2.2 Chemical Fume Hood: General Work Practices

Do not use a chemical fume hood 1) with an expired certification sticker, 2) if it is visibly or audibly alarming, or 3) if there is any other detectable indication it may not be functioning properly. In any of these cases, notify the SO that there is an issue with the ventilation and work toward a safe plan to resolve it. Additionally, observe these practices with chemical fume hoods:

- When using a chemical hood with a vertical sash design, ensure the sash level is at or below the certification-specified height.
- When using a chemical hood with a horizontal sash design, use the midsection panel as a barrier whenever possible to avoid splashes or spills.
- Do not place your head beyond the face-plane of the chemical fume hood.
- Ensure all equipment and chemical-fume-hood operations are situated beyond the first 6 inches inside the hood to maximize exposure control and containment efficacy.
- Ensure the intake slot underneath the hood threshold is kept free from obstructions and, when applicable, elevate or strategically place equipment to maximize exhaust.
- Chemical fume hoods should not be used for chemical storage.
- Minimize pedestrian traffic near chemical fume hoods when operations are conducted to avoid cross-drafts that may promote the release of contaminants.
- Keep papers, paper towels, and other small objects from being pulled into the exhaust baffles.
- Keep laboratory doors closed at all times to maximize the fume hood's ventilation as well as the lab's overall ventilation.
- Keep research notebooks, papers, pens, and other like items out of the chemical fume hood to avoid possible cross-contamination.

3.2.3 Laboratory Exhaust-Performance Testing and Certification

All laboratory exhaust units must be certified when installed. Chemical fume hoods require an annual certification for performance acceptability. A white certification sticker is applied if the chemical fume hood passes, a red sticker if the chemical

fume hood fails, and a yellow sticker if the chemical fume hood has been decommissioned. Here are other points in the testing and certification process:

- Chemical fume hoods should have an average face velocity of 100 linear feet per minute (lfpm) ±20 lfpm with every effort being made to certify the hood with the sash at 18 inches to provide added worker protection.
- If the chemical fume hood fails performance criteria, the "Do Not Use" instruction shall be enforced pending the repair or adjustment service request.
- If a chemical fume hood is not being used, a yellow sticker is applied to indicate that the associated fan has been deactivated to conserve energy. Contact the ARL Safety Office if reactivation of the chemical fume hood is desired.
- Hoods should be equipped with a local audio alarm or a visual indicator to alert operators of a malfunction if the hood is not operating adequately. It is recommended to also use a vaneometer (Fig. 1) at the base of the sash as a secondary measure of proper hood function.

Fig. 1 Vaneometer measures air-flow velocity

- Chemical fume hoods must *not* be used for biological agents.

3.2.4 Ventilation Outages

In the event there is a laboratory ventilation *failure*, immediately discontinue operations and contact the ARL Safety Office. (Do not attempt to disable an alarm.) The following also needs to occur:

- Users shall ensure all chemicals and hazardous materials are sealed, capped, and closed, and that all processes and reactions have ceased since no reactions are permitted to occur during the outage.
- Researchers should make an effort to move all chemicals and other hazardous materials to a proper storage area, and ensure gas cylinders housed in a compressed gas cabinet are closed.

If a chemical fume hood's *certification has expired*, the hood should not be used. The "Do Not Use" instruction shall be enforced until the hood is tested successfully and recertified.

Preventative maintenance is also performed routinely. When a shutdown of the laboratory's ventilation system is scheduled, the following will occur:

- An advance notification will be sent out advising all occupants of the scheduled outage with instructions for a temporary stop of associated operations and to ensure all chemicals in subject systems have been safely addressed.
- The ARL Safety Office may ensure there has been communication with the lab POC(s) that provides information concerning the outage, including 1) dates and times, 2) instruction for actions necessary to ensure the safety of the maintenance/certification personnel as well as lab/building personnel, and 3) activities that are prohibited for the duration of the outage.
- The Safety Office will perform a periodic survey to assure compliance. (For information concerning performance testing or non-operative equipment, contact the Safety Office.)

3.3 Administrative Controls

Administrative controls are procedural measures taken to reduce or eliminate hazards associated with the use of hazardous materials. These include preplanning work, practicing good housekeeping, and maintaining personal hygiene to minimize exposure to hazardous materials. Further, there are written procedures, employee training, establishing designated or restricted areas, chemical-procurement procedures, and preventive maintenance. Administrative controls must be used regardless of the type of hazardous material handled.

3.3.1 General Administrative Control Measures

- Eating, drinking, and smoking in areas of chemical use, storage, or processing is prohibited. (Section 3.3.5 amplifies this point.)
- Do not block doors or windows unless it is required by your specific program (e.g., laser labs), electrical panels, or safety equipment.
- Do not store liquids above eye level.
- Manage access to laboratories and areas where hazardous materials are used. Ensure all visitors, maintenance staff are permitted and properly trained before entering the laboratory.

- All chemicals and lab samples must remain in the lab and never used or stored in office or cubicle areas.
- No headphones are to be worn in the lab areas.

3.3.2 Work Planning

- Preplan work: stage tools, equipment, and materials in advance of the activity to be performed.
- Establish designated areas for work involving particularly hazardous substances and engineered nanomaterials.
- Use exhaust ventilation for operations that emit vapors, gases, fumes, dusts, mists, or aerosols.
- Limit the amount of hazardous materials procured, used, and stored to the minimum needed for an operation.
- Keep drip pans, secondary containment, and cleanup materials readily available.
- Be familiar with the use, limitations, and location of emergency equipment such as emergency eyewashes, safety showers, fire alarms, exits, and fire extinguishers.
- Keep containers closed/sealed when not being actively used.
- Remove jewelry, including rings, when necessary to prevent contact with electrical sources and chemicals and from catching on laboratory or shop equipment.
- Confine long hair and loose clothing when working in the laboratory/shop.

3.3.3 Housekeeping

- Keep work areas clean and free of obstructions. Clean the work area at the completion of an operation or at the end of the day.
- Wipe drips and residues from containers of hazardous materials. Skin contact with residues may cause dermal absorption, chemical burns and skin irritation and, possibly, accidental ingestion as a result of hand-to-mouth transfer.
- Clean surfaces (counter tops, bench tops, fume hoods, and floors) of all drips and residues.

- If it is safe to do so, clean spilled chemicals immediately and dispose of all wastes properly.
- Maintain access to exits, emergency equipment, and equipment controls. Do not use stairways and hallways as storage areas.
- Store equipment and chemicals properly and avoid clutter.

3.3.4 Personal Hygiene

- After handling chemicals, wash hands with soap and water (Fig. 2) before leaving the laboratory/shop area and prior to breaks and consumption of food/beverages.

Fig. 2 Hand-washing is a simple way to prevent cross contamination

- Always remove gloves before touching common-use items such as phones, doorknobs, and computers. This will prevent cross-contamination to unprotected individuals.
- When moving between labs and transporting chemicals or hazardous material, remove one glove prior to exiting the lab so not to cross contaminate facilities such as door knobs. If both hands must be gloved, request assistance from other lab personnel to assist in opening doors en route.

3.3.5 Food, Beverage, Cosmetics, and Medicine in Lab Areas

Some everyday practices should be reserved for the office or break area and not brought into the lab:

- Food, beverages (including water), gum, tobacco (including vaping utensils), and medicines may not be consumed or stored in laboratory or chemical-storage areas.

- Cosmetics, ointments, skin cream, and similar items may not be applied or stored in lab areas.
- Do not use laboratory glassware or utensils to prepare or consume food or beverages.
- Do not use common food containers/equipment for chemical storage or processing (e.g., coffee cans or Thermos containers).
- Label all refrigerators in lab area "No food allowed."

3.3.6 Use of Glassware

These common laboratory items merit special attention:

- Never use mouth suction to pipette chemicals or to start a siphon; use mechanical means, a pipette bulb, or an aspirator.
- Use adequate hand protection (e.g., proper gloves) when inserting glass tubing into rubber stoppers or corks or when placing rubber tubing on glass hose connections.
- The ends of all glass tubing, especially new tubes, should be fire-polished or rounded and lubricated prior to assembly.
- When assembling, hands should be held close together to limit movement of glass should fracture occur.
- Plastic or metal connectors should be used whenever possible.
- Do not attempt glassblowing operations unless proper annealing facilities are available.
- Handle vacuum-jacketed glass apparatus with extreme care to prevent implosions. Equipment such as Dewar flasks should be taped or shielded. Only glassware designed for vacuum work should be used for that purpose.
- Use mechanical means when picking up broken glass (tongs or dustpan and hand broom, if appropriate).
- **Disposal of glassware.** Dispose of glass in marked boxes or drums designated for that purpose. Glassware must be free of liquids prior to disposal. Consult the Hazardous Waste/Environmental Office with any questions.
- Inspect glassware prior to each use and dispose if any visible damage is found.

3.3.7 Laboratory Door Signage

- Laboratory doors shall be posted with information listing the room custodian and alternates along with telephone numbers to use in the case of an emergency.
- Door signage must be used to alert those entering the lab of special hazards such as carcinogens, acutely toxic chemicals, biological materials, lasers, or radionuclides used in the lab and the minimum PPE required to enter the lab.

3.4 Personal Protective Equipment

PPE is the last control against hazardous materials. Given the risk for PPE failure it is the preference to substitute, remove, or isolate the contaminant versus placing the researcher in PPE as the sole protection against contaminants. Examples of PPE include chemically resistant or protective gloves; eye, face, or head protection; footwear; protective clothing such as lab coats; and respiratory protection. It is to be used either in conjunction with other control measures or when all other control measures including substitution, engineering, and administrative controls do not completely eliminate the hazard. To be effective, employees must understand the uses and limitations of PPE. The necessity for the use of PPE is determined after a job hazard analysis (via the "Deliberate Risk Assessment Worksheet", DD Form 2977) is completed for a specific task and/or an SOP is generated.

3.4.1 General Requirements

Safety glasses are required at all times in all laboratories except computer laboratories. Personnel are required to evaluate their procedures to determine if safety glasses alone are sufficient. There are other considerations pertaining to PPE:

- Branches are responsible for providing PPE for researchers, staff, and visitors. Personnel should frequently inspect PPE to make sure there are no holes, tears, rips, or other damage that could compromise the protection. Be aware that material degradation occurs naturally to disposable gloves, nondisposable gloves, and even to unused gloves. Follow the manufacturer's recommended shelf-life guidelines.
- All PPE including lab coats used in the laboratory must stay in the lab. PPE is not permitted in office areas, personal vehicles, or any other areas outside the lab. Storage of PPE outside the lab (i.e., on wall immediately adjacent to the lab) can be assessed on a case-by-case basis.

- Any contaminated protective equipment should be removed and left in or properly disposed of in the lab area. Users must not touch door handles or other surfaces with PPE as this could potentially spread contamination.
- Specific decontamination and doffing procedures shall be developed for individual SOPs/JHAs and so noted therein.
- Ensure that lab-coat materials are appropriate for the hazards/operations/chemistries.
- Chemical-resistant splash aprons should also be considered for highly toxic, corrosive, or other applications.
- Employees must be trained in the uses and limitations of PPE. This is the team leader's, lab POC's, and branch chief's responsibility. The Safety Office can be consulted to provide guidance on the selection and use of PPE and to assist in training.
- Lab coats are strongly recommended when working in the labs and handling chemicals.
- Personnel shall remove and appropriately dispose of contaminated PPE through the appropriate waste stream.
- Under no circumstances should lab coats or other laboratory protective clothing be laundered at home. Contact the Safety office for more information on available laundering procedures.

3.4.2 Eye and Face Protection

Safety glasses are used when there is the potential for dust particles and flying objects to be expelled into the air. They are impact resistant.

All safety glasses, including prescription eyewear, must have side shields and be American National Standards Institute (ANSI) approved. Contact your supervisor or ARL Safety Office for more information.

3.4.2.1 Safety Goggles

Researchers must upgrade to chemical-safety splash goggles if a splash, spray, or mist hazard exists. Chemical splash goggles shield the entire eye area. They are used for protection against chemical splashes, sprays, mists and/or impact. There are several types:

- Indirect venting is used mainly in goggles designed for sprays and mists.

- Prescription inserts for goggles are available from the manufacturer. The prescription inserts must be filled by an optometrist. (Contact your supervisor for more information.)
- Impact goggles are directly vented and should be used to guard the eyes from impact hazards.

Face and neck shields are used for the protection of the head and neck area. These shields provide protection against various splash and impact hazards (and must be worn in conjunction with safety glasses or goggles).

3.4.2.2 Contact Lenses in the Lab

Laboratory POCs and team leaders are responsible for evaluation of the hazards present in the laboratory and then set the guidelines on the use of contact lenses in the lab. Contact lenses can pose an additional risk as they may trap chemicals in eye in the event of an exposure.

3.4.3 Chemical-Protective Gloves

Before using a chemical, you must check to make sure of the proper type of glove needed. You can check for the proper chemical protective clothing required by referring to the SDS (at least two different SDSs) or talking to your supervisor or staff of the ARL Safety Office.

Chemical-protective gloves are task and chemical specific; no one glove protects against all chemicals. Be aware of the **breakthrough time**, which is the time it takes for a substance to pass through the protective material of the glove. Gloves that are contaminated need to be properly disposed of through the appropriate waste stream. If the gloves becomes contaminated, promptly remove gloves, thoroughly wash hands with soap and water, and don a new pair of gloves to continue process or proceed with installation-specific procedures, if different.

3.4.3.1 Proper Selection and Wear

Chemically resistant gloves are manufactured from a variety of materials including nitrile, polyvinyl chloride, natural rubber (latex), and Viton. Gloves must be selected on the basis of their chemical resistance to the material(s) being handled and their suitability for the procedures being conducted. Chemical-resistance charts, SDSs, and the ARL Safety office are all resources for assistance with selection of the proper glove for the material(s) being handled.

- Before each use, gloves should be inspected for discoloration, punctures, and tears, and a leak test can be performed to identify pinholes. Damaged or leaking gloves shall be discarded.
- Remove gloves before leaving the lab area and wash hands immediately with soap and water. Take caution to remove gloves in such a way that skin does not come in contact with potentially contaminated surfaces.
- Thermal-protective gloves need to be considered when working with temperature extremes, both hot and cold. Cryogenic gloves are required whenever filling or handling cryogenic materials.

3.4.3.2 Latex-Allergy Information

Latex allergy can result from repeated exposures to proteins in natural rubber latex. Reactions can range from skin rash to anaphylaxis and shock. Some items that include latex are gloves, medical supplies, respirators, rubber bands, and balloons.

The National Institute for Occupational Safety and Health (commonly known as NIOSH) recommends reducing exposure to these proteins by selecting latex-free or low-protein products.

3.4.4 Respirators

Respirators must be used in accordance with the ARL Safety office recommendations and training. Improper use of respirators can result in an exposure to hazardous materials, aggravation of a pre-existing medical condition, serious injury, or even death.

Examples of respirators include the following:

- Negative-pressure N-95 particulate
- Negative-pressure P-100 oil mist
- Negative-pressure half-face air purifying
- Negative-pressure full-face air purifying
- Positive-pressure self-contained breathing apparatus
- Positive-pressure supplied-air breathing apparatus

Researchers interested in using a respirator must contact the Safety office. If a respirator is determined to be necessary, training will be provided to the individual as well as a proper-fit test. A medical evaluation by a doctor and air sampling may be necessary prior to the training and fit testing.

Respirators shall be selected and used in accordance with the requirements of OSHA's 29 CFR 1910.134.[8]

4. Chemical Health Hazards' Evaluation and Controls

"Health hazard" refers to chemicals for which there is statistically significant evidence, based on at least one study conducted in accordance with established scientific principles, that acute or chronic health effects may occur in exposed employees.

4.1 Standards

For many toxic materials, hygienic standards have been established and action must be taken to assure personnel do not receive exposures in excess of these standards. These standards may be referred to as Threshold Limit Values (TLVs) or Permissible Exposure Limits (PELs).

The SDS should list the hygienic standard for the hazardous chemical or each component of a mixture. If unsure, contact the ARL Safety Office's industrial hygienists, who have a complete listing of published TLVs and PELs and other works concerning the subject of industrial toxicology. If you would like to conduct a more thorough review of a particular compound, or if you would like an evaluation of the exposure to a specific material used in your work area, contact the Safety Office.

Personnel in the research environment should consider two principal issues. The first concern is to identify potential hazards to which they may be exposed in their research setting. The second issue is the use of engineering, administrative, and PPE controls to minimize or eliminate these hazards.

4.2 Sensitizers

Sensitizers are essentially allergens that can produce skin and lung hypersensitivity. Examples include diazomethane, chromium, nickel bichromates, formaldehyde, isocyanates, latex, and certain phenols. The following are some controls or safe practices when working with sensitizers:

- Check glove-selection guides for suitable gloves to prevent skin contact with allergens or substances of unknown allergenic activity.
- Limit or eliminate contact and exposure to latex.
- Emphasize the use of engineering controls for lab procedures that produce sensitizing aerosols.

4.3 Reproductive Health

Reproductive toxins are agents that affect the reproductive systems' capabilities through chromosomal damage (mutations) or effects on developing fetuses (teratogenesis). Reproductive toxins affect both men and women. As long as there is a potential for conception, the employee must consider the reproductive effects of the materials with which they are routinely in contact.

4.3.1 Adverse Effects of Toxins

Examples of adverse reproductive health effects include birth defects, spontaneous abortion, fetal-developmental damage, and infertility. It is important to note the first trimester of pregnancy is the period of most concern to the developing fetus because this is when the organs and the limbs are being formed; during this period, however, many women may not yet be aware they are pregnant. For this reason, it is important the use of reproductive toxins has been identified and that control measures already are in place to protect a woman and her fetus from toxic exposure levels. (Resources on reproductive toxins are found in the Appendix B.)

4.3.2 Controls or Safe Work Practices for Reproductive Hazards

In the laboratory, begin minimizing exposure potential through implementation of prudent lab practices to prevent skin contamination or inhalation. Whenever possible, conduct processes in a chemical-fume hood and wear proper protective gloves to reduce exposure potential. If work cannot be conducted in a chemical-fume hood and a mutagen or teratogen is involved, contact your supervisor and the ARL Safety Office. Lab POCs, team leaders, and supervisors should ensure the lab personnel are familiar with the Global Harmonization System labeling and the symbols. Figure 3 shows the GHS symbol for reproductive toxin.

This symbol is also used for:

- Carcinogen
- Mutagenicity
- Respiratory Sensitizer
- Target Organ Toxicity
- Aspiration Toxicity

Fig. 3 GHS symbol for reproductive toxin

- Ensure this is highlighted and addressed in the job hazard analysis/SOP.
- Store these substances in unbreakable containers or unbreakable secondary containers in well-ventilated areas.

- Guard against spills and splashes. Ensure the engineering controls are operating properly before initiating work.
- Notify your supervisor or the ARL Safety Office of all incidents of exposure or spills.
- See Appendix B of the CHP for a Partial List of Reproductive Toxins.
- If a lab employee has any doubts about his/her reproductive health, it is recommended the worker consult their personal physician and provide a list of the chemicals used in the laboratory (which is readily available). The final decision to continue to work in the laboratory rests with the employee.

4.4 Highly Toxic Chemicals and Chemical Carcinogens

4.4.1 Definition of Highly Toxic Substances

Chemicals with high acute toxicity include materials that may be fatal or cause damage to target organs from a single exposure or from exposures of short duration. They also include materials capable of causing intense irritation that can result in pulmonary edema (fluid and swelling in the lungs), chemical asphyxia, and systemic (body-wide) poisoning.

See Appendix B of this plan for a partial list of highly toxic chemicals.

4.4.1.1 Examples of Toxicity and Dose

Table 2 Example of toxicity and dose (data from *Prudent Practices in the Laboratory*[5])

Toxicity rating	Animal LD_{50} (per kg)	Lethal dose when ingested by 70-kg (150-lb) human
Extremely toxic	< 5 mg	A taste (< 7 drops)
Highly toxic	5–50 mg	7 drops–1 tsp
Moderately toxic	50–500 mg	1 tsp–1 ounce
Slightly toxic	500 mg–5 g	1 ounce–1 pint
Practically nontoxic	>5 g	> 1 pint

4.4.1.2 Carcinogen, Defined

A carcinogen is any substance that meets at least one of the following criteria:

- It is regulated by OSHA as a carcinogen.
- It is listed as a known carcinogen or reasonably anticipated to be a carcinogen in monographs by the International Agency for Research on Cancer.

See Appendix B for a partial list of chemical carcinogens.

4.4.2 Controls or Safe Practices for Working with Highly Toxic Chemicals and Chemical Carcinogens

Proper training and information (i.e., HAZCOM) must be shared with all laboratory personnel working with or around these chemicals.

Training and information should cover the following:

- all information in the SDS
- process diagrams
- process chemistry
- inventory
- safe upper and lower temperatures
- pressures
- flows or compositions to be used
- instrument information
- relief systems
- ventilation needs
- electrical issues
- materials of construction
- safety systems
- consequences of failure to adhere to the safety controls
- any other information that could affect the process safety

This training shall be documented. Additionally, there are a number of safe work practices for highly toxic chemicals and chemical carcinogens:

- Consult at least three resources (e.g., SDSs) that list the toxic properties of known substances and learn what is known about the substance that will be used; follow the specific precautions and procedures for the chemical.

- Use and store highly toxic substances only in designated (restricted-access) areas placarded with appropriate warning signs.
- On leaving the designated area, remove protective apparel and thoroughly decontaminate or dispose of contaminated items as solid chemical waste; thoroughly wash hands and forearms. (See Appendix A for the definition of "designated area".
- Use mechanical means to handle equipment/chemicals whenever possible.
- Ensure the chemical-fume hood, glove box, or other mechanical engineering control is properly functioning prior to initiating work each time; consider incorporating a trap for released vapors to prevent their discharge with hood exhaust.
- Assure at least two trained people are present at all times when working with highly toxic chemicals.
- Use wet-mop/wipe methods or a vacuum with a high-efficiency, particulate air (HEPA) filter to decontaminate surfaces. **Do not sweep dry powders**.
- Protect vacuum pumps against contamination with scrubbers or HEPA filters, and vent effluent into the hood.
- Decontaminate vacuum pumps or other contaminated equipment, including glassware, before removing them from the designated area; decontaminate the designated area before normal work is resumed.
- Store breakable containers in chemically resistant secondary containers; work and mount an apparatus inside a secondary container; and/or cover work and storage surfaces with removable, absorbent, plastic-backed paper.
- Some chemical companies offer coated glass containers that protect the contents from spilling in the event the bottle is dropped.
- Be prepared for accidents and spills by having the appropriate spill/exposure kit in the laboratory or other immediately accessible area (i.e., the unlocked adjoining laboratory or unlocked common area). If the chemical requires a specific response (e.g., hydrofluoric acid or phenol), ensure response training has been provided and documented for all laboratory workers working in the lab housing the highly toxic materials.

4.4.3 Chemicals, Materials, or Substances of Unknown Toxicity

- Chemicals whose toxic properties are unknown are defined as *a chemical for which there is no known statistically significant study conducted in accordance with established scientific principles that establishes its toxicity*. In the absences of peer-reviewed scientific toxicity data, a researcher must assume the material is toxic and follow prudent practices to include the information on the label and in the SDS (refer to Section 2.3 for labeling information).
- Store these substances in closed containers and unbreakable secondary containers in well-ventilated areas.
- Guard against spills and splashes.
- Ensure the engineering controls are operating properly before initiating work.
- Notify your supervisor and the Safety Office of all incidents of exposure or spills.
- Use and materials of unknown toxicity only in designated areas placarded with appropriate warning signs.

For questions or concerns, contact the ARL Safety Office to evaluate and conduct monitoring for highly toxic and carcinogenic materials

5. Chemicals Physical Hazards' Evaluation and Controls

This section discusses hazard identification and control for several important classes of substances used in ARL laboratories including flammable and combustible materials, corrosives (strong acids, bases, and dehydrating agents), compressed gases, peroxide formers, and water-reactive materials.

5.1 Flammable and Combustible Liquids

Flammable and combustible chemicals include liquids such as organic solvents, oils, greases, tars, oil-based paints, and lacquers, as well as flammable gases. Flammable and combustible liquids are defined by their flash points. The flash point of a liquid is the minimum temperature at which the material gives off sufficient vapor to form an ignitable mixture with the air near its surface or within its containment vessel. A liquid's flash point is a function of its vapor pressure and boiling point (Fig. 4). Generally, the higher the vapor pressure and the lower the

boiling point of a liquid, the lower its flash point will be. The lower the flash point, the greater the fire and explosion hazards.

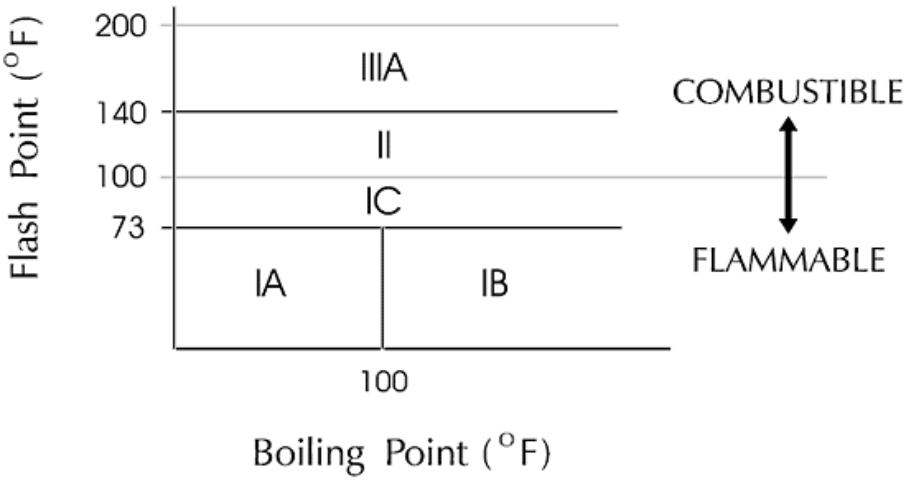

Fig. 4 Liquid's flash point is a function of vapor pressure and boiling point

5.1.1 Flammable Liquids, Class I

Liquids with flash points below 100 °F (37.8 °C) and vapor pressures not exceeding 40 pounds per square inch (absolute) at 100 °F (37.8 °C) are in Class I. Flammable Class I liquids are subdivided as follows:

- **Class IA**: Liquids having flash points below 73 °F (22.8 °C) and boiling points below 100 °F (37.8 °C). Flammable aerosols (i.e., spray cans) are included in Class IA
- **Class IB**: Liquids having flash points below 73 °F (22.8 °C) and having boiling points at or above 100 °F (37.8 °C).
- **Class IC**: Liquids having flash points at or above 73 °F (22.8 °C) and below 100 °F (37.8 °C). The boiling point is not considered.

5.1.2 Combustible Liquids, Classes II and III

These are liquids having flash points at or above 100 °F (37.8 °C). Combustible liquids in Classes II and III are subdivided as follows:

- **Class II**: Liquids having flash points at or above 100 °F (37.8 °C) and below 140 °F (60 °C).
- **Class IIIA**: Liquids having flash points at or above 140 °F (60.0 °C) and below 200 °F (93.4 °C).
- **Class IIIB**: Liquids having flashpoints at or above 200 °F (93.4 °C).

5.1.3 Working with Flammables and Combustibles

There are a number of that need to be considered and implemented when working with these materials:

- Eliminate ignition sources such as open flames; smoking materials; hot surfaces; sparks from welding, cutting, or grinding; operation of electrical equipment; and static electricity. Post conspicuous "No Smoking" signs in areas where flammable materials are used or stored, when applicable.
- A fume hood or other appropriate local exhaust ventilation should be used when handling flammable and combustible liquids in a manner that may produce an airborne hazard (such as fumes, gases, vapors, and mists). This includes procedures such as transfer operations, preparation of mixtures, blending, sonification, spraying, heating, and distilling.
- Store in approved flammable-liquid containers (safety cans) and in a Factory Mutual (FM)- or UL-approved flammable-liquid storage cabinet or in a special storage room designed for that purpose.
- Flammable-liquid storage cabinets shall not be vented without guidance and approval from the installation's Fire Department and Safety Office.
- Store away from oxidizers, which react with flammable and combustible materials, resulting in a fire.
- Refrigerators and freezers used for the storage of flammables and combustibles shall be intrinsically safe or "lab safe", indicating the unit is engineered for housing flammable and combustible materials safely. Domestic refrigerator/freezers as well as units that have been modified to remove spark sources are not acceptable alternatives.
- Assure there are proper bonding and grounding when required, such as when transferring or dispensing a flammable liquid from a large container or drum. Assure bonding and grounding are checked periodically.
- Assure appropriate fire extinguishers are in the areas where flammables/combustibles are used and/or stored.
- Open bottles or carboys slowly and carefully, and wear PPE to protect hands, face, and body from splashes and vapors/gases.
- Wipe drips/residues from containers and work surfaces and dispose of wipes through the appropriate waste stream.

- Store flammables only in approved flammable-storage cabinets or safety cans. Ensure all storage units are marked “FLAMMABLE” and are free from extremes of temperature and humidity.
- Flammable-liquid storage cabinets are designed to keep the materials in the cabinet cool during a fire so that occupants of the area have enough time to evacuate. The cabinet’s design limits internal temperature to <325 °F when subjected to a 10-minute fire test.
- Electrically bond and ground containers when transferring Class I flammable liquids and other flammable and combustible liquids at temperatures above their flashpoints. When transferring flammables from one metal container to another, use a ground wire to connect the two containers.
- When moving large volumes of flammable chemicals within the laboratory, use nonbreakable chemical carriers.
- Keep daily use quantities (<500 mL) on the laboratory bench or within engineering controls. Ensure the container is properly labeled with appropriate GHS labeling. Maintain unused portions in a flammable-storage cabinet or dispose of them properly at the end of the work shift.
- Hot-work processes must be 15 ft away from combustibles and 50 ft away from flammable gas or liquid or flammable materials’ storage cabinet.

5.1.3.1 Flammable- and Combustible-Liquid Storage

Flammable and combustible liquids may be stored in cans and various other containers. The allowed volume depends on the flammable/combustible class and container material (Table 3).

Table 3 Containers for combustible and flammable fluids

Container type	Flammable-liquid Class			Combustible-liquid Class	
	IA	IB	1C	II	III
Glass	1 pt[a]	1 qt[a]	1 gal	1 gal	1 gal
Metal (other than US DOT-approved drums)	1 gal	5 gal	5 gal	5 gal	5 gal
Approved safety cans[b]	2 gal	5 gal	5 gal	5 gal	5 gal
Metal drums (DOT specifications)	60 gal	60 gal	60 gal	60 gal	60 gal

[a] Class IA and Class IB liquids shall be permitted to be stored in glass containers of not more than 1.3-gal (5-L) capacity if the required liquid purity (such as American Chemical Society analytical-reagent grade or higher) would be affected by storage in metal containers or if the liquid can cause excessive corrosion of a metal container. Note: This exemption does not apply to the accumulation of noncorrosive ignitable hazardous waste.

[b] UL- or FM-approved container equipped with a self-closing lid, pressure relief, flame arrester, bonding/grounding tab, and a funnel.

According to the National Fire Protection Association's code, flammable liquids stored in glass containers shall not exceed the following allowable limits:

- Class IA–1 pint
- Class IB–1qt
- Class 1C–1 gal
- Class II–1 gal
- Class IIIA–5 gal

5.2 Corrosives

Corrosives are substances that can destroy or permanently damage body tissue. The extent of injury depends on factors such as the type and concentration of the chemical, route of exposure, type of tissue contacted, and speed used in applying emergency measures. The major classes of corrosives include strong bases, acids, and dehydrating agents.

The eyes are especially susceptible to acids and bases and must be immediately flushed with water for at least 15 minutes if exposure occurs. Inhalation of vapors, dusts, and mists of acids and bases irritate the nose, throat, and lungs. Secondary toxic effects may occur if the material is absorbed from the lungs into the blood stream. The extent of these effects depends on the concentration in air and the duration of exposure. Ingestion causes severe burns of the mucous membranes of the mouth, throat, esophagus, and stomach.

5.2.1 Additional Considerations when Working with Acids

Concentrated solutions of inorganic acids are not in themselves flammable; however, combustion can occur when an oxidizing acid is mixed with other chemicals or with combustible materials. Acids also react with many metals, resulting in the liberation of hydrogen, a highly flammable gas. Some acids are strong oxidizing agents and can react destructively and violently when in contact with organic or other oxidizable materials. Perchloric acid may form explosive perchlorate crystals, which are shock sensitive and can detonate.

5.2.2 Special Precautions when Working with Corrosives

Containers and equipment used for storage and processing of corrosive materials must be corrosion resistant. The following are additional safety measures:

- A fume hood or other appropriate exhaust ventilation must be used when handling acids and bases in a manner that may produce an airborne hazard. This includes procedures such as transfer operations, preparation of mixtures, blending, sonification, spraying, and heating.
- If perchloric acid is used, a fume hood equipped with a water wash-down system may be required. (Contact the Safety Office for further guidance.)
- Dilution of acids and bases is exothermic (i.e., heat is liberated). This is particularly true for sulfuric acid and potassium hydroxide. Do not pour water into acid; slowly add the acid to the water and stir.
- Never empty carboys or drums of chemicals by means of air pressure; use a tilting rack, a safety siphon, or a liquid pump.
- Open bottles or carboys slowly and carefully and wear PPE to protect hands, face, and body from splashes, vapors, gases and fumes.
- Wipe drips from containers and bench tops. Be especially careful to wipe up visible residues of sodium hydroxide and potassium hydroxide from all surfaces. Skin contact with dry residue will result in burns.
- When handling concentrated corrosives, wear a rubber apron, goggles or a full-face shield, and long-sleeved gloves. Be sure to conduct a hazard assessment as gloves and chemical resistant apron are made from various materials and have different resistance properties. (Contact the Safety Office for assistance.)
- Acids and bases must be stored separately from each other. Organic acids (e.g., acetic acid, citric acid, and formic acid) are flammable and may be

stored with flammable materials provided they are separated by secondary containment but separate from oxidizers and oxidizing acids.

- An eyewash and safety shower must be readily accessible in areas where corrosives are used and stored per ANSI Z358.1.[9]

5.3 Oxidizers

OSHA defines an oxidizer as a chemical other than a blasting agent or explosive that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.

5.3.1 Additional Considerations when Working with Oxidizers

Oxidizers accept electrons and undergo reduction. The intensity of the reaction depends on the oxidizing-reducing potential of the materials involved. Oxidation reactions are the most frequent cause of chemical accidents. Examples of chemical oxidizers include nitrites, chlorates, perchloric acid, and inorganic peroxides.

5.3.2 Special Precautions for Working with Oxidizers

Know the reactivity of the materials involved in the experiment or process. The following steps also should be followed:

- Ensure there are not extraneous materials in the area that could become involved in a reaction.
- If the reaction can be violent or explosive, use shields or other methods to isolate the materials or the process.
- Use the minimum amounts necessary for the procedure; do not keep excessive amounts of the material in the vicinity of the process.
- In laboratories, do not use corks, rubber stoppers, or stopcock grease to seal containers of strong oxidizing materials.
- Use fiberglass heating mantles or sand baths instead of oil baths to heat reaction vessels containing significant amounts of oxidizing materials.
- Store properly, away from organic materials, flammable materials, and reducers.

5.4 Water-Reactive Materials

Water-reactive materials are those that react violently with water. Of chief concern are the alkali metals.

5.4.1 Additional Considerations when Working with Alkali Metals

All alkali metals react vigorously with water to form hydroxide and gaseous hydrogen. The alkali-metal–water reaction is exothermic; the heat generated can ignite the hydrogen gas. The rate of reaction increases as the atomic weight increases. Lithium reacts the slowest and poses the least hazard, while rhubidium and cesium react explosively. Other examples include metal powders such as aluminum and titanium.

5.4.2 Special Precautions for Working with Water-Reactive Materials

Water-reactive chemicals should be stored in a cool and dry location in the manner that is recommended by manufacturer. Also, take the following precautions:

- Keep water-reactive chemicals segregated from all other chemicals in the laboratory and minimize their quantities.
- Water-reactive storage areas will be posted "Caution—Water-Reactive Chemical".
- Store all metals in the container provided by the manufacturer.
- Store alkali metals under mineral oil or in an inert atmosphere (note: lithium reacts with nitrogen). Containers should be stored in a cool, dry environment, away from light and free from extremes of temperature and humidity.
- Potassium can form unstable and highly reactive peroxides if stored for extended periods of time. If you see any crystal formation on the exterior of the container, contact the ARL Safety Office.
- Alkali metals shall be handled in a glove box with an inert atmosphere such as a dry argon-filled glove box made of materials that are compatible with the metal. Nitrogen may be used to backfill—except when handling lithium.
- Avoid all skin and eye contact with the material. Where possible use tongs or appropriate tools to handle solids.
- Remove all water-sensitive chemicals out of your stock whenever they are no longer required for current research.

- All tools used to handle alkali metals must be dry, rust free, and clean and composed of a material compatible with the metal.
- Oxidized materials (with a white surface coating) may make the material more hazardous to handle because the oxide can flake off. Note: Materials with a *yellow or orange coating may indicate the presence of peroxides*, which may detonate if cut or abraded. Do not handle these materials. Contact the Safety Office for assistance.
- Assume that containers with alkali metals—sodium, potassium, rubidium, lithium, and cesium—contain flammable hydrogen gas in the head space, even if stored under mineral oil or an inert gas. Thus, no source of ignition should be present where these containers are opened. Use nonsparking tools to open containers.
- All labs that house or conduct processes with water-reactive materials must have a full, unused "Class D" (combustible metals) fire extinguisher readily available in the work and storage areas.
- Contact the ARL Safety Office for assistance with proper PPE selection.

5.5 Pyrophoric Materials

Pyrophoric materials ignite spontaneously upon contact with air. Moreover, they are commonly associated with flammable solvents such as pentane, hexane, heptane, and diethyl ether. This combination poses a significant hazard to users.

5.5.1 Other Hazards

Other hazards posed by these materials include corrosivity, water reactivity, peroxide formation, and toxicity. Examples of pyrophoric materials are silane, silicon tetrachloride, and white or yellow phosphorous.

5.5.2 Special Precautions for Working with Pyrophoric Materials

Pyrophorics should only be used and stored in inert environments. The hazards they pose warrant additional precautions:

- Synthetic-fiber clothes should not be worn when working with pyrophoric materials. Flame-resistant lab coats and the use of fire-resistant gloves, such as Nomex pilot's gloves, are required for the handling of pyrophoric materials. These are not fireproof, but are a good compromise between dexterity and (limited) flame resistance.

- Never work alone with pyrophorics; always ensure someone can see or hear you.
- Glass bottles of pyrophoric reagents should not be handled or stored unprotected. The metal can that is shipped with each bottle should be retained as a protective container for each bottle during transport and storage.
- All labs that house or conduct processes with pyrophorics must have a full, unused "Class D" (combustible metals) fire extinguisher readily available in the lab area.
- Know where the safety shower and eyewash are located before work with pyrophorics is initiated.
- Use a portable shield if necessary.
- Remove any flammable or combustible material from work area.

5.6 Peroxidizables

Organic peroxide's formation in common laboratory chemicals is the result of an autoxidation reaction caused by exposure to air (oxygen). The reaction can be accelerated by exposure to light (UV radiation) or heat or by the introduction of a contaminant. Some chemicals have inhibitors added such as BHT (2,6-di-tert-butyl-4-methyl phenol), hydroquinone, and diphenylamine to prevent the accumulation of peroxides by reacting with the peroxide to form a stable product. However, once the inhibitor is consumed, organic-peroxide formation will progress. In addition, some volatile compounds (higher vapor pressure, lower boiling point) present a hazard, since evaporation allows the peroxide to concentrate.

Most organic-peroxide crystals are sensitive to heat, shock, or friction, and their accumulation in laboratory reagents has resulted in numerous explosions at other facilities. For this reason, it is important to identify and manage chemicals that form potentially explosive peroxides.

Note: Containers of peroxide-forming compounds showing signs of peroxide-crystal formation, those of unknown age or history (e.g., lack of labeling), those that have exceeded their shelf lives, or those showing signs of leakage should not be opened or disturbed. Contact your supervisor and ARL Safety office. Upon examining the container, it may necessary to dispose of it as hazardous waste.

Researchers should take special care with the management of peroxide formers. Table 4 lists chemical classes known to form peroxides, from "most likely" at no. 1 to "least likely" at no. 14.

Table 4 Peroxidizable organic moieties* most to least likely to form peroxides[9]

1. Ethers and acetyls with alpha-hydrogen	6. Vinylalkynes with alpha-hydrogen	11. Secondary alcohols
2. Alkenes with allylic hydrogen	7. Alkylalkynes with alpha-hydrogen	12. Ketones with alpha hydrogen
3. Chloroalkenes, fluoroalkenes	8. Alkylarenes with tertiary alpha hydrogen	13. Aldehydes
4. Vinylhalides, esters, ethers	9. Alkanes and cycloalkenes with tertiary hydrogen	14. Urea, amides, and lactams with alpha hydrogen atom on a carbon attached to nitrogen
5. Dienes	10. Acrylates, methacrylates	

5.6.1 Special Precautions for Working with Peroxidizables

Some common compounds that are known to form peroxides and the associated recommended storage times are listed in Appendix F of this plan. That is not an exhaustive list. Researchers must consult the peroxidizable organic-moieties chart (Table 4), SDSs, and other sources of information for chemicals used in their work areas to determine their peroxide-forming potential.

There are other safe-work practices for peroxides:

- Date all peroxidizables upon receipt and upon opening.
- Unless an inhibitor has been added by the manufacturer, materials should be properly disposed of after 18 months from the date of receipt, or 3 months from the date of opening.
- Store closed containers in cool, dark, storage area.
- Avoid evaporation and do not distill.
- Do not use metal spatulas or magnetic stirring bars with peroxide-forming compounds, since contamination with metals can lead to explosive decomposition. Ceramic or Teflon spatulas and stirring blades are usually safe to use.

* A **moiety** is a part of a molecule that is typically given a name as it can be found within other kinds of molecules as well.

- It is best not to use glass containers with screw-top lids or glass stoppers; polyethylene bottles with screw-top lids may be used.
- Do not stockpile chemicals; periodically clean out inventory to prevent accumulating unneeded chemicals.
- Never scrape or scrub glassware or containers that have been used with peroxide-forming compounds if you see an oily or crusty residue.
- Label containers with receiving, opening, and disposal dates.
- If old containers of peroxide-forming chemicals are found, do not move them; contact the ARL Safety office for assistance in disposal.
- Do not purchase these compounds in quantities greater than can be used in the specified storage time period.
- A fume hood or other appropriate exhaust ventilation must be used when handling peroxide-forming chemicals in a manner that may produce airborne vapors, including procedures such as transfer operations, preparation of mixtures, blending, sonification, spraying, heating, evaporation, and distilling.
- Keep the fume-hood sash in its lowest practical position when handling these compounds; if the hood is equipped with one, use the horizontal sliding sash.

5.6.2 Storage of Peroxidizables

Refer to the tables in Appendix F for allowable storage times; peroxide-forming compounds may be stored. Additionally, follow these steps:

- Store peroxide-forming chemicals in sealed, air-impermeable containers. Dark amber glass containers with tight-fitting caps are required. Do not use containers with loose-fitting lids or glass stoppers, which may allow the introduction of air and result in peroxide formation.
- Septum-capped containers such as Sure Seal bottles and air-free transfer techniques (e.g., Schlenk line) minimize entrainment of air.
- Storage in inert glove boxes provides an added measure of safety since there is no contact with air.

5.7 Light-Sensitive Materials

Light-sensitive materials react in the presence of light, forming new compounds that can be hazardous or creating conditions such as pressure buildup inside a container that may be hazardous.

Special precautions for working with light-sensitive materials are as follows:

- Store light-sensitive materials in a cool, dark place in amber-colored bottles or other containers that reduce or eliminate the penetration of light.
- Date containers on receipt and upon opening.
- Dispose of surplus material after 1 year if unopened or 6 months if opened.

5.8 Shock-Sensitive or Explosive Materials

Note: *Work with Class 1 ammunition and explosives is only permitted in ARL Explosives Safety Office (ESO)-approved laboratories and experimental facilities.* Special precautions, training, certification, and site approval for working with ammunition or explosive materials must be obtained from the ESO prior to procurement or development of any such material.

5.8.1 Potential Energy Release

Shock-sensitive/explosive materials can spontaneously release large amounts of energy under normal conditions or when struck, vibrated, or otherwise agitated. The mixture of incompatible chemicals such as oxidizers and flammables or acids and bases can produce the release of large amounts of energy. Some chemicals become increasingly shock-sensitive with age. Of great concern in the laboratory is the inadvertent formation of explosive or shock-sensitive materials such as peroxides, perchlorates (from perchloric acid), and azides.

5.8.2 Special Precautions for Working with Shock-Sensitive Materials

Contact the Safety Office when work with shock-sensitive or explosive materials is planned or when it is suspected the inadvertent formation of shock-sensitive materials in ductwork, piping, or chemicals being stored has occurred. The following also must be observed:

- Control all ignition sources when handling explosives; also, this applies to flammable and combustible solvents in which the material may be either dissolved or dispersed.

- Date all containers of explosive or shock-sensitive materials upon receipt and when opened.
- Unless an inhibitor has been added, unopened shock-sensitive materials should be discarded within 12 months after receipt; open containers of shock-sensitive materials should be discarded within 6 months of the date opened.
- Order and use the minimum amount of materials necessary for a procedure; moreover, keep only a minimum amount of material on hand.
- If the job hazard analysis (Appendix D) for shock-sensitive materials indicates 1) there is a chance of explosion or 2) the inadvertent formation of shock-sensitive materials in ductwork, piping, or chemicals being stored may occur, contact the ARL ESO prior to procurement of such material.

5.9 Cryogenic Liquids

Cryogenic liquids are liquefied gases that are kept in their liquid state at very low temperatures. Cryogenic liquids have boiling points below –150 °C (–238 °F).* All cryogenic liquids are gases at normal temperatures and pressures. (See Appendix C.)

5.9.1 Hazards

Hazards associated with cryogens are fire, pressure, embrittlement of materials, skin or eye burns upon contact with the liquid, and chemical asphyxiation. Cryogens condense oxygen from the air, creating an oxygen-rich atmosphere, increasing potential for fire if flammable or combustible materials and a source of ignition are present. Pressure is a hazard because of the large expansion ratio from liquid to gas, causing pressure to build up in containers. Many materials become brittle at extreme low temperatures. Brief contact with materials at extreme low temperatures can cause burns similar to thermal burns. Vapors and surfaces cooled by cryogenic liquids present the same cold-temperature hazard as the cryogenic liquids.

5.9.2 Special Precautions for Working with Cryogens

Equipment should be kept clean, especially when working with liquid or gaseous oxygen. Liquid nitrogen is cold enough to condense the surrounding air into a liquid form. The concentration of oxygen in this condensed air is enhanced. This

* Carbon dioxide and nitrous oxide, which have slightly higher boiling points, are sometimes included in this category.

condensed “liquid air” can be observed dripping from the outer surfaces of uninsulated/nonvacuum-jacketed lines carrying liquid nitrogen. This “liquid air” will comprise approximately 50% oxygen and will *amplify any combustion/flammable hazards* in the surrounding areas.

There are other considerations with working with cryogens:

- Open Dewars of liquid nitrogen can condense oxygen from the air into the liquid nitrogen and cause an oxygen enrichment of the liquid that can reach levels as high as 80% oxygen.
- Air should be prevented from condensing into liquid nitrogen through the use of loose-fitting stoppers or covers that allow for the venting of nitrogen boil-off gas.
- Large quantities of liquid nitrogen spilled onto oily surfaces (such as asphalt) could condense enough oxygen to present a combustion hazard.
- Liquid helium can also condense air into a liquid or even solid with an enriched oxygen content.
- For flammable cryogens such as hydrogen, methane, and liquefied natural gas, the precautions listed in Section 5.1.3, Safely Working with Flammables and Combustibles, of this plan must also be used.
- Always wear safety glasses with side shields or goggles and full face shield, an impervious apron or laboratory coat, cuff-less trousers, and close-toed shoes must be worn when handling cryogens.
- Watches, rings, and other jewelry should not be worn (a spill/splash could freeze the jewelry to your skin). Gloves must be specifically engineered for handling cryogenic materials and sufficiently large as to be readily removed should a cryogen be spilled.
- Containers and systems containing cryogens must have pressure-relief mechanisms, be specifically engineered to house cryogenic materials, and be able to withstand extreme cold without becoming brittle.
- Due to the expansion ratio for cryogens and their asphyxiation capacity, bulk-filling areas require oxygen detection and special ventilation. Contact the Safety Office for assistance.
- Never leave a filling process unattended, and do not overfill Dewars.
- Always use mechanical means such as a cryoclaw to retrieve items or samples that have fallen into a Dewar.

- Always use an appropriate wheeled cart to transport a Dewar or storage vessel; never pull, push, or roll a Dewar or storage vessel.

5.10 Compressed Gases

Compressed gases have compound hazards that must be considered and properly addressed to ensure the safety of each user and lab or building occupant. For example, compressed gases require special systems for not only handling materials under a large amount of pressure but also to address the possible hazards of the contents of the cylinder itself (chemical, asphyxiant, high flammability, reactivity, etc.) There are special considerations that must be assessed for cylinder-storage rooms as well such as whether or not there is a need for a chemical sensor (i.e., oxygen sensor) and storage compatibility.

5.10.1 Restrictions

The storage, handling, and use of compressed gases shall conform to the requirements of regulations, national fire codes and standards, Department of Transportation, and any applicable provisions referenced herein. Researchers shall not possess cylinders without first obtaining the proper equipment to use, handle, and store them accordingly. No personnel shall use compressed gases in any manner that is inconsistent with this CHP.

5.10.2 Special Precautions for Working with Compressed Gases

When work with toxic, corrosive, or reactive gases is planned, the ARL Safety Office must be contacted for information concerning specific handling requirements for the gas involved. Additionally, there are these considerations:

- Cylinders of gases having a Globally Harmonized System health rating of 1 or 1A or gases having a health-hazard rating of 2 and up with no physiological warning properties will most likely need to be kept in a continuously mechanically ventilated enclosure. Contact the Safety Office for review and confirmation prior to purchasing the gas or systems.
- Know the contents of the cylinder and be familiar with the chemical and physical properties of that gas before use.
- Never use a cylinder that cannot be positively identified.
- Immediately replace any damaged labels on gas cylinders; if the label is missing, please contact the Safety Office for assistance.

- All hoses, pipes, fittings, and other equipment that may be used in a compressed-gas system must be pressure-rated by the manufacturer and this pressure not exceeded.
- Keep only cylinders necessary for current lab needs within the lab.
- When gas cylinders are not in use, close and tighten the hand valves, attach the valve-protector caps, and move them to the designated compressed-gas storage area outside the lab.
- Gas cylinders shall be segregated and stored by their hazard classification (i.e., flammable, toxic, or oxidizer).
- Cylinders considered to be empty should be handled with the same precautions as cylinders filled with gas because so-called "empty" cylinders still contain residual gas and pressure.
- Gas cylinders should be left with residual pressure (i.e., typically 200 kPa or 30 psi) to prevent contamination of cylinder contents.
- Empty gas cylinders shall be returned to the manufacturer for refilling; nonrefillable cylinders shall be managed through the hazardous waste stream.
- Gas cylinders shall be secured by the use of clamps, chains, straps, or racks. The preferred method is to secure each one individually two-thirds of the way up the cylinder to a fixed location with a chain.
- Keep lab doors closed where gas cylinders are in use: labs are engineered to have a negative pressure to the hallway, which will contain gas in the event of a catastrophic release.
- Oxidizers shall be separated from flammable gases by at least 20 ft, and the Safety Office must approve exceptions.
- The type of vacuum-pump oil to be used with gases and chemicals must be analyzed for its compatibility with those gases and chemicals; hydrocarbon oil should not be used with an oxidizer (i.e., oxygen in concentrations greater than or equal to 25%) or with pyrophoric gases.
- Before a pump oil can be selected for use on a system involving an oxidizer or pyrophorics gases, the manufacturer must be contacted for compatible lubricant alternatives.
- Pumps must have a pressure-relief or shutdown device that protects the pump from damage if a line becomes plugged.

- Check valves or other backflow-prevention devices must be provided when the backflow of materials could create a hazardous condition.
- Flow limiters will be used for any highly flammable gases (e.g., hydrogen) not housed in compressed-gas cabinets.
- Keep cylinders away from sources of ignition, heat, or open flames.
- Gas-cylinder parts must not be modified, tampered with, obstructed, removed, repaired, or painted by the gas user.
- Regulator valves, gauges, and fittings must not be interchanged between different types of gases; for example, do not use a regulator or fitting from an oxygen cylinder or system on a nitrogen cylinder or system.
- All components on a system that will house oxygen gas must be specifically for that gas; thus, during purchase researchers must specify that all components of the system must be cleaned and approved for oxygen use.
- Two people must be present during hazardous-gas purge and cylinder-change procedures.
- Prior to changing any toxic, reactive, or corrosive gas, ensure the compressed-gas cabinet is on and functioning. If there is any question about proper functioning of the cabinet, contact the ARL Safety Office for guidance.
- All pressurized hazardous- and toxic-gas system connections must be leak-checked on new gas systems and after reconnection of any fitting; the leak-test agent should be appropriate for each specific gas. Check with the gas manufacturer for information or contact the Safety Office.
- Gas cylinders designed to have valve-protection caps and valve-outlet caps and plugs must have these devices in place. Exception: when the cylinder is in use or being serviced.
- Visual inspections of equipment, including portable cylinders, are needed to ensure equipment is in safe operating condition prior to each use.
- Always wear safety glasses with side shields when connecting a gas regulator and when performing any operation with compressed gases; additional PPE may be required depending on the circumstances.
- Compressed gas from cylinders shall be reduced through the use of a regulator specifically designed for that specific gas.

- Use cylinders only with matching Compressed Gas Association (CGA) connections on the cylinder valve and the regulator. Additionally, there are these precautions:
    - Never install cylinder adapters on a regulator.
    - Hand tighten the gas fitting, then snug with a wrench.
    - Never use a wrench extension lever—it will distort the machine threads. A proper connection will go together smoothly.
    - *Do not overtighten the CGA connection to try and achieve a leak-tight seal*.
- The valve on an unregulated cylinder should never be "cracked" open to blow out dust; rather, if there is concern a valve is damaged, dirty, or contaminated, do not use and contact the gas vendor to remove the cylinder from service.
- "Cracking" open may freeze the valve in the open position and, in the case of a flammable gas, can cause static-discharge ignition; also, it is a safe practice to open the main valve only 1/2 to 1 turn, as opening the valve all the way could produce excessive flow.
- No materials shall be released into the environment except when in compliance with state, local, and federal agencies.
- Always replace the gasket washer on flat-faced CGA fittings.
- Do not use Teflon thread tape on any CGA cylinder's valve fitting (parallel machine threads) as it interferes with the fitting, causes leaks, and will clog small orifices and sintered filters. Use thread tape only on tapered pipe threads.
- A preventative-maintenance program is required for all gas regulators.
- Anytime a regulator shows gauge-pressure discrepancies, bubbles upon leak testing, or other abnormal characteristics, it will be removed from service and factory overhauled.
- Pressurized systems are subject to OSHA lockout regulations for energy sources, which require that compressed-gas or fluid-powered equipment have lockout valves to protect repair personnel.
- Some lockout valves are designed to bleed off the pressure in addition to locking the valve to protect personnel working on air or fluid-powered equipment.

- Injury caused by high-pressure gas injected through the skin into the body is prevented by not directing any open gas flow at yourself or other lab workers.

5.10.3 Quantity Limitations

All classes of gases must be kept below lab-designated quantity limitations. Please contact the ARL Safety Office for guidance as these limitations vary depending on the type of gas and the location within a building.

5.10.4 Transporting Gas Cylinders

The movement of gas cylinders requires particular caution:

- The safety cap must be securely in place to protect the valve anytime the cylinder is to be moved or transported.
- Use a gas-cylinder cart to move a cylinder from storage to the point of use and vice versa; never substitute an ordinary dolly for a cylinder cart, which is designed to cradle the cylinder and to restrain it with a chain.
- Be aware of the mechanical hazards of gas cylinders, which are usually of steel or aluminum construction: average weight of a 200-ft^3 standard gas cylinder is 175 lb, and crushing injuries occur when hands are trapped between cylinders or when a foot or leg is crushed by a toppled cylinder.
- Never enter/ride an elevator with a compressed gas cylinder, as sudden release of gas (e.g., valve breakage or rupture-disc blow-out) could cause death by asphyxiation.
- When transporting a gas cylinder in an elevator, send it up/down *unescorted* to a person waiting to meet it at the destination; moreover, those encountering a cylinder on the elevator must not enter until it is off-loaded at the destination.
- For elevator transport, place a sign on the unescorted cylinder-transport dolly that reads “DO NOT ENTER ELEVATOR WHEN COMPRESSED GAS IS IN TRANSIT” to alert others not to get on the elevator until the compressed has been removed.
- Cylinders shall not be transported in privately owned motor vehicles; instead, transport should be handled by a licensed outside vendor.
- If motor-vehicle transport of a gas cylinder by ARL personnel is absolutely necessary, contact the SO for assistance.

5.11 Gas-Detection Systems

Certain types of compressed gas will require gas detection. Typically, gas detection will be required for highly toxic and pyrophoric gases and bulk-filling locations. There are several considerations with gas-detection systems:

- In general, detection systems should be designed to these minimal specifications:
    - Monitoring points in gas cabinet, equipment, and rooms
    - Alarms will shut off gas supply by solenoids
    - Alarms to trigger building alarms
    - Separate annunciation for gas detection
- Employees must be knowledgeable of the gas characteristics and other warning properties' information obtained in the SDS for each gas they are using.
- Employees should ensure all detection systems are within calibration and all sensors are changed out and replaced per the manufacturer's recommendations.

6. Emergency Procedures and Equipment and Spill Response

Researchers must be familiar with the emergency procedures specific to their operations. The following general procedures also apply:

- Dial 911 (or initiate your local emergency-response procedures) to report all emergencies including injuries, fires, and spills.
- All SOPs and JHAs must identify procedures to be followed in the event of an incident or mishap; that includes instructions for shutting down equipment or apparatus in the event of an emergency.
- Emergency telephone numbers and identities of POCs shall be posted near each laboratory telephone.

6.1 Spill-Response Procedures

Each SOP/JHA describes methods of spill containment and emergency actions that will be taken in case of an accidental release.

The spill of any quantity of a hazardous chemical that may potentially result in a release to the environment (i.e., air, land, or water) or that may cause a harmful exposure to personnel shall immediately be reported by dialing 911 (or initiation of local emergency response procedures); SO and supervisor must also be notified.

Note: Care must be taken to *avoid spreading* contamination or tracking chemical contamination to other areas. With that in mind, laboratory personnel may take action to stop, contain, or clean up a spill if 1) they are trained to do so and 2) it can be done without endangering themselves or other personnel. The following requirements must also be met:

- No students or visitors/guests are permitted to assist with a spill response.
- The hazards of the material(s) are known, and appropriate precautions can be taken to prevent personal exposure.
- Personnel are knowledgeable about the appropriate waste streams for the disposal of the cleanup material.
- There is no potential of a release to the environment.
- There are no personal injuries as a result of the spill.
- The proper spill-response equipment (e.g., PPE, absorbents, neutralizers, mops, buckets, and waste containers) is available.
- The spill does not involve *elemental mercury*, which requires special cleanup and air monitoring—dial 911 or initiate your local emergency response procedures—as mercury contamination is easily tracked to other areas.

If the aforementioned requirements are not met, or if you have any doubts about your ability to safely and effectively clean up the spill, then take these actions:

- Call or have someone call 911 (or initiate your local emergency-response procedures) for assistance; the Fire Department HAZMAT team will provide support for spill cleanup, and lab personnel must be prepared to report as much information as possible relating to the spill.
- Complete the following to ensure your safety while awaiting emergency responders:
    - Leave the immediate area
    - Close the door

- If it is safe to do so, stay close by and control access
- Post the entrance with a warning such as "Spill—Do Not Enter"
- Inform your supervisor and the Safety Office of all spills and clean-up actions.

- Personnel who have had skin, eye or inhalation exposure to hazardous materials during a spill situation shall be directed to report to the local medical facility for evaluation.
- Reporting of a spill via 911, or initiation of local emergency-response procedures, is required even if lab personnel are able to clean up the spill.

6.2 Personal Injury from Exposure to Chemicals

Lab personnel are required to know the hazards and controls of chemicals in their work areas. This includes emergency first-aid procedures for inhalation, skin/eye contact, ingestion, and injection. Safety Data Sheets should be consulted for this information.

In general, adhere to the following procedures for accidental exposures, beginning with self-protective measures: If you are assisting with an exposure incident/decontamination, wear lab coat, chemical goggles, and gloves to prevent a secondary contamination exposure.

The following are the routes of exposure:

- **Inhalation**. If the material or its reaction/combustion products are inhaled and if it is safe to do so, remove the person from the area and seek medical attention. For serious exposures, call 911 (or initiate your local emergency-response procedures). Lay the individual down and keep him or her warm and calm until medical care can be provided.
- **Skin or eye contact**. Remove all potentially contaminated clothing. Flush the affected area for at least 15 minutes (There are exceptions for phenol and hydrofluoric acid, which should be spelled out in the lab's SOP/JHA.) Call 911, or initiate local emergency-response procedures, if the injury is serious or life threatening.
- **Ingestion**. Call 911 or initiate local emergency-response procedures. If spontaneous vomiting appears imminent or occurs, help the person keep a clear airway. If victims are unconscious or cannot sit up, turn them on their

side to help avoid possible aspiration of vomit. Never give liquid to a person showing signs of sleepiness or who may become unconscious.

- **Injection**. This can occur from lacerations and punctures when handling sharps that are contaminated with chemicals. First, stop the bleeding. Minor cuts and scrapes usually stop bleeding on their own. If they do not, apply gentle pressure with a clean cloth or bandage. Rinse out the wound with clear water; soap can irritate the wound. Call 911 or initiate local emergency-response procedures if the injury is serious or life-threatening.

It is important for personnel to identify the chemical involved in order to provide treatment. Provide the SDSs or the chemical name to emergency responders and health-care professionals.

6.3 Emergency Equipment

6.3.1 Eyewashes and Safety Showers

Plumbed eyewash fountains and safety showers must be provided in areas where there are corrosives, eye irritants, or chemicals that are toxic via skin and/or eye contact.

At least one plumbed emergency eyewash/safety shower should be installed in any new or remodeled location meeting any of the following conditions:

- Defined as a laboratory area—excluding those areas that conduct computer or other studies not requiring chemicals or biological or radiological materials.
- Having a specialized fume hood.
- An area used for the charging of wet-acid storage batteries.

If an area meets the criteria for having this safety equipment, these points must be considered:

- For all unplumbed systems it is the responsibility of the researcher to adhere to the manufacturer's recommendations for maintenance and expiration date.
- Refer to ANSI's Standard Z358.1-2014 (latest version)[10] for guidance regarding the selection, installation, and use of eyewash fountains and safety showers, and/or contact the Safety Office for guidance.
- All eyewash and safety-shower purchases and installation locations, both plumbed and unplumbed, must be approved by the Safety Office.

- Inspection of eye washes and safety showers shall be in accordance with the most recent ANSI standard and be conducted at least weekly.
- Equipment shall be accessible at all times and remain free from obstructions; personnel shall not store equipment, apparatus, or containers in front of an eyewash or safety shower.
- Access to eye washes and safety showers must be within 10 seconds' walking distance from the source of the hazard.
- In the event of skin or eye contact, flush the affected area for at least 15 minutes and immediately seek medical attention unless otherwise instructed via an SOP/JHA.

6.3.2 Fire Extinguishers

Only personnel trained to do so shall use a fire extinguisher to fight an incipient (early)-stage fire unless necessary for safe exit. Additional considerations:

- If confronted with a fire situation and you are not trained to use an extinguisher, evacuate the area, closing the door behind you, pull the building alarm, and contact 911 (or initiate local emergency-response procedures) when you get to a safe-exit location.
- All areas must have access to a functional fire extinguisher, typically the Class-ABC combination extinguisher unless otherwise specified by the Fire Department or Safety Office.
- All laboratories using combustible metals shall have a Class-D fire extinguisher.
- After a fire extinguisher has been deployed, please contact the Safety office for a replacement.
- The Fire Department may provide fire-extinguisher training; contact your Safety Office for more information.
- Fire extinguishers must be inspected each month by the building custodian.

6.3.3 First Aid

For all injuries or illnesses that require emergency care, dial 911 (or initiate your local emergency-response procedures) from any landline and report the nature and extent of the emergency. Emergency operators will provide instructions and coordinate the needed assistance from fire and medical emergency-response personnel.

All injuries that involve potential exposure to bodily fluids must adhere to universal precautions. Any necessary cleanup must be carried out by a trained response personnel, and it must be reported to the Safety office.

There are several considerations with regard to first aid:

- You may administer first aid only if you have completed approved first-aid training.
- In general, the placement of first-aid kits in work areas is discouraged. Exceptions can be made where work areas are geographically distant from a medical-treatment facility or where extremely hazardous exposures may occur and require immediate treatment for exposure.
- Local medical personnel approve first-aid kits placed in work areas, their contents, intended use, and maintenance procedures.
- All first-aid treatment rendered is reported to occupational health personnel.
- Personnel with job duties that may include potential exposure to a blood-borne pathogen or other potentially infectious substances must be trained on ARL's *Bloodborne Pathogen Exposure Control Plan*,[11] and offered Hepatitis B vaccination.
- First-aid kits must be inspected and documented by designated/authorized (possibly building manager) person looking specifically for missing items and expired or soon-to-be expired materials.

7. Training and Hazard Information

7.1 Training for Lab Employees

Supervisors and lab POCs are responsible for ensuring all employees receive required training. Training for employees working in laboratories regarding hazardous chemicals is an ongoing process and completed in several ways:

- **ARL New Employee training,** including HAZCOM awareness and chemical hygiene, is mandatory for new employees who work with or around chemicals and provides an overview of ARL's hazard-communication program.
- **Operation/procedure/site-specific training** is to be provided individually or in small groups by the supervisor, lab POC, or equipment subject-matter expert. The training reviews the hazards of an employee's assigned work, uses and limitations of controls, warning signs of exposure to hazardous

materials used in the operations (odors, irritation, etc.), and emergency procedures. Laboratory SOPs and JHAs (via DD Form 2977) are great training tools; additionally, these document must be reviewed annually by employees, when new operations occur, and when changes are made to SOPs. SDSs or other references on chemicals may be used as part of the training.

- **Risk Management training** must be completed by all incoming lab personnel. It outlines the DOD mechanism for hazard analysis, using DD Form 2977, to facilitate risk reduction through application of controls by training, procedures, cautions, and warnings to help reduce accident probability.

Supervisors and lab POC's are responsible for ensuring all employees are trained in the hazards associated with new materials and processes in the work area and how to control the hazardous. Safety Office employees are responsible for assisting with guidance and training upon request.

7.2 Medical Surveillance

Medical consultations and examinations for civilians and military are provided by the local Army medical clinic. This includes examinations specified in occupational-health surveillance programs required by the Army or OSHA. (Local Army clinics do not provide medical surveillance for contracted employees working in ARL laboratories; it is provided by the contractor.) The Army medical professionals obtain occupational-health histories from patients and/or review chemical-exposure data from industrial-hygiene surveys and determine the need for ongoing medical surveillance.

The medical-surveillance programs in which ARL laboratory workers are most commonly enrolled pertain to respiratory protection.

In addition, medical consultation and/or medical examinations shall be provided to employees under the following circumstances:

- When the employee develops signs or symptoms associated with occupational exposure to a hazardous chemical.
- When exposure monitoring reveals exposure levels routinely above the OSHA action level or the PEL or the Army airborne-exposure limit for a regulated substance for which there are exposure-monitoring and medical-surveillance requirements. (Medical surveillance shall be conducted as prescribed by the particular OSHA or Army standard.)

- When an abnormal event such as a spill, leak, or other incident takes place in the laboratory and the potential for employee exposure exists.
- When an employee is sent to the local Army clinic for a medical consultation for one of the aforementioned reasons, ARL management or the employee will identity the hazardous chemical(s) to which the employee may have been exposed; describe the conditions under which the exposure occurred including quantitative exposure data, if available; and describe of the signs and symptoms of exposure that the employee is experiencing, if any.
- It shall be requested that the examining physician provide a written opinion for examinations or consultations related to occupational exposures, which shall include the following:
    - Recommendations for further medical follow-up;
    - Results of the medical examination and testing;
    - Any medical condition that may place the employee at increased risk as a result of exposure to a hazardous chemical found in the workplace; and
    - A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.

8. Recordkeeping

Records documenting the training provided by the ARL Safety Office are kept for at least three years in the SO and are available for review upon request. POCs/supervisors are responsible for documenting and maintaining training records for laboratory-specific safety training. These records must be kept for three years, as well.

Any reports and results from air sampling or any measurements taken by an industrial hygienist monitoring employee exposures must be provided to the local medical authority. These records will be kept in the employee's medical record by the local medical authority in accordance with CFR 1910.1020.

9. References

1. Occupational Safety and Health Administration. Occupational exposure to hazardous chemicals in laboratories. Washington (DC): Department of Labor (US); 1990. Code of Federal Regulations (CFR) 1910.1450.

2. Occupational Safety and Health Administration. Hazardous communication. Washington (DC): Department of Labor (US); Revised 2012. Code of Federal Regulations (CFR) 1910.1200.

3. Headquarters, Department of the Army. Preventive medicine. Washington (DC): HQ, DA (US); 2007 May. Army Regulation 40–5.

4. Headquarters, Department of the Army. The Army driver and operator standardization program (selection, training, testing, and licensing). Washington (DC): HQ, DA (US); 2019 Sep. Army Regulation 600–55.

5 National Research Council of the National Academies. Prudent practices in the laboratory: handling and management of chemical hazards. Washington (DC): National Academies Press; updated 2011.

6. Furr AK. CRC handbook of laboratory safety. 5th ed. Boca Raton (FL): CRC Press; 2000.

7. Headquarters, Department of the Army. Safety standards for microbiological and biomedical laboratories. Washington (DC): HQ, DA (US); 2013 Feb. Pamphlet No.: 385–69.

8. Occupational Safety and Health Administration. Respiratory protection. Washington (DC): Department of Labor (US); Revised 2012. Code of Federal Regulations (CFR) 1910.134.

9. American National Standards Institute. American national standard for emergency eyewash and shower equipment. Washington (DC): ANSI; 2014. Standard No.: ANSI Z358.1.

10. American National Standards Institute. American national standard for emergency eyewash and shower equipment. Washington (DC): ANSI; 2014. Standard No.: ANSI Z358.1-2014.

11. US Army Research Laboratory. Bloodborne pathogen exposure control plan (ECP). Adelphi (MD): Army Research, Development and Engineering Command (US); 2012 Aug 27. ARL Pamphlet No.: 385-503.

Appendix A. Definitions

Action Level: The concentration designated in 29 CFR 1910 for a specific substance calculated as an eight-hour time-weighted average. The action level initiates certain required activities such as exposure monitoring and medical surveillance.

Carcinogen: Any substance that meets one of the following criteria:

It is regulated by the US Occupational Safety and Health Administration (OSHA) as a carcinogen; or

- It is listed under the category "known to be carcinogens" in the latest edition of the Annual Report on Carcinogens published by the National Toxicology Program (NTP)at http://ntp.niehs.nih.gov; or
- It is listed under Group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer (IARC) monographs (latest editions) at http://monographs.iarc.fr/ENG/Classification/index.php; or
- It is listed in either Group 2A or 2B by IARC at http://monographs.iarc.fr/ENG/Classification/index.php or under the category "reasonably anticipated to be carcinogens" by NTP at http://ehp.niehs.nih.gov/, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria:
    - After inhalation exposure of 6–7 h per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m^3;
    - After repeated skin application of less than 300 mg/kg of body weight) per week; or
    - After oral dosages of less than 50 mg/kg of body weight per day.

Chemical *Health* Hazard: OSHA defines a hazardous chemical as a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes.

Chemical *Physical* Hazard: A chemical is a physical hazard if it possesses flammable, combustible, explosive, oxidizing, pyrophoric or reactive properties, or if it is an organic peroxide or compressed gas. The following list is not all-inclusive

and many products used in the workplace are mixtures of different chemicals. Mixtures are also considered hazardous chemicals because they may present the same or worse health hazards as each component. The list:

- OSHA, 29 CFR 1910.1000, Tables Z-l to Z-3
- *Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment*, American Conference of Governmental Industrial Hygienists (ACGIH); latest edition is available in the Safety Office.

Chemical Hygiene Officer: An employee who is designated by the employer, and who is qualified by training and experience, to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan.

Chemical Hygiene Plan: A written program developed and implemented by the employer that sets forth procedures, equipment, personal protective equipment, and work practices that 1) are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace and 2) meets the requirements of this CHP in keeping exposures below the permissible exposure limits (PEL) set forth by OSHA.

Designated Area: Specific locations within a laboratory for work involving particularly hazardous substances. Their purpose is to ensure proper controls are in place and all activities involving these higher-hazard materials are confined within the designated area. There are other considerations:

- Designated areas can be a piece of equipment, such as a fume hood or a centrifuge, or they can be entire laboratories. However, it is best to limit the number and size of designated areas to the minimum needed because there are additional control procedures required.
- The work lead must establish and post designated areas. The Designated Area template must be used for this purpose (see Appendix E, this CHP).
- Employees working in designated areas must be informed of the hazards and controls of the materials used.

Emergency Response: A response to an incident requiring assistance from outside the immediate area by a hazmat team or entities such as the local Fire Department. Responses to releases of hazardous substances where there is no potential safety or health hazard (i.e., fire, explosion, chemical exposure, or environmental damage) are not considered to be emergency responses.

Employee: This includes civilians, contractors, and guests/visitors.

Global Harmonization System: GHS is an international system for standardizing the classification, labeling, and Safety Data Sheet information of chemicals.

Job Hazard Analysis: A JHA is a technique that focuses on job tasks as a way to identify hazards before they occur. It focuses on the relationships among the worker, the task, the tools, and the work environment. Ideally, after you identify uncontrolled hazards, you will take steps to mitigate them to an acceptable risk level. The DD Form 2977 is the DOD's mechanism for completing and recording the JHA. Refer to Appendix D for the DD Form 2977.

Laboratory: Any facility where the "laboratory use of hazardous chemicals" occurs; a workplace where relatively small quantities of hazardous chemicals are used on a nonproduction or exploratory basis.

Laboratory Manager: An individual who works in and oversees all operations in a laboratory.

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

Laboratory Use of Hazardous Chemicals: The handling or use of such chemicals in which all of the following conditions are met:

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

Occupational Safety and Health Administration: An agency of the US government under the Department of Labor with the responsibility of ensuring safety at work and a healthful work environment. OSHA's mission is to prevent work-related injuries, illnesses, and deaths.

Permissible Exposure Level: PELs are OSHA-driven regulatory limits on the amount or concentration of a substance in the air. They may also contain a skin designation. OSHA PELs are based on an 8-h time weighted average (TWA) exposure.

Reproductive Toxin: A chemical that affects reproductive capabilities including chromosomal damage (mutations) and has effects on fetuses (teratogenesis).

Safety Data Sheet: An SDS is an informational document that provides data regarding the properties of a particular material or chemical. It is provided by the manufacturer with each chemical purchase. Information found on the sheets include physical characteristics, toxicity, health effects, first aid, reactivity, storage requirements and compatibility, disposal considerations, recommended personal protective equipment (PPE), and emergency-response procedures.

Standard Operating Procedure: A set of step-by-step instructions written by the researcher in conjunction with the Safety Office to help workers carry out routine operations. An SOP's goal is efficiency, quality output, and uniformity of performance, while reducing miscommunication and failure to comply with industry regulations. The SOP will also highlight the proper employment of controls, engineering and administrative, as well as PPE to minimize the aggregate risks of the activities.

Threshold Limit Value: The TLV is similar to the PEL; however, the American Conference of Governmental Industrial Hygienists establishes these airborne concentration levels. The TLVs can be more stringent than the PELs but they do not hold the weight of the Law.

Appendix B. Partial List of Carcinogens and Reproductive Toxins[*]

[*] Office of Environmental Health Hazard Assessment. Safe drinking water and toxic enforcement act of 1986. State of California: Environmental Protection Agency; updated 2020 Jan.

Table B-1 List of carcinogens and reproductive toxins

Chemical	Type of Toxicity	CAS No.*	Date Listed
A-alpha-C (2-Amino-9H-pyrido[2,3-b]indole)	cancer	26148-68-5	1-Jan-90
Abiraterone acetate	developmental, female, male	154229-18-2	8-Apr-16
Acetaldehyde	cancer	75-07-0	1-Apr-88
Acetamide	cancer	60-35-5	1-Jan-90
Acetazolamide	developmental	59-66-5	20-Aug-99
Acetochlor	cancer	34256-82-1	1-Jan-89
Acetohydroxamic acid	developmental	546-88-3	1-Apr-90
2-Acetylaminofluorene	cancer	53-96-3	1-Jul-87
Acifluorfen sodium	cancer	62476-59-9	1-Jan-90
Acrylamide	cancer	79-06-1	1-Jan-90
Acrylamide	developmental, male	79-06-1	25-Feb-11
Acrylonitrile	cancer	107-13-1	1-Jul-87
Actinomycin D (basis for listing changed effective 22 Feb 2013)	cancer	50-76-0	1-Oct-89
Actinomycin D	developmental	50-76-0	1-Oct-92
AF-2;[2-(2-furyl)-3-(5-nitro-2-furyl)]acrylamide	cancer	3688-53-7	1-Jul-87
Aflatoxins	cancer	. . .	1-Jan-88
Alachlor	cancer	15972-60-8	1-Jan-89
Alcoholic beverages	cancer	. . .	29-Apr-11
Alcoholic beverages, when associated with alcohol abuse	cancer	. . .	1-Jul-88
Aldrin	cancer	309-00-2	1-Jul-88
All-trans retinoic acid	developmental	302-79-4	1-Jan-89
Aloe Vera, non-decolorized whole leaf extract	cancer	. . .	4-Dec-15
Alprazolam	developmental	28981-97-7	1-Jul-90
Altretamine	developmental, male	645-05-6	20-Aug-99
Amantadine hydrochloride	developmental	665-66-7	27-Feb-01
Amikacin sulfate	developmental	39831-55-5	1-Jul-90
2-Aminoanthraquinone	cancer	117-79-3	1-Oct-89
p-Aminoazobenzene	cancer	60-09-3	1-Jan-90

* CAS = Chemical Abstracts Service

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
o-Aminoazotoluene	cancer	97-56-3	1-Jul-87
4-Aminobiphenyl (4-aminodiphenyl)	cancer	92-67-1	27-Feb-87
1-Amino-2,4-dibromoanthraquinone	cancer	81-49-2	26-Aug-97
3-Amino-9-ethylcarbazole hydrochloride	cancer	6109-97-3	1-Jul-89
2-Aminofluorene	cancer	153-78-6	29-Jan-99
Aminoglutethimide	developmental	125-84-8	1-Jul-90
Aminoglycosides	developmental	. . .	1-Oct-92
1-Amino-2-methylanthraquinone	cancer	82-28-0	1-Oct-89
2-Amino-5-(5-nitro-2-furyl)-1,3,4-thiadiazole	cancer	712-68-5	1-Jul-87
4-Amino-2-nitrophenol	cancer	119-34-6	29-Jan-99
Aminopterin	developmental, female	54-62-6	1-Jul-87
Amiodarone hydrochloride	developmental, female, male	19774-82-4	26-Aug-97
Amitraz	developmental	33089-61-1	30-Mar-99
Amitrole	cancer	61-82-5	1-Jul-87
Amoxapine	developmental	14028-44-5	15-May-98
Amsacrine	cancer	51264-14-3	7-Aug-09
Anabolic steroids	female, male	. . .	1-Apr-90
Analgesic mixtures containing Phenacetin	cancer	. . .	27-Feb-87
Androstenedione	cancer	63-05-8	3-May-11
Angiotensin converting enzyme (ACE) inhibitors	developmental	. . .	1-Oct-92
Aniline	cancer	62-53-3	1-Jan-90
Aniline hydrochloride	cancer	142-04-1	15-May-98
o-Anisidine	cancer	90-04-0	1-Jul-87
o-Anisidine hydrochloride	cancer	134-29-2	1-Jul-87
Anisindione	developmental	117-37-3	1-Oct-92
Anthraquinone	cancer	84-65-1	28-Sep-07
Antimony oxide (Antimony trioxide)	cancer	1309-64-4	1-Oct-90
Aramite	cancer	140-57-8	1-Jul-87

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Areca nut	cancer	. . .	3-Feb-06
Aristolochic acids	cancer	. . .	9-Jul-04
Arsenic (inorganic arsenic compounds)	cancer	. . .	27-Feb-87
Arsenic (inorganic oxides)	developmental	. . .	1-May-97
Asbestos	cancer	1332-21-4	27-Feb-87
Aspirin (Note: It is especially important not to use aspirin during the last 3 months of pregnancy, unless specifically directed to do so by a physician because it may cause problems in the unborn child or complications during delivery.)	developmental, female	50-78-2	1-Jul-90
Atenolol	developmental	29122-68-7	26-Aug-97
Atrazine	developmental, female	1912-24-9	15-Jul-16
Auramine	cancer	492-80-8	1-Jul-87
Auranofin	developmental	34031-32-8	29-Jan-99
Avermectin B1 (Abamectin)	developmental	71751-41-2	3-Dec-10
Azacitidine	cancer	320-67-2	1-Jan-92
Azaserine	cancer	115-02-6	1-Jul-87
Azathioprine	cancer	446-86-6	27-Feb-87
Azathioprine	developmental	446-86-6	1-Sep-96
Azobenzene	cancer	103-33-3	1-Jan-90
Barbiturates	developmental	. . .	1-Oct-92
Beclomethasone dipropionate	developmental	5534-09-8	15-May-98
Benomyl	developmental, male	17804-35-2	1-Jul-91
Benthiavalicarb-isopropyl	cancer	177406-68-7	1-Jul-08
Benz[a]anthracene	cancer	56-55-3	1-Jul-87
Benzene	cancer	71-43-2	27-Feb-87
Benzene	developmental, male	71-43-2	26-Dec-97
Benzidine [and its salts]	cancer	92-87-5	27-Feb-87
Benzidine-based dyes	cancer	. . .	1-Oct-92
Benzodiazepines	developmental	. . .	1-Oct-92
Benzo[b]fluoranthene	cancer	205-99-2	1-Jul-87
Benzo[j]fluoranthene	cancer	205-82-3	1-Jul-87
Benzo[k]fluoranthene	cancer	207-08-9	1-Jul-87

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Benzofuran	cancer	271-89-6	1-Oct-90
Benzophenone	cancer	119-61-9	22-Jun-12
Benzo[a]pyrene	cancer	50-32-8	1-Jul-87
Benzotrichloride	cancer	98-07-7	1-Jul-87
Benzphetamine hydrochloride	developmental	5411-22-3	1-Apr-90
Benzyl chloride	cancer	100-44-7	1-Jan-90
Benzyl violet 4B	cancer	1694-09-3	1-Jul-87
Beryllium and beryllium compounds	cancer	. . .	1-Oct-87
Beryllium	. . .	. . .	. . .
Beryllium oxide	. . .	. . .	. . .
Beryllium sulfate	. . .	. . .	. . .
Betel quid with tobacco	cancer	. . .	1-Jan-90
Betel quid without tobacco	cancer	. . .	3-Feb-06
Bevacizumab	developmental, female	216974-75-3	8-Mar-19
2,2-Bis(bromomethyl)-1,3-propanediol	cancer	3296-90-0	1-May-96
Bis(2-chloroethyl)ether	cancer	111-44-4	1-Apr-88
N,N-Bis(2-chloroethyl)-2-naphthylamine (Chlornapazine)	cancer	494-03-1	27-Feb-87
Bischloroethyl nitrosourea (BCNU) (Carmustine)	cancer	154-93-8	1-Jul-87
Bischloroethyl nitrosourea (BCNU) (Carmustine)	developmental	154-93-8	1-Jul-90
Bis(chloromethyl)ether	cancer	542-88-1	27-Feb-87
Bis(2-chloro-1-methylethyl)ether, technical grade	cancer	. . .	29-Oct-99
Bisphenol A (BPA)	female	80-05-7	11-May-15
Bitumens, extracts of steam-refined and air refined	cancer	. . .	1-Jan-90
Bracken fern	cancer	. . .	1-Jan-90
Bromacil lithium salt	developmental	53404-19-6	18-May-99
Bromacil lithium salt	male	53404-19-6	17-Jan-03
Bromate	cancer	15541-45-4	31-May-02
Bromochloroacetic acid	cancer	5589-96-8	6-Apr-10
Bromodichloroacetic acid	cancer	71133-14-7	29-Jul-16

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Bromodichloromethane	cancer	75-27-4	1-Jan-90
Bromoethane	cancer	74-96-4	22-Dec-00
Bromoform	cancer	75-25-2	1-Apr-91
1-Bromopropane (1-BP)	cancer	106-94-5	5-Aug-16
1-Bromopropane (1-BP)	developmental, female, male	106-94-5	7-Dec-04
2-Bromopropane (2-BP)	female, male	75-26-3	31-May-05
Bromoxynil	developmental	1689-84-5	1-Oct-90
Bromoxynil octanoate	developmental	1689-99-2	18-May-99
Butabarbital sodium	developmental	143-81-7	1-Oct-92
1,3-Butadiene	cancer	106-99-0	1-Apr-88
1,3-Butadiene	developmental, female, male	106-99-0	16-Apr-04
1,4-Butanediol dimethanesulfonate (Busulfan)	cancer	55-98-1	27-Feb-87
1,4-Butanediol dimethanesulfonate (Busulfan)	developmental	55-98-1	1-Jan-89
Butylated hydroxyanisole	cancer	25013-16-5	1-Jan-90
Butyl benzyl phthalate (BBP)	developmental	85-68-7	2-Dec-05
beta-Butyrolactone	cancer	3068-88-0	1-Jul-87
Cacodylic acid	cancer	75-60-5	1-May-96
Cadmium	developmental, male	. . .	1-May-97
Cadmium and cadmium compounds	cancer	. . .	1-Oct-87
Cadmium	. . .	. . .	. . .
Caffeic acid	cancer	331-39-5	1-Oct-94
Captafol	cancer	2425-06-1	1-Oct-88
Captan	cancer	133-06-2	1-Jan-90
Carbamazepine	developmental	298-46-4	29-Jan-99
Carbaryl	cancer	63-25-2	5-Feb-10
Carbaryl	developmental, female, male	63-25-2	7-Aug-09
Carbazole	cancer	86-74-8	1-May-96
Carbon black (airborne, unbound particles of respirable size)	cancer	1333-86-4	21-Feb-03
Carbon-black extracts	cancer	. . .	1-Jan-90

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Carbon disulfide	developmental, female, male	75-15-0	1-Jul-89
Carbon monoxide	developmental	630-08-0	1-Jul-89
Carbon tetrachloride	cancer	56-23-5	1-Oct-87
Carboplatin	developmental	41575-94-4	1-Jul-90
N-Carboxymethyl-N-nitrosourea	cancer	60391-92-6	25-Jan-02
Catechol	cancer	120-80-9	15-Jul-03
Ceramic fibers (airborne particles of respirable size)	cancer	. . .	1-Jul-90
Certain combined chemotherapy for lymphomas	cancer	. . .	27-Feb-87
Chenodiol	developmental	474-25-9	1-Apr-90
Chloral	cancer	75-87-6	13-Sep-13
Chloral hydrate	cancer	302-17-0	13-Sep-13
Chlorambucil	cancer	305-03-3	27-Feb-87
Chlorambucil	developmental	305-03-3	1-Jan-89
Chloramphenicol sodium succinate	cancer	982-57-0	27-Sep-13
Chlorcyclizine hydrochloride	developmental	1620-21-9	1-Jul-87
Chlordane	cancer	57-74-9	1-Jul-88
Chlordecone (Kepone)	cancer	143-50-0	1-Jan-88
Chlordecone (Kepone)	developmental	143-50-0	1-Jan-89
Chlordiazepoxide	developmental	58-25-3	1-Jan-92
Chlordiazepoxide hydrochloride	developmental	438-41-5	1-Jan-92
Chlordimeform	cancer	6164-98-3	1-Jan-89
Chlorendic acid	cancer	115-28-6	1-Jul-89
Chlorinated paraffins (average chain length, C12; approximately 60% chlorine by weight)	cancer	108171-26-2	1-Jul-89
p-Chloroaniline	cancer	106-47-8	1-Oct-94
p-Chloroaniline hydrochloride	cancer	20265-96-7	15-May-98
Chloroethane (Ethyl chloride)	cancer	75-00-3	1-Jul-90
1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU) (Lomustine)	cancer	13010-47-4	1-Jan-88
1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU) (Lomustine)	developmental	13010-47-4	1-Jul-90

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea (Methyl-CCNU)	cancer	13909-09-6	1-Oct-88
Chloroform	cancer	67-66-3	1-Oct-87
Chloroform	developmental	67-66-3	7-Aug-09
Chloromethyl methyl ether (technical grade)	cancer	107-30-2	27-Feb-87
3-Chloro-2-methylpropene	cancer	563-47-3	1-Jul-89
1-Chloro-4-nitrobenzene	cancer	100-00-5	29-Oct-99
4-Chloro-*o*-phenylenediamine	cancer	95-83-0	1-Jan-88
Chloroprene	cancer	126-99-8	2-Jun-00
2-Chloropropionic acid	male	598-78-7	7-Aug-09
Chlorothalonil	cancer	1897-45-6	1-Jan-89
p-Chloro-*o*-toluidine	cancer	95-69-2	1-Jan-90
p-Chloro-*o*-toluidine, strong acid salts of	cancer	. . .	15-May-98
p-Chloro-*o*-toluidine, hydrochloride	. . .	. . .	. . .
5-Chloro-*o*-toluidine and its strong acid salts	cancer	. . .	24-Oct-97
Chlorotrianisene	cancer	569-57-3	1-Sep-96
Chlorozotocin	cancer	54749-90-5	1-Jan-92
Chlorpyrifos	developmental	2921-88-2	15-Dec-17
Chromium (hexavalent compounds)	cancer	. . .	27-Feb-87
Chromium (hexavalent compounds)	developmental, female, male	. . .	19-Dec-08
Chrysene	cancer	218-01-9	1-Jan-90
C.I. Acid Red 114	cancer	6459-94-5	1-Jul-92
C.I. Basic Red 9 monohydrochloride	cancer	569-61-9	1-Jul-89
C.I. Direct Blue 15	cancer	2429-74-5	26-Aug-97
C.I. Direct Blue 218	cancer	28407-37-6	26-Aug-97
C.I. Disperse Yellow 3	cancer	2832-40-8	8-Feb-13
C.I. Solvent Yellow 14	cancer	842-07-9	15-May-98
Ciclosporin (Cyclosporin A; Cyclosporine)	cancer	59865-13-3; 79217-60-0	1-Jan-92

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Cidofovir	cancer, developmental, female, male	113852-37-2	29-Jan-99
Cinnamyl anthranilate	cancer	87-29-6	1-Jul-89
Cisplatin	cancer	15663-27-1	1-Oct-88
Citrus Red No. 2	cancer	6358-53-8	1-Oct-89
Cladribine	developmental	4291-63-8	1-Sep-96
Clarithromycin	developmental	81103-11-9	1-May-97
Clobetasol propionate	developmental, female	25122-46-7	15-May-98
Clofibrate	cancer	637-07-0	1-Sep-96
Clomiphene citrate	cancer	50-41-9	24-May-13
Clomiphene citrate	developmental	50-41-9	1-Apr-90
Clorazepate dipotassium	developmental	57109-90-7	1-Oct-92
CMNP (pyrazachlor)	cancer	6814-58-0	25-Aug-15
Cobalt metal powder	cancer	7440-48-4	1-Jul-92
Cobalt [II] oxide	cancer	1307-96-6	1-Jul-92
Cobalt sulfate	cancer	10124-43-3	20-May-05
Cobalt sulfate heptahydrate	cancer	10026-24-1	2-Jun-00
Cocaine	developmental, female	50-36-2	1-Jul-89
Coconut oil diethanolamine condensate (cocamide diethanolamine)	cancer	. . .	22-Jun-12
Codeine phosphate	developmental	52-28-8	15-May-98
Coke oven emissions	cancer	. . .	27-Feb-87
Colchicine	developmental, male	64-86-8	1-Oct-92
Conjugated estrogens	cancer	. . .	27-Feb-87
Conjugated estrogens	developmental	. . .	1-Apr-90
Creosotes	cancer	. . .	1-Oct-88
p-Cresidine	cancer	120-71-8	1-Jan-88
Cumene	cancer	98-82-8	6-Apr-10
Cupferron	cancer	135-20-6	1-Jan-88
Cyanazine	developmental	21725-46-2	1-Apr-90
Cycasin	cancer	14901-08-7	1-Jan-88
Cycloate	developmental	1134-23-2	19-Mar-99
Cycloheximide	developmental	66-81-9	1-Jan-89
Cyclopenta[cd]pyrene	cancer	27208-37-3	29-Apr-11

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Cyclophosphamide (anhydrous)	cancer	50-18-0	27-Feb-87
Cyclophosphamide (anhydrous)	developmental, female, male	50-18-0	1-Jan-89
Cyclophosphamide (hydrated)	cancer	6055-19-2	27-Feb-87
Cyclophosphamide (hydrated)	developmental, female, male	6055-19-2	1-Jan-89
Cyhexatin	developmental	13121-70-5	1-Jan-89
Cytarabine	developmental	147-94-4	1-Jan-89
Cytembena	cancer	21739-91-3	15-May-98
D&C Orange No. 17	cancer	3468-63-1	1-Jul-90
D&C Red No. 8	cancer	2092-56-0	1-Oct-90
D&C Red No. 9	cancer	5160-02-1	1-Jul-90
D&C Red No. 19	cancer	81-88-9	1-Jul-90
Dacarbazine	cancer	4342-03-4	1-Jan-88
Dacarbazine	developmental	4342-03-4	29-Jan-99
Daminozide	cancer	1596-84-5	1-Jan-90
Danazol	developmental	17230-88-5	1-Apr-90
Dantron (Chrysazin; 1,8-Dihydroxyanthraquinone)	cancer	117-10-2	1-Jan-92
Daunomycin	cancer	20830-81-3	1-Jan-88
Daunorubicin hydrochloride	developmental	23541-50-6	1-Jul-90
2,4-D butyric acid	male	94-82-6	18-Jun-99
DDD (Dichlorodiphenyl-dichloroethane)	cancer	72-54-8	1-Jan-89
DDE (Dichlorodiphenyl-dichloroethylene)	cancer	72-55-9	1-Jan-89
DDT (Dichlorodiphenyl-trichloroethane)	cancer	50-29-3	1-Oct-87
o,p'-DDT	developmental, female, male	789-02-6	15-May-98
p,p'-DDT	developmental, female, male	50-29-3	15-May-98
DDVP (Dichlorvos)	cancer	62-73-7	1-Jan-89
Demeclocycline hydrochloride (internal use)	developmental	64-73-3	1-Jan-92
Des-ethyl atrazine (DEA)	developmental, female	6190-65-4	15-Jul-16
Des-isopropyl atrazine (DIA)	developmental, female	1007-28-9	15-Jul-16

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
N,N'-Diacetylbenzidine	cancer	613-35-4	1-Oct-89
2,4-Diaminoanisole	cancer	615-05-4	1-Oct-90
2,4-Diaminoanisole sulfate	cancer	39156-41-7	1-Jan-88
2,4-Diamino-6-chloro-*s*-triazine (DACT)	developmental, female	3397-62-4	15-Jul-16
4,4'-Diaminodiphenyl ether (4,4'-Oxydianiline)	cancer	101-80-4	1-Jan-88
2,4-Diaminotoluene	cancer	95-80-7	1-Jan-88
Diazepam	developmental	439-14-5	1-Jan-92
Diazoaminobenzene	cancer	136-35-6	20-May-05
Diazoxide	developmental	364-98-7	27-Feb-01
Dibenz[a,h]acridine	cancer	226-36-8	1-Jan-88
Dibenz[a,j]acridine	cancer	224-42-0	1-Jan-88
Dibenzanthracenes	cancer	. . .	26-Dec-14
Dibenz[a,c]anthracene	cancer	215-58-7	26-Dec-14
Dibenz[a,h]anthracene	cancer	53-70-3	1-Jan-88
Dibenz[a,j]anthracene	cancer	224-41-9	26-Dec-14
7H-Dibenzo[c,g]carbazole	cancer	194-59-2	1-Jan-88
Dibenzo[a,e]pyrene	cancer	192-65-4	1-Jan-88
Dibenzo[a,h]pyrene	cancer	189-64-0	1-Jan-88
Dibenzo[a,i]pyrene	cancer	189-55-9	1-Jan-88
Dibenzo[a,l]pyrene	cancer	191-30-0	1-Jan-88
Dibromoacetic acid	cancer	631-64-1	17-Jun-08
Dibromoacetonitrile	cancer	3252-43-5	3-May-11
1,2-Dibromo-3-chloropropane (DBCP)	cancer	96-12-8	1-Jul-87
1,2-Dibromo-3-chloropropane (DBCP)	male	96-12-8	27-Feb-87
2,3-Dibromo-1-propanol	cancer	96-13-9	1-Oct-94
Dichloroacetic acid	cancer	79-43-6	1-May-96
Dichloroacetic acid	developmental, male	79-43-6	7-Aug-09
p-Dichlorobenzene	cancer	106-46-7	1-Jan-89
3,3'-Dichlorobenzidine	cancer	91-94-1	1-Oct-87
3,3'-Dichlorobenzidine dihydrochloride	cancer	612-83-9	15-May-98

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
1,1-Dichloro-2,2-bis(*p*-chloropheny)ethylene (DDE)	developmental, male	72-55-9	30-Mar-10
1,4-Dichloro-2-butene	cancer	764-41-0	1-Jan-90
3,3'-Dichloro-4,4'-diamino-diphenyl ether	cancer	28434-86-8	1-Jan-88
1,1-Dichloroethane	cancer	75-34-3	1-Jan-90
Dichloromethane (Methylene chloride)	cancer	75-09-2	1-Apr-88
Dichlorophene	developmental	97-23-4	27-Apr-99
Dichlorphenamide	developmental	120-97-8	27-Feb-01
1,2-Dichloropropane	cancer	78-87-5	1-Jan-90
1,3-Dichloro-2-propanol (1,3-DCP)	cancer	96-23-1	8-Oct-10
1,3-Dichloropropene	cancer	542-75-6	1-Jan-89
Diclofop-methyl	cancer	51338-27-3	6-Apr-10
Diclofop methyl	developmental	51338-27-3	5-Mar-99
Dicumarol	developmental	66-76-2	1-Oct-92
Dieldrin	cancer	60-57-1	1-Jul-88
Diepoxybutane	cancer	1464-53-5	1-Jan-88
Diesel engine exhaust	cancer	. . .	1-Oct-90
Diethanolamine	cancer	111-42-2	22-Jun-12
Di(2-ethylhexyl)phthalate (DEHP)	cancer	117-81-7	1-Jan-88
Di(2-ethylhexyl)phthalate (DEHP)	developmental, male	117-81-7	24-Oct-03
1,2-Diethylhydrazine	cancer	1615-80-1	1-Jan-88
Diethylstilbestrol (DES)	cancer	56-53-1	27-Feb-87
Diethylstilbestrol (DES)	developmental	56-53-1	1-Jul-87
Diethyl sulfate	cancer	64-67-5	1-Jan-88
Diflunisal	developmental, female	22494-42-4	29-Jan-99
Diglycidyl resorcinol ether (DGRE)	cancer	101-90-6	1-Jul-89
Dihydroergotamine mesylate	developmental	6190-39-2	1-May-97
Dihydrosafrole	cancer	94-58-6	1-Jan-88
Di-isodecyl phthalate (DIDP)	developmental	68515-49-1/ 26761-40-0	20-Apr-07
Diisononyl phthalate (DINP)	cancer	. . .	20-Dec-13
Diisopropyl sulfate	cancer	2973-10-6	1-Apr-93
Diltiazem hydrochloride	developmental	33286-22-5	27-Feb-01

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
3,3'-Dimethoxybenzidine (*o*-Dianisidine)	cancer	119-90-4	1-Jan-88
3,3'-Dimethoxybenzidine dihydrochloride	cancer	20325-40-0	1-Oct-90
3,3'-Dimethoxybenzidine-based dyes metabolized to 3,3'-dimethoxybenzidine	cancer	. . .	11-Jun-04
N,N-Dimethylacetamide	developmental, male	127-19-5	21-May-10
4-Dimethylaminoazobenzene	cancer	60-11-7	1-Jan-88
trans-2-[(Dimethylamino)methylimino]-5-[2-(5-nitro-2-furyl)vinyl]-1,3,4-oxadiazole	cancer	55738-54-0	1-Jan-88
7,12-Dimethylbenz(a)anthracene	cancer	57-97-6	1-Jan-90
3,3'-Dimethylbenzidine (ortho-Tolidine)	cancer	119-93-7	1-Jan-88
3,3'-Dimethylbenzidine-based dyes metabolized to 3,3'-dimethylbenzidine	cancer	. . .	11-Jun-04
3,3'-Dimethylbenzidine dihydrochloride	cancer	612-82-8	1-Apr-92
Dimethylcarbamoyl chloride	cancer	79-44-7	1-Jan-88
N,N-Dimethylformamide	cancer	68-12-2	27-Oct-17
1,1-Dimethylhydrazine (UDMH)	cancer	57-14-7	1-Oct-89
1,2-Dimethylhydrazine	cancer	540-73-8	1-Jan-88
2,6-Dimethyl-N-nitrosomorpholine (DMNM)	cancer	1456-28-6	8-Feb-13
Dimethyl sulfate	cancer	77-78-1	1-Jan-88
N,*N*-Dimethyl-*p*-toluidine	cancer	99-97-8	2-May-14
Dimethylvinylchloride	cancer	513-37-1	1-Jul-89
Di-*n*-butyl phthalate (DBP)	developmental, female, male	84-74-2	2-Dec-05
Di-*n*-hexyl phthalate (DnHP)	female, male	84-75-3	2-Dec-05
m-Dinitrobenzene	male	99-65-0	1-Jul-90
o-Dinitrobenzene	male	528-29-0	1-Jul-90
p-Dinitrobenzene	male	100-25-4	1-Jul-90
3,7-Dinitrofluoranthene	cancer	105735-71-5	26-Aug-97
3,9-Dinitrofluoranthene	cancer	22506-53-2	26-Aug-97

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
1,3-Dinitropyrene	cancer	75321-20-9	2-Nov-12
1,6-Dinitropyrene	cancer	42397-64-8	1-Oct-90
1,8-Dinitropyrene	cancer	42397-65-9	1-Oct-90
2,4-Dinitrotoluene	cancer	121-14-2	1-Jul-88
2,4-Dinitrotoluene	male	121-14-2	20-Aug-99
2,6-Dinitrotoluene	cancer	606-20-2	1-Jul-95
2,6-Dinitrotoluene	male	606-20-2	20-Aug-99
Dinitrotoluene (technical grade)	female, male	. . .	20-Aug-99
Dinitrotoluene mixture, 2,4-/2,6-	cancer	. . .	1-May-96
Dinocap	developmental	39300-45-3	1-Apr-90
Dinoseb	developmental, male	88-85-7	1-Jan-89
Di-*n*-propyl isocinchomeronate (MGK Repellent 326)	cancer	136-45-8	1-May-96
1,4-Dioxane	cancer	123-91-1	1-Jan-88
Diphenylhydantoin (Phenytoin)	cancer	57-41-0	1-Jan-88
Diphenylhydantoin (Phenytoin)	developmental	57-41-0	1-Jul-87
Diphenylhydantoin (Phenytoin), sodium salt	cancer	630-93-3	1-Jan-88
Direct Black 38 (technical grade)	cancer	1937-37-7	1-Jan-88
Direct Blue 6 (technical grade)	cancer	2602-46-2	1-Jan-88
Direct Brown 95 (technical grade)	cancer	16071-86-6	1-Oct-88
Disodium cyanodithioimidocarbonate	developmental	138-93-2	30-Mar-99
Disperse Blue 1	cancer	2475-45-8	1-Oct-90
Diuron	cancer	330-54-1	31-May-02
Doxorubicin hydrochloride (Adriamycin)	cancer	25316-40-9	1-Jul-87
Doxorubicin hydrochloride (Adriamycin)	developmental, male	25316-40-9	29-Jan-99
Doxycycline (internal use)	developmental	564-25-0	1-Jul-90
Doxycycline calcium (internal use)	developmental	94088-85-4	1-Jan-92
Doxycycline hyclate (internal use)	developmental	24390-14-5	1-Oct-91
Doxycycline monohydrate (internal use)	developmental	17086-28-1	1-Oct-91
Emissions from combustion of coal	cancer	. . .	7-Aug-13

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Emissions from high-temperature unrefined rapeseed oil	cancer	. . .	3-Jan-14
Endrin	developmental	72-20-8	15-May-98
Environmental tobacco smoke (ETS)	developmental	. . .	9-Jun-06
Epichlorohydrin	cancer	106-89-8	1-Oct-87
Epichlorohydrin	male	106-89-8	1-Sep-96
Epoxiconazole	cancer	135319-73-2	15-Apr-11
Ergotamine tartrate	developmental	379-79-3	1-Apr-90
Erionite	cancer	12510-42-8; 66733-21-9	1-Oct-88
Estradiol 17B	cancer	50-28-2	1-Jan-88
Estragole	cancer	140-67-0	29-Oct-99
Estrogens, steroidal	cancer	. . .	19-Aug-05
Estrogen-progestogen (combined) used as menopausal therapy	cancer	. . .	4-Nov-11
Estrone	cancer	53-16-7	1-Jan-88
Estropipate	cancer, developmental	7280-37-7	26-Aug-97
Ethinylestradiol	cancer	57-63-6	1-Jan-88
Ethionamide	developmental	536-33-4	26-Aug-97
Ethoprop	cancer	13194-48-4	27-Feb-01
Ethyl acrylate	cancer	140-88-5	1-Jul-89
Ethyl alcohol in alcoholic beverages	developmental	. . .	1-Oct-87
Ethylbenzene	cancer	100-41-4	11-Jun-04
Ethyl dipropylthiocarbamate	developmental	759-94-4	27-Apr-99
Ethyl-4,4'-dichlorobenzilate	cancer	510-15-6	1-Jan-90
Ethylene dibromide	cancer	106-93-4	1-Jul-87
Ethylene dibromide	developmental, male	106-93-4	15-May-98
Ethylene dichloride (1,2-Dichloroethane)	cancer	107-06-2	1-Oct-87
Ethylene glycol (ingested)	developmental	107-21-1	19-Jun-15
Ethylene glycol monoethyl ether	developmental, male	110-80-5	1-Jan-89
Ethylene glycol monoethyl ether acetate	developmental, male	111-15-9	1-Jan-93

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Ethylene glycol monomethyl ether	developmental, male	109-86-4	1-Jan-89
Ethylene glycol monomethyl ether acetate	developmental, male	110-49-6	1-Jan-93
Ethyleneimine (Aziridine)	cancer	151-56-4	1-Jan-88
Ethylene oxide	cancer	75-21-8	1-Jul-87
Ethylene oxide	female	75-21-8	27-Feb-87
Ethylene oxide	developmental, male	75-21-8	7-Aug-09
Ethylene thiourea	cancer	96-45-7	1-Jan-88
Ethylene thiourea	developmental	96-45-7	1-Jan-93
Ethyl methanesulfonate	cancer	62-50-0	1-Jan-88
Etodolac	developmental, female	41340-25-4	20-Aug-99
Etoposide	cancer	33419-42-0	4-Nov-11
Etoposide	developmental	33419-42-0	1-Jul-90
Etoposide in combination with cisplatin and bleomycin	cancer	. . .	4-Nov-11
Etretinate	developmental	54350-48-0	1-Jul-87
Fenoxaprop ethyl	developmental	66441-23-4	26-Mar-99
Fenoxycarb	cancer	72490-01-8	2-Jun-00
Filgrastim	developmental	121181-53-1	27-Feb-01
Fluazifop butyl	developmental	69806-50-4	6-Nov-98
Flunisolide	developmental, female	3385-03-3	15-May-98
Fluorouracil	developmental	51-21-8	1-Jan-89
Fluoxymesterone	developmental	76-43-7	1-Apr-90
Flurazepam hydrochloride	developmental	1172-18-5	1-Oct-92
Flurbiprofen	developmental, female	5104-49-4	20-Aug-99
Flutamide	developmental	13311-84-7	1-Jul-90
Fluticasone propionate	developmental	80474-14-2	15-May-98
Fluvalinate	developmental	69409-94-5	6-Nov-98
Folpet	cancer	133-07-3	1-Jan-89
Formaldehyde (gas)	cancer	50-00-0	1-Jan-88
2-(2-Formylhydrazino)-4-(5-nitro-2-furyl)thiazole	cancer	3570-75-0	1-Jan-88
Fumonisin B_1	cancer	116355-83-0	14-Nov-03
Furan	cancer	110-00-9	1-Oct-93

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Furazolidone	cancer	67-45-8	1-Jan-90
Furfuryl alcohol	cancer	98-00-0	30-Sep-16
Furmecyclox	cancer	60568-05-0	1-Jan-90
Fusarin C	cancer	79748-81-5	1-Jul-95
Gallium arsenide	cancer	1303-00-0	1-Aug-08
Ganciclovir	cancer, developmental, male	82410-32-0	26-Aug-97
Ganciclovir sodium	developmental, male	107910-75-8	26-Aug-97
Gasoline engine exhaust (condensates/extracts)	cancer	. . .	1-Oct-90
Gemfibrozil	cancer	25812-30-0	22-Dec-00
Gemfibrozil	female, male	25812-30-0	20-Aug-99
Gentian violet (Crystal violet)	cancer	548-62-9	23-Nov-18
Glass wool fibers (inhalable and biopersistent)	cancer	. . .	1-Jul-90
Glu-P-1 (2-Amino-6-methyldipyrido[1,2- a:3',2'-d]imidazole)	cancer	67730-11-4	1-Jan-90
Glu-P-2 (2-Aminodipyrido[1,2-a:3',2'-d]imidazole)	cancer	67730-10-3	1-Jan-90
Glycidaldehyde	cancer	765-34-4	1-Jan-88
Glycidol	cancer	556-52-5	1-Jul-90
Glyphosate	cancer	1071-83-6	7-Jul-17
Goldenseal root powder	cancer	. . .	4-Dec-15
Goserelin acetate	developmental, female, male	65807-02-5	26-Aug-97
Griseofulvin	cancer	126-07-8	1-Jan-90
Gyromitrin (Acetaldehyde methylformylhydrazone)	cancer	16568-02-8	1-Jan-88
Halazepam	developmental	23092-17-3	1-Jul-90
Halobetasol propionate	developmental	66852-54-8	20-Aug-99
Haloperidol	developmental, female	52-86-8	29-Jan-99
Halothane	developmental	151-67-7	1-Sep-96
HC Blue 1	cancer	2784-94-3	1-Jul-89
Heptachlor	cancer	76-44-8	1-Jul-88
Heptachlor	developmental	76-44-8	20-Aug-99

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Heptachlor epoxide	cancer	1024-57-3	1-Jul-88
Herbal remedies containing plant species of the genus *Aristolochia*	cancer	. . .	9-Jul-04
Hexachlorobenzene	cancer	118-74-1	1-Oct-87
Hexachlorobenzene	developmental	118-74-1	1-Jan-89
Hexachlorobutadiene	cancer	87-68-3	3-May-11
Hexachlorocyclohexane (technical grade)	cancer	. . .	1-Oct-87
Hexachlorocyclohexane (alpha isomer)	. . .	. . .	. . .
Hexachlorocyclohexane (beta isomer)	. . .	. . .	. . .
Hexachlorocyclohexane (gamma isomer)	. . .	. . .	. . .
Hexachlorodibenzodioxin	cancer	34465-46- 8	1-Apr-88
Hexachloroethane	cancer	67-72-1	1-Jul-90
2,4-Hexadienal (89% trans, trans isomer; 11% cis, trans isomer)	cancer	. . .	4-Mar-05
Hexafluoroacetone	developmental, male	684-16-2	1-Aug-08
Hexamethylphosphoramide	cancer	680-31-9	1-Jan-88
Hexamethylphosphoramide	male	680-31-9	1-Oct-94
n-Hexane	male	110-54-3	15-Dec-17
2,5-Hexanedione	male	110-13-4	4-Dec-15
Histrelin acetate	developmental	. . .	15-May-98
Hydramethylnon	developmental, male	67485-29-4	5-Mar-99
Hydrazine	cancer	302-01-2	1-Jan-88
Hydrazine sulfate	cancer	10034-93-2	1-Jan-88
Hydrazobenzene (1,2-Diphenylhydrazine)	cancer	122-66-7	1-Jan-88
Hydrogen cyanide (HCN) and cyanide salts (CN salts)	male	. . .	5-Jul-13
1-Hydroxyanthraquinone	cancer	129-43-1	27-May-05
Hydroxyurea	developmental	127-07-1	1-May-97
Idarubicin hydrochloride	developmental, male	57852-57-0	20-Aug-99
Ifosfamide	developmental	3778-73-2	1-Jul-90
Iodine-131	developmental	10043-66-0	1-Jan-89
Imazalil	cancer	35554-44-0	20-May-11

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Indeno[1,2,3-cd]pyrene	cancer	193-39-5	1-Jan-88
Indium phosphide	cancer	22398-80-7	27-Feb-01
IQ (2-Amino-3-methylimidazo[4,5-f] quinoline)	cancer	76180-96-6	1-Apr-90
Iprodione	cancer	36734-19-7	1-May-96
Iprovalicarb	cancer	140923-17-7/ 140923-25-7	1-Jun-07
Iron dextran complex	cancer	9004-66-4	1-Jan-88
Isobutyl nitrite	cancer	542-56-3	1-May-96
Isoprene	cancer	78-79-5	1-May-96
Isopyrazam	cancer	881685-58-1	24-Jul-12
Isotretinoin	developmental	4759-48-2	1-Jul-87
Isoxaflutole	cancer	141112-29-0	22-Dec-00
Kresoxim-methyl	cancer	143390-89-0	3-Feb-12
Lactofen	cancer	77501-63-4	1-Jan-89
Lasiocarpine	cancer	303-34-4	1-Apr-88
Lead	developmental, female, male	. . .	27-Feb-87
Lead and lead compounds	cancer	. . .	1-Oct-92
Lead	. . .	. . .	. . .
Lead acetate	cancer	301-04-2	1-Jan-88
Lead phosphate	cancer	7446-27-7	1-Apr-88
Lead subacetate	cancer	1335-32-6	1-Oct-89
Leather dust	cancer	. . .	29-Apr-11
Leuprolide acetate	developmental, female, male	74381-53-6	26-Aug-97
Levodopa	developmental	59-92-7	29-Jan-99
Levonorgestrel implants	female	797-63-7	15-May-98
Lindane and other hexachlorocyclohexane isomers	cancer	. . .	1-Oct-89
Linuron	developmental	330-55-2	19-Mar-99
Lithium carbonate	developmental	554-13-2	1-Jan-91
Lithium citrate	developmental	919-16-4	1-Jan-91
Lorazepam	developmental	846-49-1	1-Jul-90
Lovastatin	developmental	75330-75-5	1-Oct-92

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Lynestrenol	cancer	52-76-6	27-Feb-01
Malathion	cancer	121-75-5	20-May-16
Malonaldehyde, sodium salt	cancer	24382-04-5	3-May-11
Mancozeb	cancer	8018-01-7	1-Jan-90
Maneb	cancer	12427-38-2	1-Jan-90
Marijuana smoke	cancer	. . .	19-Jun-09
Me-A-alpha-C (2-Amino-3-methyl-9H-pyrido[2,3-b]indole)	cancer	68006-83-7	1-Jan-90
Mebendazole	developmental	31431-39-7	20-Aug-99
Medroxyprogesterone acetate	cancer	71-58-9	1-Jan-90
Medroxyprogesterone acetate	developmental	71-58-9	1-Apr-90
Megestrol acetate	cancer	595-33-5	28-Mar-14
Megestrol acetate	developmental	595-33-5	1-Jan-91
MeIQ (2-Amino-3,4-dimethylimidazo[4,5-f]quinoline)	cancer	77094-11-2	1-Oct-94
MeIQx (2-Amino-3,8-dimethylimidazo[4,5-f]quinoxaline)	cancer	77500-04-0	1-Oct-94
Melphalan	cancer	148-82-3	27-Feb-87
Melphalan	developmental	148-82-3	1-Jul-90
Menotropins	developmental	9002-68-0	1-Apr-90
Mepanipyrim	cancer	110235-47-7	1-Jul-08
Meprobamate	developmental	57-53-4	1-Jan-92
2-Mercaptobenzothiazole	cancer	149-30-4	27-Oct-17
Mercaptopurine	developmental	6112-76-1	1-Jul-90
Mercury and mercury compounds	developmental	. . .	1-Jul-90
Merphalan	cancer	531-76-0	1-Apr-88
Mestranol	cancer	72-33-3	1-Apr-88
Metam potassium	cancer	137-41-7	31-Dec-10
Methacycline hydrochloride	developmental	3963-95-9	1-Jan-91
Metham sodium	cancer	137-42-8	6-Nov-98
Metham sodium	developmental	137-42-8	15-May-98
Methanol	developmental	67-56-1	16-Mar-12
Methazole	developmental	20354-26-1	1-Dec-99
Methimazole	developmental	60-56-0	1-Jul-90
Methotrexate	developmental	59-05-2	1-Jan-89

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Methotrexate sodium	developmental	15475-56-6	1-Apr-90
5-Methoxypsoralen with ultraviolet A therapy	cancer	484-20-8	1-Oct-88
8-Methoxypsoralen with ultraviolet A therapy	cancer	298-81-7	27-Feb-87
2-Methylaziridine (Propyleneimine)	cancer	75-55-8	1-Jan-88
Methylazoxymethanol	cancer	590-96-5	1-Apr-88
Methylazoxymethanol acetate	cancer	592-62-1	1-Apr-88
Methyl bromide, as a structural fumigant	developmental	74-83-9	1-Jan-93
Methyl carbamate	cancer	598-55-0	15-May-98
Methyl chloride	developmental	74-87-3	10-Mar-00
Methyl chloride	male	74-87-3	7-Aug-09
3-Methylcholanthrene	cancer	56-49-5	1-Jan-90
5-Methylchrysene	cancer	3697-24-3	1-Apr-88
4,4'-Methylene bis(2-chloroaniline)	cancer	101-14-4	1-Jul-87
4,4'-Methylene bis(N,N-dimethyl)benzenamine	cancer	101-61-1	1-Oct-89
4,4'-Methylene bis(2-methylaniline)	cancer	838-88-0	1-Apr-88
4,4'-Methylenedianiline	cancer	101-77-9	1-Jan-88
4,4'-Methylenedianiline dihydrochloride	cancer	13552-44-8	1-Jan-88
Methyleugenol	cancer	93-15-2	16-Nov-01
Methylhydrazine and its salts	cancer	. . .	1-Jul-92
Methylhydrazine	. . .	. . .	. . .
Methylhydrazine sulfate	. . .	. . .	. . .
2-Methylimidazole	cancer	693-98-1	22-Jun-12
4-Methylimidazole	cancer	822-36-6	7-Jan-11
Methyl iodide	cancer	74-88-4	1-Apr-88
Methyl isobutyl ketone	cancer	108-10-1	4-Nov-11
Methyl isobutyl ketone (MIBK)	developmental	108-10-1	28-Mar-14
Methyl isocyanate (MIC)	developmental, female	624-83-9	12-Nov-10
Methyl mercury	developmental	. . .	1-Jul-87
Methylmercury compounds	cancer	. . .	1-May-96

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Methyl methanesulfonate	cancer	66-27-3	1-Apr-88
Methyl-n-butyl ketone	developmental	591-78-6	4-Dec-15
Methyl-n-butyl ketone	male	591-78-6	7-Aug-09
2-Methyl-1-nitroanthraquinone (of uncertain purity)	cancer	129-15-7	1-Apr-88
N-Methyl-N'-nitro-N-nitrosoguanidine	cancer	70-25-7	1-Apr-88
N-Methylolacrylamide	cancer	924-42-5	1-Jul-90
N-Methylpyrrolidone	developmental	872-50-4	15-Jun-01
α-Methyl styrene (alpha-Methylstyrene)	cancer	98-83-9	2-Nov-12
Methyltestosterone	developmental	58-18-4	1-Apr-90
Methylthiouracil	cancer	56-04-2	1-Oct-89
Metiram	cancer	9006-42-2	1-Jan-90
Metiram	developmental	9006-42-2	30-Mar-99
Metronidazole	cancer	443-48-1	1-Jan-88
Michler's ketone	cancer	90-94-8	1-Jan-88
Midazolam hydrochloride	developmental	59467-96-8	1-Jul-90
Minocycline hydrochloride (internal use)	developmental	13614-98-7	1-Jan-92
Mirex	cancer	2385-85-5	1-Jan-88
Misoprostol	developmental	59122-46-2	1-Apr-90
Mitomycin C	cancer	50-07-7	1-Apr-88
Mitoxantrone hydrochloride	cancer	70476-82-3	23-Jan-15
Mitoxantrone hydrochloride	developmental	70476-82-3	1-Jul-90
Molinate	developmental, female, male	2212-67-1	11-Dec-09
MON 4660 (dichloroacetyl-1-oxa-4-azaspiro(4,5)-decane	cancer	71526-07-3	22-Mar-11
MON 13900 (furilazole)	cancer	121776-33-8	22-Mar-11
3-Monochloropropane-1,2-diol (3-MCPD)	cancer	96-24-2	8-Oct-10
Monocrotaline	cancer	315-22-0	1-Apr-88
MOPP (vincristine-prednisone-nitrogen mustard-procarbazine mixture)	cancer	113803-47-7	4-Nov-11

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
5-(Morpholinomethyl)-3-[(5-nitrofurfuryl-idene)-amino]-2-oxazolidinone	cancer	139-91-3	1-Apr-88
Mustard Gas	cancer	505-60-2	27-Feb-87
MX (3-chloro-4-dichloromethyl-5-hydroxy-2(5H)-furanone)	cancer	77439-76-0	22-Dec-00
Myclobutanil	developmental, male	88671-89-0	16-Apr-99
beta-Myrcene	cancer	123-35-3	27-Mar-15
Nabam	developmental	142-59-6	30-Mar-99
Nafarelin acetate	developmental	86220-42-0	1-Apr-90
Nafenopin	cancer	3771-19-5	1-Apr-88
Nalidixic acid	cancer	389-08-2	15-May-98
Naphthalene	cancer	91-20-3	19-Apr-02
1-Naphthylamine	cancer	134-32-7	1-Oct-89
2-Naphthylamine	cancer	91-59-8	27-Feb-87
Neomycin sulfate (internal use)	developmental	1405-10-3	1-Oct-92
Netilmicin sulfate	developmental	56391-57-2	1-Jul-90
Nickel (Metallic)	cancer	7440-02-0	1-Oct-89
Nickel acetate	cancer	373-02-4	1-Oct-89
Nickel carbonate	cancer	3333-67-3	1-Oct-89
Nickel carbonyl	cancer	13463-39-3	1-Oct-87
Nickel carbonyl	developmental	13463-39-3	1-Sep-96
Nickel compounds	cancer	. . .	7-May-04
Nickel (soluble compounds)	developmental, male	. . .	26-Oct-18
Nickel hydroxide	cancer	12054-48-7; 12125-56-3	1-Oct-89
Nickelocene	cancer	1271-28-9	1-Oct-89
Nickel oxide	cancer	1313-99-1	1-Oct-89
Nickel refinery dust from the pyrometallurgical process	cancer	. . .	1-Oct-87
Nickel subsulfide	cancer	12035-72-2	1-Oct-87
Nicotine	developmental	54-11-5	1-Apr-90
Nifedipine	developmental, female, male	21829-25-4	29-Jan-99
Nimodipine	developmental	66085-59-4	24-Apr-01
Niridazole	cancer	61-57-4	1-Apr-88

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Nitrapyrin	cancer	1929-82-4	5-Oct-05
Nitrapyrin	developmental	1929-82-4	30-Mar-99
Nitrilotriacetic acid	cancer	139-13-9	1-Jan-88
Nitrilotriacetic acid, trisodium salt monohydrate	cancer	18662-53-8	1-Apr-89
5-Nitroacenaphthene	cancer	602-87-9	1-Apr-88
o-Nitroanisole	cancer	91-23-6	1-Oct-92
Nitrobenzene	cancer	98-95-3	26-Aug-97
Nitrobenzene	male	98-95-3	30-Mar-10
4-Nitrobiphenyl	cancer	92-93-3	1-Apr-88
6-Nitrochrysene	cancer	7496-02-8	1-Oct-90
Nitrofen (technical grade)	cancer	1836-75-5	1-Jan-88
2-Nitrofluorene	cancer	607-57-8	1-Oct-90
Nitrofurantoin	male	67-20-9	1-Apr-91
Nitrofurazone	cancer	59-87-0	1-Jan-90
1-[(5-Nitrofurfurylidene)-amino]-2-imidazolidinone	cancer	555-84-0	1-Apr-88
N-[4-(5-Nitro-2-furyl)-2-thiazolyl]acetamide	cancer	531-82-8	1-Apr-88
Nitrogen mustard (Mechlorethamine)	cancer	51-75-2	1-Jan-88
Nitrogen mustard (Mechlorethamine)	developmental	51-75-2	1-Jan-89
Nitrogen mustard hydrochloride (Mechlorethamine hydrochloride)	cancer	55-86-7	1-Apr-88
Nitrogen mustard hydrochloride (Mechlorethamine hydrochloride)	developmental	55-86-7	1-Jul-90
Nitrogen mustard N-oxide	cancer	126-85-2	1-Apr-88
Nitrogen mustard N-oxide hydrochloride	cancer	302-70-5	1-Apr-88
Nitromethane	cancer	75-52-5	1-May-97
2-Nitropropane	cancer	79-46-9	1-Jan-88
1-Nitropyrene	cancer	5522-43-0	1-Oct-90
4-Nitropyrene	cancer	57835-92-4	1-Oct-90
N-Nitrosodi-*n*-butylamine	cancer	924-16-3	1-Oct-87
N-Nitrosodiethanolamine	cancer	1116-54-7	1-Jan-88
N-Nitrosodiethylamine	cancer	55-18-5	1-Oct-87

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
N-Nitrosodimethylamine	cancer	62-75-9	1-Oct-87
p-Nitrosodiphenylamine	cancer	156-10-5	1-Jan-88
N-Nitrosodiphenylamine	cancer	86-30-6	1-Apr-88
N-Nitrosodi-*n*-propylamine	cancer	621-64-7	1-Jan-88
N-Nitroso-N-ethylurea	cancer	759-73-9	1-Oct-87
N-Nitrosohexamethyleneimine	cancer	932-83-2	23-Nov-18
3-(N-Nitrosomethylamino) propionitrile	cancer	60153-49-3	1-Apr-90
4-(N-Nitrosomethylamino)-1-(3-pyridyl)1-butanone	cancer	64091-91-4	1-Apr-90
N-Nitrosomethyl-n-butylamine	cancer	7068-83-9	26-Dec-14
N-Nitrosomethyl-n-decylamine	cancer	75881-22-0	26-Dec-14
N-Nitrosomethyl-n-dodecylamine	cancer	55090-44-3	26-Dec-14
N-Nitrosomethylethylamine	cancer	10595-95-6	1-Oct-89
N-Nitrosomethyl-n-heptylamine	cancer	16338-99-1	26-Dec-14
N-Nitrosomethyl-n-hexylamine	cancer	28538-70-7	26-Dec-14
N-Nitrosomethyl-n-nonylamine	cancer	75881-19-5	26-Dec-14
N-Nitrosomethyl-n-octylamine	cancer	34423-54-6	26-Dec-14
N-Nitrosomethyl-n-pentylamine	cancer	13256-07-0	26-Dec-14
N-Nitrosomethyl-n-propylamine	cancer	924-46-9	26-Dec-14
N-Nitrosomethyl-n-tetradecylamine	cancer	75881-20-8	26-Dec-14
N-Nitrosomethyl-n-undecylamine	cancer	68107-26-6	26-Dec-14
N-Nitroso-N-methylurea	cancer	684-93-5	1-Oct-87
N-Nitroso-N-methylurethane	cancer	615-53-2	1-Apr-88
N-Nitrosomethylvinylamine	cancer	4549-40-0	1-Jan-88
N-Nitrosomorpholine	cancer	59-89-2	1-Jan-88
N-Nitrosonornicotine	cancer	16543-55-8	1-Jan-88
N-Nitrosopiperidine	cancer	100-75-4	1-Jan-88
N-Nitrosopyrrolidine	cancer	930-55-2	1-Oct-87
N-Nitrososarcosine	cancer	13256-22-9	1-Jan-88
o-Nitrotoluene	cancer	88-72-2	15-May-98
Nitrous oxide	developmental, female	10024-97-2	1-Aug-08
Norethisterone (Norethindrone)	cancer	68-22-4	1-Oct-89
Norethisterone (Norethindrone)	developmental	68-22-4	1-Apr-90

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Norethisterone acetate (Norethindrone acetate)	developmental	51-98-9	1-Oct-91
Norethisterone (Norethindrone) /Ethinyl estradiol	developmental	68-22-4/57-63-6	1-Apr-90
Norethisterone (Norethindrone) /Mestranol	developmental	68-22-4/72-33-3	1-Apr-90
Norethynodrel	cancer	68-23-5	27-Feb-01
Norgestrel	developmental	6533-00-2	1-Apr-90
Ochratoxin A	cancer	303-47-9	1-Jul-90
Oil Orange SS	cancer	2646-17-5	1-Apr-88
Oral contraceptives, combined	cancer	. . .	1-Oct-89
Oral contraceptives, sequential	cancer	. . .	1-Oct-89
Oryzalin	cancer	19044-88-3	12-Sep-08
Oxadiazon	cancer	19666-30-9	1-Jul-91
Oxadiazon	developmental	19666-30-9	15-May-98
Oxazepam	cancer	604-75-1	1-Oct-94
Oxazepam	developmental	604-75-1	1-Oct-92
Oxydemeton methyl	female, male	301-12-2	6-Nov-98
Oxymetholone	cancer	434-07-1	1-Jan-88
Oxymetholone	developmental	434-07-1	1-May-97
Oxytetracycline (internal use)	developmental	79-57-2	1-Jan-91
Oxytetracycline hydrochloride (internal use)	developmental	2058-46-0	1-Oct-91
Oxythioquinox (Chinomethionat)	cancer	2439-01-2	20-Aug-99
Oxythioquinox (Chinomethionat)	developmental	2439-01-2	6-Nov-98
Paclitaxel	developmental, female, male	33069-62-4	26-Aug-97
Palygorskite fibers (> 5µm in length)	cancer	12174-11-7	28-Dec-99
Panfuran S	cancer	794-93-4	1-Jan-88
Paramethadione	developmental	115-67-3	1-Jul-90
Parathion	cancer	56-38-2	20-May-16
Penicillamine	developmental	52-67-5	1-Jan-91
pentabromodiphenyl ether mixture [DE-71 (technical grade)]	cancer	. . .	7-Jul-17
Pentachlorophenol	cancer	87-86-5	1-Jan-90

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Pentachlorophenol and by-products of its synthesis (complex mixture)	cancer	. . .	21-Oct-16
Pentobarbital sodium	developmental	57-33-0	1-Jul-90
Pentosan polysulfate sodium	cancer	. . .	18-Apr-14
Pentostatin	developmental	53910-25-1	1-Sep-96
Perfluorooctane sulfonate (PFOS)	developmental	1763-23-1	10-Nov-17
Perfluorooctanoic acid (PFOA)	developmental	335-67-1	10-Nov-17
Pertuzumab	developmental	380610-27-5	27-Jan-17
Phenacemide	developmental	63-98-9	1-Jul-90
Phenacetin	cancer	62-44-2	1-Oct-89
Phenazopyridine	cancer	94-78-0	1-Jan-88
Phenazopyridine hydrochloride	cancer	136-40-3	1-Jan-88
Phenesterin	cancer	3546-10-9	1-Jul-89
Phenobarbital	cancer	50-06-6	1-Jan-90
Phenolphthalein	cancer	77-09-8	15-May-98
Phenoxybenzamine	cancer	59-96-1	1-Apr-88
Phenoxybenzamine hydrochloride	cancer	63-92-3	1-Apr-88
Phenprocoumon	developmental	435-97-2	1-Oct-92
o-Phenylenediamine and its salts	cancer	95-54-5	15-May-98
o-Phenylenediamine	. . .	. . .	. . .
o-Phenylenediamine dihydochloride	. . .	. . .	. . .
Phenyl glycidyl ether	cancer	122-60-1	1-Oct-90
Phenylhydrazine and its salts	cancer	. . .	1-Jul-92
Phenylhydrazine	. . .	. . .	. . .
Phenylhydrazine hydrochloride	. . .	. . .	. . .
o-Phenylphenate, sodium	cancer	132-27-4	1-Jan-90
o-Phenylphenol	cancer	90-43-7	4-Aug-00
Phenylphosphine	male	638-21-1	7-Aug-09
PhiP(2-Amino-1-methyl-6-phenylimidazol[4,5-b]pyridine)	cancer	105650-23-5	1-Oct-94
Pimozide	developmental, female	2062-78-4	20-Aug-99
Pioglitazone	cancer	111025-46-8	18-Apr-14
Pipobroman	developmental	54-91-1	1-Jul-90
Pirimicarb	cancer	23103-98-2	1-Jul-08

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Plicamycin	developmental	18378-89-7	1-Apr-90
Polybrominated biphenyls	cancer	. . .	1-Jan-88
Polybrominated biphenyls	developmental	. . .	1-Oct-94
Polychlorinated biphenyls	cancer	. . .	1-Oct-89
Polychlorinated biphenyls	developmental	. . .	1-Jan-91
Polychlorinated biphenyls (containing 60 or more percent chlorine by molecular weight)	cancer	. . .	1-Jan-88
Polychlorinated dibenzo-*p*-dioxins	cancer	. . .	1-Oct-92
Polychlorinated dibenzofurans	cancer	. . .	1-Oct-92
Polygeenan	cancer	53973-98-1	1-Jan-88
Ponceau MX	cancer	3761-53-3	1-Apr-88
Ponceau 3R	cancer	3564-09-8	1-Apr-88
Potassium bromate	cancer	7758-01-2	1-Jan-90
Potassium dimethyldithiocarbamate	developmental	128-03-0	30-Mar-99
Pravastatin sodium	developmental	81131-70-6	3-Mar-00
Prednisolone sodium phosphate	developmental	125-02-0	20-Aug-99
Primidone	cancer	125-33-7	20-Aug-99
Procarbazine	cancer	671-16-9	1-Jan-88
Procarbazine hydrochloride	cancer	366-70-1	1-Jan-88
Procarbazine hydrochloride	developmental	366-70-1	1-Jul-90
Procymidone	cancer	32809-16-8	1-Oct-94
Progesterone	cancer	57-83-0	1-Jan-88
Pronamide	cancer	23950-58-5	1-May-96
Propachlor	cancer	1918-16-7	27-Feb-01
1,3-Propane sultone	cancer	1120-71-4	1-Jan-88
Propargite	cancer	2312-35-8	1-Oct-94
Propargite	developmental	2312-35-8	15-Jun-99
Propazine	developmental, female	139-40-2	15-Jul-16
beta-Propiolactone	cancer	57-57-8	1-Jan-88
Propoxur	cancer	114-26-1	11-Aug-06
Propylene glycol mono-*t*-butyl ether	cancer	57018-52-7	11-Jun-04
Propylene oxide	cancer	75-56-9	1-Oct-88
Propylthiouracil	cancer	51-52-5	1-Jan-88

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Propylthiouracil	developmental	51-52-5	1-Jul-90
Pulegone	cancer	89-82-7	18-Apr-14
Pymetrozine	cancer	123312-89-0	22-Mar-11
Pyridine	cancer	110-86-1	17-May-02
Pyrimethamine	developmental	58-14-0	29-Jan-99
Quazepam	developmental	36735-22-5	26-Aug-97
Quinoline and its strong acid salts	cancer	. . .	24-Oct-97
Quizalofop-ethyl	male	76578-14-8	24-Dec-99
Radionuclides	cancer	. . .	1-Jul-89
Reserpine	cancer	50-55-5	1-Oct-89
Residual (heavy) fuel oils	cancer	. . .	1-Oct-90
Resmethrin	cancer	10453-86-8	1-Jul-08
Resmethrin	developmental	10453-86-8	6-Nov-98
Retinol/retinyl esters, when in daily dosages in excess of 10,000 IU, or 3,000 retinol equivalents. (Note: Retinol/retinyl esters are required and essential for maintenance of normal reproductive function. The recommended daily level during pregnancy is 8,000 IU.)	developmental	. . .	1-Jul-89
Ribavirin	developmental	36791-04-5	1-Apr-90
Ribavirin	male	36791-04-5	27-Feb-01
Riddelliine	cancer	23246-96-0	3-Dec-04
Rifampin	developmental, female	13292-46-1	27-Feb-01
Safrole	cancer	94-59-7	1-Jan-88
Salted fish, Chinese-style	cancer	. . .	29-Apr-11
Secobarbital sodium	developmental	309-43-3	1-Oct-92
Sedaxane	cancer	874967-67-6	1-Jul-16
Selenium sulfide	cancer	7446-34-6	1-Oct-89
Sermorelin acetate	developmental	. . .	20-Aug-99
Shale-oils	cancer	68308-34-9	1-Apr-90
Silica, crystalline (airborne particles of respirable size)	cancer	. . .	1-Oct-88
Simazine	developmental, female	122-34-9	15-Jul-16
Sodium dimethyldithiocarbamate	developmental	128-04-1	30-Mar-99
Sodium fluoroacetate	male	62-74-8	6-Nov-98

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Soots, tars, and mineral oils (untreated and mildly treated oils and used engine oils)	cancer	. . .	27-Feb-87
Spirodiclofen	cancer	148477-71-8	8-Oct-10
Spironolactone	cancer	52-01-7	1-May-97
Stanozolol	cancer	10418-03-8	1-May-97
Sterigmatocystin	cancer	10048-13-2	1-Apr-88
Streptomycin sulfate	developmental	3810-74-0	1-Jan-91
Streptozocin (streptozotocin)	developmental, female, male	18883-66-4	20-Aug-99
Streptozotocin (streptozocin)	cancer	18883-66-4	1-Jan-88
Strong inorganic acid mists containing sulfuric acid	cancer	. . .	14-Mar-03
Styrene	cancer	100-42-5	22-Apr-16
Styrene oxide	cancer	96-09-3	1-Oct-88
Sulfallate	cancer	95-06-7	1-Jan-88
Sulfasalazine (Salicylazosulfapyridine)	cancer	599-79-1	15-May-98
Sulfasalazine (Salicylazosulfapyridine)	male	599-79-1	29-Jan-99
Sulfur dioxide	developmental	7446-09-5	29-Jul-11
Sulindac	developmental, female	38194-50-2	29-Jan-99
Talc containing asbestiform fibers	cancer	. . .	1-Apr-90
Tamoxifen and its salts	cancer	10540-29-1	1-Sep-96
Tamoxifen citrate	developmental	54965-24-1	1-Jul-90
Temazepam	developmental	846-50-4	1-Apr-90
Teniposide	developmental	29767-20-2	1-Sep-96
Terbacil	developmental	5902-51-2	18-May-99
Teriparatide	cancer	52232-67-4	14-Aug-15
Terrazole	cancer	2593-15-9	1-Oct-94
Testosterone and its esters	cancer	58-22-0	1-Apr-88
Testosterone cypionate	developmental	58-20-8	1-Oct-91
Testosterone enanthate	developmental	315-37-7	1-Apr-90
Tetrabromobisphenol A	cancer	79-94-7	27-Oct-17
3,3',4,4'-Tetrachloroazobenzene	cancer	14047-09-7	24-Jul-12

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	cancer	1746-01-6	1-Jan-88
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	developmental	1746-01-6	1-Apr-91
1,1,1,2-Tetrachloroethane	cancer	630-20-6	13-Sep-13
1,1,2,2-Tetrachloroethane	cancer	79-34-5	1-Jul-90
Tetrachloroethylene (Perchloroethylene)	cancer	127-18-4	1-Apr-88
p-a,a,a-Tetrachlorotoluene	cancer	5216-25-1	1-Jan-90
Tetrachlorvinphos	cancer	22248-79-9	20-May-16
Tetracycline (internal use)	developmental	60-54-8	1-Oct-91
Tetracyclines (internal use)	developmental	. . .	1-Oct-92
Tetracycline hydrochloride (internal use)	developmental	64-75-5	1-Jan-91
Tetrafluoroethylene	cancer	116-14-3	1-May-97
Tetranitromethane	cancer	509-14-8	1-Jul-90
Thalidomide	developmental	50-35-1	1-Jul-87
Thioacetamide	cancer	62-55-5	1-Jan-88
4,4'-Thiodianiline	cancer	139-65-1	1-Apr-88
Thiodicarb	cancer	59669-26-0	20-Aug-99
Thioguanine	developmental	154-42-7	1-Jul-90
Thiophanate methyl	female, male	23564-05-8	18-May-99
Thiouracil	cancer	141-90-2	11-Jun-04
Thiourea	cancer	62-56-6	1-Jan-88
Thorium dioxide	cancer	1314-20-1	27-Feb-87
Titanium dioxide (airborne, unbound particles of respirable size)	cancer	. . .	2-Sep-11
Tobacco, oral use of smokeless products	cancer	. . .	1-Apr-88
Tobacco smoke	cancer	. . .	1-Apr-88
Tobacco smoke (primary)	developmental, female, male	. . .	1-Apr-88
Tobramycin sulfate	developmental	49842-07-1	1-Jul-90
Toluene	developmental	108-88-3	1-Jan-91
Toluene diisocyanate	cancer	26471-62-5	1-Oct-89
o-Toluidine	cancer	95-53-4	1-Jan-88

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
o-Toluidine hydrochloride	cancer	636-21-5	1-Jan-88
Topiramate	developmental	97240-79-4	27-Nov-15
Toxaphene (Polychlorinated camphenes)	cancer	8001-35-2	1-Jan-88
Toxins derived from *Fusarium moniliforme (Fusarium verticillioides)*	cancer	. . .	7-Aug-09
Treosulfan	cancer	299-75-2	27-Feb-87
Triadimefon	developmental, female, male	43121-43-3	30-Mar-99
Triamterene	cancer	396-01-0	18-Apr-14
Triazolam	developmental	28911-01-5	1-Apr-90
S,S,S-Tributyl phosphorotrithioate (Tribufos, DEF)	cancer	78-48-8	25-Feb-11
Tributyltin methacrylate	developmental	2155-70-6	1-Dec-99
Trichlormethine (Trimustine hydrochloride)	cancer	817-09-4	1-Jan-92
Trichloroacetic acid	cancer	76-03-9	13-Sep-13
Trichloroethylene	cancer	79-01-6	1-Apr-88
Trichloroethylene	developmental, male	79-01-6	31-Jan-14
2,4,6-Trichlorophenol	cancer	88-06-2	1-Jan-88
1,2,3-Trichloropropane	cancer	96-18-4	1-Oct-92
Trientine hydrochloride	developmental	38260-01-4	27-Feb-01
Triforine	developmental	26644-46-2	18-Jun-99
Trilostane	developmental	13647-35-3	1-Apr-90
Trimethadione	developmental	127-48-0	1-Jan-91
2,4,5-Trimethylaniline and its strong acid salts	cancer	. . .	24-Oct-97
Trimethyl phosphate	cancer	512-56-1	1-May-96
Trimetrexate glucuronate	developmental	82952-64-5	26-Aug-97
TRIM® VX	cancer	. . .	25-May-18
2,4,6-Trinitrotoluene (TNT)	cancer	118-96-7	19-Dec-08
Triphenyltin hydroxide	cancer	76-87-9	1-Jul-92
Triphenyltin hydroxide	developmental	76-87-9	18-Mar-02
Tris(1-aziridinyl)phosphine sulfide (Thiotepa)	cancer	52-24-4	1-Jan-88
Tris(2-chloroethyl) phosphate	cancer	115-96-8	1-Apr-92

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Tris(2,3-dibromopropyl)phosphate	cancer	126-72-7	1-Jan-88
Tris(1,3-dichloro-2-propyl) phosphate (TDCPP)	cancer	13674-87-8	28-Oct-11
Trp-P-1 (Tryptophan-P-1)	cancer	62450-06-0	1-Apr-88
Trp-P-2 (Tryptophan-P-2)	cancer	62450-07-1	1-Apr-88
Trypan blue (commercial grade)	cancer	72-57-1	1-Oct-89
Unleaded gasoline (wholly vaporized)	cancer	. . .	1-Apr-88
Uracil mustard	cancer	66-75-1	1-Apr-88
Uracil mustard	developmental, female, male	66-75-1	1-Jan-92
Urethane (Ethyl carbamate)	cancer	51-79-6	1-Jan-88
Urethane (Ethyl carbamate)	developmental	51-79-6	1-Oct-94
Urofollitropin	developmental	97048-13-0	1-Apr-90
Valproate (Valproic acid)	developmental	99-66-1	1-Jul-87
Vanadium pentoxide (orthorhombic crystalline form)	cancer	1314-62-1	11-Feb-05
Vinblastine sulfate	developmental	143-67-9	1-Jul-90
Vinclozolin [basis for listing changed on November 16, 2006]	cancer	50471-44-8	20-Aug-99
Vinclozolin	developmental	50471-44-8	15-May-98
Vincristine sulfate	developmental	2068-78-2	1-Jul-90
Vinyl bromide	cancer	593-60-2	1-Oct-88
Vinyl chloride	cancer	75-01-4	27-Feb-87
4-Vinylcyclohexene	cancer	100-40-3	1-May-96
4-Vinylcyclohexene	female	100-40--3	7-Aug-09
4-Vinyl-1-cyclohexene diepoxide (Vinyl cyclohexenedioxide)	cancer	106-87-6	1-Jul-90
Vinyl cyclohexene dioxide (4-Vinyl-1-cyclohexene diepoxide)	female	106-87-6	1-Aug-08
Vinyl fluoride	cancer	75-02-5	1-May-97
Vinylidene chloride (1,1-Dichloroethylene)	cancer	75-35-4	29-Dec-17
Vinyl trichloride (1,1,2-Trichloroethane)	cancer	79-00-5	1-Oct-90
Vismodegib	developmental, female, male	879085-55-9	27-Jan-17

Table B-1 List of carcinogens and reproductive toxins (continued)

Chemical	Type of Toxicity	CAS No.	Date Listed
Warfarin	developmental	81-81-2	1-Jul-87
Wood dust	cancer	. . .	18-Dec-09
2,6-Xylidine (2,6-Dimethylaniline)	cancer	87-62-7	1-Jan-91
Zalcitabine	cancer	7481-89-2	7-Aug-09
Zidovudine (AZT)	cancer	30516-87-1	18-Dec-09
Zileuton	cancer, developmental, female	111406-87-2	22-Dec-00

Appendix C. Cryogens

C.1 Liquid Helium

Liquid helium is the coldest of all the cryogens, with a boiling point of approximately 4 K (–268.9 °C or –452.1 °F). This incredibly low temperature is cold enough to solidify air (the nitrogen and oxygen, not just the water) into a kind of ice. Because of this, it is far more common to accumulate solid obstructions in the valves of pressurized liquid-helium cylinders than with nitrogen or argon. Users of liquid-helium cylinders must exercise extreme care to prevent ice obstructions, which can cause liquid helium vessels to over-pressurize rapidly.

At the Lawrence Berkley National Lab (LBNL), this exact situation occurred. A liquid helium cylinder was in use at the LBNL, and a user failed to close one of the valves when finished with their operation. Nothing seemed amiss until a few days later, when another user went to withdraw liquid from the cylinder. This particular cylinder required that a long metal tube, a "stinger", be inserted through the top of the cylinder all the way to the bottom of the cryogenic liquid reservoir in order to withdraw liquid. But the user found that the tube would not insert all the way; instead, it hit something hard well above the bottom of the reservoir. It turned out that air had entered the cylinder through the valve that was left open, had frozen solid on top of the liquid helium, and formed an impenetrable plug. Had the situation not been discovered and remedied, the cylinder may have exploded as the helium trapped below the plug slowly vaporized and built up pressure in the confined space.[*]

Unlike nitrogen and argon, which are denser as gases than air, helium as a gas is far less dense than air. With liquid nitrogen and liquid argon, the largest danger of asphyxiation is close to the ground, especially in recessed areas. However, with liquid helium the largest danger of asphyxiation is at ceiling level, where the helium gas will accumulate and displace oxygen most rapidly. Therefore, when working with cryogenic helium, users must be aware of what is above them. People on catwalks or ladders will be more quickly affected by a release of helium gas than someone on the ground.

Pressurized liquid-helium cylinders are rarely operated at high pressures like liquid nitrogen or liquid argon which come in cylinders with pressures up to 350 psig. Instead, most liquid helium cylinders are operated at less than 20 psig. Cryogenic-liquid cylinders used for helium sometimes have more complex insulation systems to minimize loss rates, which can be quite high for liquid helium. Cryogenic-liquid

[*] Lawrence Livermore National Laboratory. Safe handling of cryogenic liquids. Berkeley (CA): University of California. Chapter 29, ES&H Manual (PUB-3000). Revised 2017 Aug.

cylinders intended for use with liquid nitrogen or liquid argon are likely to be completely unsuitable for containing liquid helium.

Always check that the cryogenic liquid cylinder is clearly marked for use with helium before attempting to fill it with liquid helium. Follow all manufacturer's instructions for the cylinder carefully to prevent ice obstructions and over-pressurization of the cylinder. Valve sequencing may be far more complex, even for routine operations, and is incredibly important, as demonstrated by the incident at LBNL.

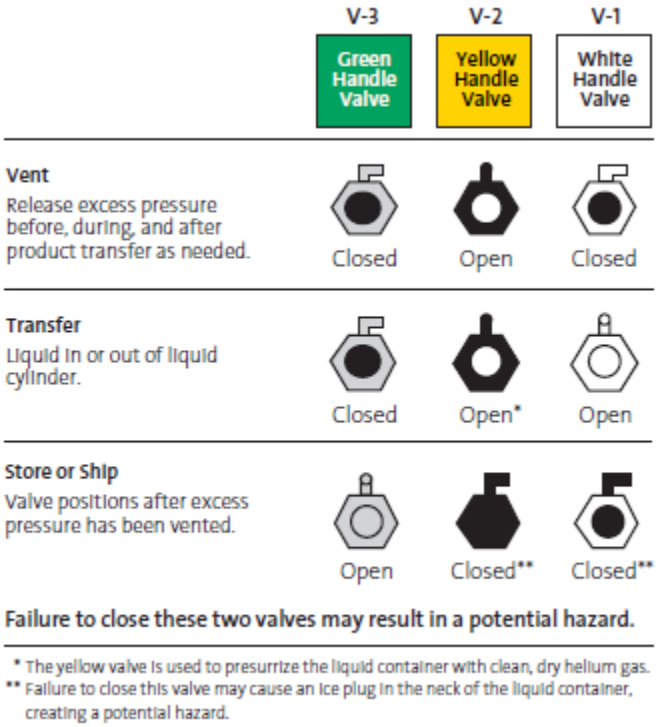

Fig. C-1 Example of a relatively simple valve sequence from Air Products

C.2 Liquid Hydrogen

In addition to being one of the coldest cryogenic liquids with a boiling point of 423.2 °F, hydrogen is an extremely flammable material. Hydrogen gas is explosive in air from concentrations as low as 4% by volume. Even if an asphyxiation hazard does not exist from boil-off of hydrogen gas, the atmosphere around the source may still be flammable and/or explosive. The initiation energy for this reaction is also incredibly low, meaning that even a small spark, a static electricity discharge, or a nearby hot material may initiate a hydrogen gas fire or explosion. All equipment used for or near liquid-hydrogen operations must therefore be electrically grounded and bonded to reduce the risk of explosion. A hydrogen leak that catches fire will

produce a very pale blue, almost invisible flame that is easy to miss and personnel may unknowingly walk into or place a hand into a hydrogen flame.

Because hydrogen is so flammable and readily explosive, extreme care must be taken so that it never comes into contact with air. Liquid-hydrogen cylinders should never be used for other cryogenic liquids, and cylinders intended for other cryogenic liquids should never be used for liquid hydrogen. All lines used to transfer hydrogen gas or liquid must be thoroughly purged of air by evacuating the lines and backfilling with inert gas at least three times. Additionally, any pressure-relief valves on a liquid-hydrogen cylinder must be routed to minimize the risk of creating a flammable or explosive mixture with air. Transfer lines carrying liquid hydrogen are also prone to condensing air and forming oxygen-enriched liquid or atmosphere, which only increases the risks of fire or explosion when working with liquid hydrogen. Vacuum-insulated transfer lines are thus a necessity with liquid hydrogen.

Unlike nitrogen and argon, which are denser as gases than air, hydrogen as a gas is far less dense than air. With liquid nitrogen and liquid argon, the largest concentrations of released cryogen will be close to the ground, especially in recessed areas. However, with liquid hydrogen the vented gas will accumulate at ceiling level, at the highest point. Hydrogen concentrations can be far greater in vaulted areas of the ceiling or in the open area above a drop ceiling, where room ventilation systems may not flush it out as effectively. These types of features pose a large asphyxiation and fire/explosion hazard.

The inherent dangers of working with liquid hydrogen cannot be overstated. A thorough review by Safety personnel will be needed for any proposed work with cryogenic liquid hydrogen.

C.3 Liquid Oxygen

Although oxygen is not flammable in itself, it is a strong oxidizer and can cause flammable and combustible materials to catch fire and burn. Our atmosphere typically contains about 21% oxygen by volume. This is plenty of oxidizer to burn a wide range of flammable and combustible materials. Liquid oxygen is not only 100% oxygen by volume, but that oxygen is far more concentrated as a liquid than as a gas, since liquid oxygen expands by 860 times when allowed to warm to room temperature. A single drop of liquid oxygen has as many oxygen molecules, and thus as much oxidizing power, as approximately half a liter of air. It should not be surprising, then, that liquid oxygen is capable of causing fires in materials that are not normally considered flammable by the layperson, while materials that are known to burn in air will burn far more vigorously in atmospheres with increased

oxygen concentration. Some materials may even ignite spontaneously on contact with liquid oxygen or high gaseous-oxygen concentrations.

Hair, clothing, oil, grease, kerosene, tar, asphalt, and many plastics and rubbers will all burn readily in oxygen-rich environments. In particular, cloth and clothing can trap oxygen gas in the porous weave of the fibers and remain incredibly prone to ignition long after the source of oxygen has been removed. Clothing that has been exposed to liquid oxygen will burn incredibly hot and fast if ignited, and will ignite more easily. **All sources of ignition and incompatible materials must be kept away from liquid-oxygen operations.**

Vessels that contain liquid oxygen must be cleaned to very strict standards to ensure no hydrocarbon or other incompatible contaminant is present. Oxidation of incompatible materials by liquid oxygen produces significant heat that causes the liquid oxygen to vaporize and expand quickly, potentially leading to the rupture of its container. The construction of a vessel to contain liquid oxygen must also avoid the use of any material that may oxidize or burn on contact with liquid oxygen. This makes liquid-oxygen vessels unique in their construction. **Liquid oxygen should never be added to any vessel of any type unless it is specifically constructed for use with LOx and has been cleaned according to strict protocols to ensure the complete removal of incompatible contamination.**

Unlike every other cryogenic liquid, LOx does not pose an asphyxiation risk. However, at high enough concentrations oxygen may damage the lungs, airways, and eyes.

A thorough review by Safety personnel will be required for any proposed work with cryogenic liquid oxygen.

Appendix D. Job Hazard Analysis–DD Form 2977

This appendix appears in its original form, without editorial change.

DELIBERATE RISK ASSESSMENT WORKSHEET

1. MISSION/TASK DESCRIPTION	2. DATE *(DD/MM/YYYY)*

3. PREPARED BY

a. Name (Last, First Middle Initial)	b. Rank/Grade	c. Duty Title/Position

d. Unit	e. Work Email	f. Telephone *(DSN/Commercial (Include Area Code))*

g. UIC/CIN *(as required)*	h. Training Support/Lesson Plan or OPORD *(as required)*	i. Signature of Preparer

Five steps of Risk Management: (1) Identify the hazards (2) Assess the hazards (3) Develop controls & make decisions (4) Implement controls (5) Supervise and evaluate *(Step numbers not equal to numbered items on form)*

	4. SUBTASK/SUBSTEP OF MISSION/TASK	5. HAZARD	6. INITIAL RISK LEVEL	7. CONTROL	8. HOW TO IMPLEMENT/ WHO WILL IMPLEMENT	9. RESIDUAL RISK LEVEL
+ -					How: Who:	

10. OVERALL RESIDUAL RISK LEVEL *(All controls implemented)*:

☐ EXTREMELY HIGH ☐ HIGH ☐ MEDIUM ☐ LOW

11. OVERALL SUPERVISION PLAN AND RECOMMENDED COURSE OF ACTION

12. APPROVAL OR DISAPPROVAL OF MISSION OR TASK ☐ Approve ☐ Disapprove

a. Name (Last, First, Middle Initial)	b. Rank/Grade	c. Duty Title/Position	d. Signature of Approval Authority

e. Additional Guidance:

Risk Assessment Matrix		Probability *(expected frequency)*				
		Frequent: Continuous, regular, or inevitable occurrences	**Likely:** Several or numerous occurrences	**Occasional:** Sporadic or intermittent occurrences	**Seldom:** Infrequent occurrences	**Unlikely:** Possible occurrences but improbable
Severity *(expected consequence)*		**A**	**B**	**C**	**D**	**E**
Catastrophic: *Mission failure, unit readiness eliminated; death, unacceptable loss or damage*	**I**	EH	EH	H	H	M
Critical: *Significantly degraded unit readiness or mission capability; severe injury, illness, loss or damage*	**II**	EH	H	H	M	L
Moderate: *Somewhat degraded unit readiness or mission capability; minor injury, illness, loss, or damage*	**III**	H	M	M	L	L
Negligible: *Little or no impact to unit readiness or mission capability; minimal injury, loss, or damage*	**IV**	M	L	L	L	L

Legend: EH - Extremely High Risk H - High Risk M - Medium Risk L - Low Risk

13. RISK ASSESSMENT REVIEW *(Required when assessment applies to ongoing operations or activities)*

a. Date	b. Last Name	c. Rank/Grade	d. Duty Title/Position	e. Signature of Reviewer

14. FEEDBACK AND LESSONS LEARNED

15. ADDITIONAL COMMENTS OR REMARKS

Instructions for Completing DD Form 2977, "Deliberate Risk Assessment Worksheet"	
1. Mission/Task Description: Briefly describe the overall Mission or Task for which the deliberate risk assessment is being conducted. **2. Date** *(DD/MM/YYY)*: Self Explanatory. **3. Prepared By:** Information provided by the individual conducting the deliberate risk assessment for the operation or training. **Legend: UIC** = Unit Identification Code; **CIN** = Course ID Number; **OPORD** = operation order; **DSN** = defense switched network; **COMM** = commercial **4. Sub-task/Sub-Step of Mission/Task:** Briefly describe all subtasks or substeps that warrant risk management. **5. Hazard:** Specify hazards related to the subtask in block 4. **6. Initial Risk Level:** Determine probability and severity. Using the risk assessment matrix (page 3), determine level of risk for each hazard specified. probability, severity and associated Risk Level; enter level into column. **7. Control:** Enter risk mitigation resources/ controls identified to abate or reduce risk relevant to the hazard identified in block 5. **8. How to Implement / Who Will Implement:** Briefly describe the means of employment for each control (i.e., OPORD, briefing, rehearsal) and the name of the individual unit or office that has primary responsibility for control implementation. **9. Residual Risk Level:** After controls are implemented, determine resulting probability, severity, and residual risk level. **10. Overall Risk After Controls are Implemented:** Assign an overall residual risk level. This is equal to or greater than the highest residual risk level (from block 9).	**11. Supervision Plan and Recommended Course of Action:** Completed by preparer. Identify specific tasks and levels of responsibility for supervisory personnel and provide the decision authority with a recommend course of action for approval or disapproval based upon the overall risk assessment. **12. Approval/Disapproval of Mission/Task:** Risk approval authority approves or disapproves the mission or task based on the overall risk assessment, including controls, residual risk level, and supervision plan. **13. Risk Assessment Review:** Should be conducted on a regular basis. Reviewers should have sufficient oversight of the mission or activity and controls to provide valid input on changes or adjustments needed. If the residual risk rises above the level already approved, operations should cease until the appropriate approval authority is contacted and approves continued operations. **14. Feedback and Lessons Learned:** Provide specific input on the effectiveness of risk controls and their contribution to mission success or failure. Include recommendations for new or revised controls, practicable solutions, or alternate actions. Submit and brief valid lessons learned as necessary to persons affected. **15. Additional Comments or Remarks:** Preparer or approval authority provides any additional comments, remarks, or information to support the integration of risk management. **Additional Guidance:** Blocks 4-9 may be reproduced as necessary for processing of all subtasks/ substeps of the mission/task. The addition and subtraction buttons are designed to enable users to accomplish this task.

Appendix E. 'Designated Area' Posting

This appendix appears in its original form, without editorial change.

Designated Area

This area is designated for the chemicals listed below. Use of these materials in this area is limited to personnel who understand the physical and health hazards associated with the chemicals and the control procedures necessary to minimize personal exposure and area contamination. Designated areas for engineered nanomaterials shall be cleaned (e.g., wet wiped) at the end of the work day when these materials are used.

Appendix F. Organic Peroxide-Forming Chemical Groups—Storage Times

Table F-1 Organic peroxide-forming chemical groups—storage times

Group A: Chemicals that Form Explosive Levels of Peroxides without Concentration (Storage Time after Opening: 3 Months)				
Chemical	**Chemical Abstract Service**	**Synonyms**	**State**	**Note/Reference**
Butadiene	106-99-0	1,3-Butadiene	gas	1, 3, 4, 6
Chloroprene	126-99-8	2-Chloro-1,3- butadiene	liquid	1, 3, 4, 5, 6
Divinyl acetylene	821-08-9	1,5-Hexadien- 3-yne	l	5, 6
Isopropyl ether	108-20-3	. . .	l	5, 6
Tetrafluoroethylene	116-14-3	. . .	g	4, 6
Vinylidene chloride	75-35-4	1,1- Dichloroethylene	l	5,6

Group B: Chemicals that Form Explosive Levels of Peroxides on Concentration (Storage Time after Opening: 12 Months; Storage Time if Container is Unopened: 18 Months)				
Chemical	**CAS**	**Synonyms**	**State**	**Note/Reference**
Acetal	105-57-7	. . .	l	4, 5, 6
Acetaldehyde	75-07-0	. . .	l	4, 6
Benzyl alcohol	100-51-6	. . .	l	4, 6
2-Butanol	78-92-2	. . .	l	4, 6
Chlorofuoroethylene	359-10-4	. . .	g	6
Cyclohexanol	108-93-0	. . .	l	4
Cyclohexene	110-83-8	. . .	l	5, 6
2-Cyclohexen-1-ol	822-67-3	. . .	l	4, 6
Cyclooctene	931-88-4	. . .	l	5
Cyclopentene	142-29-0	. . .	l	5, 6
Decahydronaphthalene	91-17-8	Decalin	l	4, 6
Diacetylene	460-12-8	. . .	g	4, 5, 6
Dicyclopentadiene	77-73-6	. . .	l	4, 5, 6
Diethylene glycol dimethyl ether	111-96-6	Diglyme	l	4, 5, 6
Dioxane	123-91-1	1,4-Dioxane, p-dioxane	l	4, 5
Ethylene glycol dimethyl ether	110-71-4	Glyme	l	4, 5
Ethyl ether	60-29-7	Diethyl ether	l	4, 5, 6
Furan	110-0-9	. . .	l	5, 6
4-Heptanol	589-55-9	. . .	l	4, 6
2-Hexanol	626-93-7	. . .	l	4, 6
Isopropyl benzene	98-82-8	Cumene	l	5, 6
Methyl acetylene	74-99-7	Propyne	g	4, 5, 6
3-Methyl-1-butanol	123-51-3	Isoamyl alcohol	l	4, 6
Methyl cyclopentane	96-37-7	. . .	l	5, 6
Methyl isobutyl ketone	108-10-1	Methyl-i-butyl ketone	l	4, 6
4-Methyl-2-pentanol	108-11-2	. . .	l	4, 6
2-Pentanol	6032-29-7	. . .	l	4, 6
4-Penten-1-ol	821-09-0	. . .	l	4, 6
1-Phenylethanol	98-85-1	alpha-Methyl-benzyl alcohol	l	4, 6
2-Phenylethanol	60-12-8	Phenethyl alcohol	l	4, 6
2-Propanol	67-63-0	Isopropanol	l	4, 6
Tetrahydrofuran	109-99-9	. . .	l	5, 6
Tetrahydronaphthalene	119-64-2	. . .	l	5

Table F-1 Organic peroxide-forming chemical groups—storage times (continued)

Group C: Chemicals that May Autopolymerize as a Result of Peroxide Accumulation (Safe Storage Time after Opening: Inhibited Chemicals, 12 Months; Uninhibited Chemicals, 24 Hours)

Chemical	CAS	Synonyms	State	Note/Reference
Acrylic acid	79-10-7	. . .	l	2, 5
Acrylonitrile	107-13-1	. . .	l	2, 4
Butadiene	106-99-0	. . .	g	1, 3, 5, 6
Buten-3-yne	689-97-4	Vinyl acetylene & Butenyne	g	4
Chloroprene	126-99-8	2-Chloro-1,3-butadiene	l	1, 3, 5
Chlorotrifluoroethylene	79-38-9	. . .	g	5
Methyl methracrylate	80-62-6	. . .	l	2, 5
Styrene	100-42-5	. . .	l	5
Tetrafluoroethylene	116-14-3	. . .	g	5
Vinyl acetate	108-05-4	. . .	l	5
Vinyl chloride	75-01-4	Mono-chloroethylene	g	5
Vinylidene chloride	75-35-4	1,1-Dichloroethylene	l	5

Table Notes/References:

1. When stored as a liquid monomer.
2. Although these form peroxides, no explosions involving these monomers have been reported.
3. Also stored as a gas in gas cylinders.
4. Kelly RJ. Review of Safety Guidelines for Peroxidizable Organic Chemicals, Chemical Health and Safety. Sep/Oct 1996.
5. National Research Council. Prudent Practices in the Laboratory, Handling and Disposal of Chemicals; Washington (DC): National Academy Press; 2011.
6. Clark DE. Peroxides and Peroxide-Forming Compounds, Chemical Health and Safety. Sep/Oct 2001.
7. Storage times can be increased to 18 months for Group B chemicals if the containers have never been opened and exposed to air.
8. This material is peroxidizable but is not dangerous unless distilled or concentrated.

List of Symbols, Abbreviations, and Acronyms

ANSI	American National Standards Institute
AR	Army Regulation
ARL	Army Research Laboratory
BCHO	Branch Chemical Hygiene Officer
CAS	Chemical Abstracts Service
CCDC	US Army Combat Capabilities Development Command
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CHP	Chemical Hygiene Plan
DOD	US Department of Defense
DOT	US Department of Transportation
ESO	Explosives Safety Office
FM	Factory Mutual
GHS	Globally Harmonized System
HAZCOM	Hazard Communication
HEPA	high-efficiency, particulate air
IAW	in accordance with
JHA	job hazard analysis
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
POC	point of contact
PPE	personal protective equipment
RM	Risk Management
SDS	Safety Data Sheet
SOP	standard operating procedure

TLV	Threshold Limit Value
UL	Underwriters Laboratories
UV	ultraviolet
w.g.	water gauge

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