Manual De Seguridad Química y Biología en Laboratorios

TABLA DE CONTENIDOS

1.0 INTRODUCCION

El Manual de *Seguridad Química y Biológica en Laboratorios* provee información y guía para ayudar a desarrollar su trabajo de laboratorio en forma segura y de acuerdo con las normas de seguridad y cuidado ambiental y las políticas de la FCEN. Sirve también como un recurso de entrenamiento útil para los Investigadores Responsables, supervisores de personal y trabajadores de laboratorios. Principalmente está dedicado al trabajo en el laboratorio pero su contenido se aplica también en áreas que no son de laboratorios pero en los que hay presentes riesgos químicos.
El Manual de *Seguridad Química y Biológica en Laboratorios* es el Plan General de Higiene de la FCEN. El *Plan de Protección* de su laboratorio es la parte específica para su laboratorio del Plan de Higiene. Los *Planes de Protección* deben presentarse para todos los laboratorios de investigación, apoyo a la investigación y docencia.
Este documento debe estar a disposición de todas las personas que trabajen con agentes con riesgo químico o biológico.
Si bien la información incluida en este documento ha tratado de ser completa, debe considerarse como un punto de partida para las buenas prácticas en el laboratorio. El Investigado5r Responsable deberá incorporar la información específica relacionada con el laboratorio.
Cuando se use la palabra ***deberá*** indicará que es un procedimiento requerido. La palabra ***podrá*** indica una recomendación para buenas practicas.
El trabajo con materiales radioactivos está cubierto por el *Manual de Seguridad Radiológica*, que está disponible en el Servicio de Higiene y Seguridad (SHyS).
Este documento ha sido revisado por el Comité de Seguridad (CS) y aprobado por el Decano y El Consejo Directivo.

Números de Emergencias	
Departamento de Seguridad y Control	**Int 311**

2.0 RESPONSABILIDADES

Esta sección describe y asigna las responsabilidades que conciernen directamente con los laboratorios que usan materiales químicos y/o biológicos.

2.1 El Decano de la Facultad

El Decano de la Facultad, delega en el Secretario responsable del área de Higiene y Seguridad la responsabilidad administrativa de los programas de protección química, biológica y radiológica.

2.2 Secretario responsable del área y subsecretario de hábitat

El secretario responsable del área de higiene y seguridad y el subsecretario de hábitat supervisan las las actividades del Servicio de Higiene y Seguridad.

2.3 Servicio de Higiene y Seguridad

El Director del Servicio de Higiene y Seguridad reporta administrativamente al Subsecretario de Hábitat, si bien mantiene la independencia de gestión que resulte de las atribuciones que le asigna la legislación vigente. El Servicio de Higiene y Seguridad (SHyS) es responsable de desarrollar y coordinar los programas de protección química, biológica y de radiación.
El SHyS provee información, entrenamiento, y medios técnicos a los Directores de Departamento, Directores de Centros e Investigadores Responsables que los asistan en implementar los programas de seguridad química y biológica.
Las responsabilidades del SHyS incluyen:

- Mantener disponible información sobre Material Safety Data Sheets (MSDSs), que son necesarios por la legislación vigente.
- Compiling chemical inventory information and submitting reports to federal, state, and local agencies
- Collecting and disposing of waste and surplus chemicals

- Advising with respect to the collection and disposal of biological wastes
- Surveying laboratory facilities and offering recommendations for improved practice
- Maintaining records for laboratory facilities
- Coordinating the *Plan de Protección* and recombinant DNA registration programs
- Providing emergency response to spills or other accidents and investigating incidents involving hazardous materials from 9AM to 7PM from monday to friday
- Training and advising FCEN personnel in safe work practices, personal protective clothing and equipment, engineering controls, and regulatory requirements
- Conducting or arranging for environmental monitoring
- Inspecting laboratory equipment such as chemical fume hoods
- Recommending policies and procedures for the safe conduct of work with chemicals and biological material

SHyS representatives are authorized to enter FCEN facilities within their jurisdiction at any time to observe working conditions, monitor equipment, and sample for contaminants. The director and the designated chemical hygiene and biohazards safety officers are authorized to close a facility or stop a process or procedure that poses an imminent danger to life or property.

2.4 Comité de Seguridad

El Comité de Seguridad supervisa los programas de seguridad química, biológica y radiológica. Los miembros serán miembros de distintos departamentos de la FCEN que cubran las disciplinas con distinto riesgo que se desarrollan en la misma y son designados por el Decano.
Los aspectos involucrados con la seguridad en el uso de la radiación ionizante y no-ionizante y moléculas con ADN recombinante están controladas por subcomisiones específicas. La investigación que involucra animales está supervisada por la Comisión de Control de Manejo y Usos de Animales que coordina la directora del Bioterio.
The general purposes of the committee are:

- To formulate and recommend to the Subsecretario de Habitat policies governing the use of biological agents, chemical carcinogens, and other chemicals in the laboratory
- To monitor the compliance of the FCEN with respect to federal, state, and local regulations pertaining to hazardous materials in the laboratory

The Committee has a number of specific responsibilities, including:

- Recommending policies and procedures for a chemical and biological safety program, including, but not limited to, educational programs, laboratory inspections, containment requirements, waste disposal programs, and medical surveillance
- Reviewing and approving *Planes de Seguridad* and *Incident Reports*

2.5 Subcomité de Seguridad de ADN Recombinante

El Subcomité de Seguridad de ADN Recombinante es responsable de supervisar la seguridad en la investigación con ADN recombinante. El subcomité recomendará políticas que lleven a implementar las normas legales vigentes.
Los investigadores deberán registrar por escrito ante el SHyS todos los proyectos de investigación en ADN recombinante. Por favor consulte el *Programa de Seguridad de ADN Recombinante* para mas información.

2.6 Department Heads, Center Directors, and Other Facility Directors

The term department head will be used in this text to include center directors and other facility directors.
El Decano ha asignado responsabilidad directa por el cumplimiento de los programas de seguridad y salud a los Directores de Departamento. This means that the department head shall provide a safe workplace and shall implement the safety and health programs. This includes ensuring that personnel are adequately trained, developing Safety Desk Books, and overseeing the preparation and submission of *Planes de Protección* and annual chemical inventories. Department heads shall cooperate to develop evacuation plans for buildings, appoint building safety committees, and appoint building safety managers and alternates.
The department head shall maintain discipline, enforce rules and regulations, and take prompt, effective corrective action when necessary. The department head shall also provide assistance to SHyS staff when situations arise involving investigators and other personnel in the department.
The department head shall be familiar with and understand the federal, state, and local regulations and FCEN policies applicable to the department's work and shall ensure compliance through investigadores responsables and other supervisory personnel. Regulatory and policy documents are available from SHyS.

The department head may delegate safety and health-related responsibilities to investigadores responsables or other supervisors, but it is the department head's responsibility to see that the requirements are met.
The department head is responsible for ensuring that biological safety cabinets are certified as required by this document and that safety showers and eyewash stations are available in the department and inspected as required. The department head will require the investigador responsable to institute medical surveillance programs for personnel with occupational exposure to certain agents (e.g., carcinogens, human materials).
When a investigador responsable vacates a laboratory, the department head (or appointed designate) is responsible for ensuring that the lab is properly cleaned out and prepared for the next occupant. The principal investigator shall report to the department head that all hazardous chemical and biological materials have been removed and work surfaces (lab furniture, refrigerators, freezers, chemical fume hoods, etc.) decontaminated with an appropriate and SHyS-approved method. Should a investigador responsable abandon surplus chemicals, the department becomes responsible for arranging disposal, both in terms of inventory and funding. The department head shall also be responsible for providing decontamination of the lab if the principal investigator shirks this duty.

2.7 Investigatores Responsables y Supervisores

The term investigador responsable as used in this document shall include laboratory and other supervisors (such as managers or directors of common facilities). El investigador responsable is defined as any faculty member who has been granted permission by the Secretaría de Investigación to serve as a principal investigator on a project or to submit a proposal. All persons granted faculty-level research appointments are eligible to be investigadores responsables. El Decano may authorize others to be investigadores responsables.
El investigador responsable is responsible to the department head for the safe and legal conduct of research under his or her purview. This responsibility shall not be delegated. El investigador responsable shall be aware of the physical and health hazards associated with all materials present in the laboratory. In the event of an accident, el investigador responsable shall initiate appropriate emergency procedures. Written *Incident Reports* shall be provided to SHyS.
El investigador responsable shall prepare a *Plan de Protección*, make all laboratory personnel aware of the plan, and enforce the safety rules and procedures described therein. See Section 3.0 for information about the Plan de Protección.
The investigator responsable shall be familiar with and understand the rules, regulations, and FCEN policies pertaining to the workplace. These encompass but are not limited to the following items: training, record keeping, maintaining and providing easy access to MSDSs, labeling chemicals, labeling and proper disposal of surplus and waste chemicals and biological materials, posting warnings, medical surveillance, inventory reporting, engineering controls, safe work practices, providing personal protective clothing and equipment, and access restrictions.
The national laws states that it is *"clear that it is the employer's responsibility to compel compliance… it is the employer, and not the employee, who controls the conditions of work at a given workplace."* According to FCEN interpretation, the investigador responsable or lab supervisor is defined as the employer responsible for ensuring adherence to safety regulations and proper use of safety equipment in the lab. The investigador responsable shall correct any deficiencies that could lead to health and safety repercussions for lab personnel.

2.8 The Individual

Each individual working in a laboratory or other worksite where hazardous materials are used shall know and comply with the FCEN's safety policies and rules and shall follow both oral and written instructions from the principal investigator or supervisor. The individual shall report to the investigador responsable any unsafe conditions and any accident or exposure to chemicals or biological agents. If the individual receives no response or an unsatisfactory response, (s)he shall contact the department head or SHyS. The department head or SHyS shall ensure confidentiality for the individual reporting a safety concern.
The individual shall know the hazards of the chemical and biological agents in the workplace as well as proper handling and disposal procedures. Training shall be provided or arranged by the investigador responsable.

2.9 Laws and Regulations

Numerous laws and regulations govern work with chemicals and biological materials and the responsibilities of employers and employees. A list of the major regulations follows.
FEDERAL LAWS

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STATE LAW

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LOCAL LAWS

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2.10 Students

Although the National laws apply only to employees (including student employees), it is the policy of FCEN to ensure that all students who might be exposed to hazardous materials in the course of their activities at the FCEN are also adequately protected and trained. Therefore, *Planes de Protección* shall also be prepared for teaching laboratories. Students shall receive instruction in the appropriate safety precautions for their specific teaching lab and will be expected to follow the given rules, as shall the lab supervisors.

3.0 PROGRAMA DE PROTECCION QUIMICA Y BIOLOGICA

3.1 Bases del Programa de Protección Química y Biologica

El Programa de Protección Química y Biológica consolida el cumplimiento de las normas de comunicación de riesgos, los estándares de riesgos ocupacionales en laboratorios, exposición ocupacional a patógenos en sangre, las normas de trabajo en ADN recombinante y otros programas de seguridad en laboratorios.

3.2 Manual de Seguridad del Laboratorio

Los documentos de Protección Química y Biológica están diseñados para ser compilados en el Manual de Seguridad del Laboratorio. El Manual de Seguridad del Laboratorio es el recurso central de seguridad en el laboratorio. El Manual de Seguridad del Laboratorio completo incluye estas secciones, en el caso que se aplique:

- *Reacciones Alérgicas* a guantes de Latex
- *Programa de Patógenos en Sangre*
- *Seguridad Química y Biológica en Laboratorios*
- *Programa de Comunicación de Riesgos*
- Procedimientos de Emergencia
- *Política de Primeros Auxilios y Botiquines en Laboratorio*
- *Manual de Protección Radiológica*
- *Programa de Protección Respiratoria*
- *Programa de ADN Recombinante*
- Registro de inspección de equipos de seguridad
- *Plan de Protección, Revisión Anual, Aclaraciones*, y correspondencia relacionada con la documentación del *Plan de Protección*
- *Manual de Campanas Químicas*

El Manual de Seguridad de Laboratorio completo debe existir a nivel de Departamento y debe crearse por el Director de cada Departamento donde se usan materiales riesgosos. El Manual de Seguridad de cada Laboratorio debe contener como mínimo el *Plan de Protección* del laboratorio, Plan de evacuación del Departamento, y los procedimiento y protocolos específicos del laboratorio necesarios para proteger la salud y seguridad de los miembros del laboratorio.

3.3 Plan de Protección

El *Plan de Protección* es el plán de específico de cada laboratorio para investigación, enseñanza y facilidades comunes. En el caso de facilidades comunes el Director o Coordinador o Supervisor de la facilidad debe remitir el *Plan de Protección*.

> **3.3.1 Initial Submission.** If chemical or biological agents or processes with physical or health hazards are used, the resonsable investigator shall submit a *Plan de Protección* to the SHyS assistant director for review. The assistant director may also submit the plan to the Comite de Seguridad (CS)

for further review if the lab operations are considered to be unique or high-hazard. The *Plan de Protección* contains the following sections:

- Research Overview
- Safety Infrastructure
- Chemical Safety
- Biological Safety
- Radiological Safety
- Certification of Agreement

Planes de Protección are available from HyS. Appendix A at the end of this document contains a list of carcinogens to help you complete the "Inventory of Chemical Agents del*Plan de Protección*.

The assistant director or SHyS may determine that the information listed in the *Plan de Protección* is not clear or indicates a need for further investigation of safety protocols. In such instances, responsable investigators will be requested to complete a Process Safety Review of the procedure that has caused concern.

3.3.2 Annual Review. An annual update of each *Plan de Protección* shall be submitted to SHyS. The *Plan de Protección* shall be kept current between Annual Review submissions. The *Plan de Protección* shall reflect new or modified tasks and procedures which affect occupational exposure and new or revised employee positions with occupational exposure.

3.3.3 Change of Facility. If you open new laboratory facilities or move to an alternate location, those sections of the *Plan de Protección* affected by relocation must be replaced with corrected sheets. For example, you will need to revise the section concerning *Ventilation Controls for Inhalation Hazards* and indicate the number and site of chemical fume hoods in the new space. The same applies to the *Area Monitoring and Alarms* section. Review the entire plan to ensure that you have modified all the necessary parts of the plan, in keeping with the infrastructure existing at the new location. Resubmit the fresh pages to SHyS as soon as possible after your move.

3.3.4 Addition of or Change to a Specific Project. A replacement *Plan de Protección* shall be submitted to SHyS for new projects that require a *Plan de Protección* and are not covered by the original *Plan de Protección*.

3.4 Laboratory Surveys

The FCEN provides an inspection program for all laboratories. Laboratory surveys are conducted by the staff of SHyS. The survey consists of an interview with the principal investigator followed by a visit to the laboratory. Investigators may be asked to update the *Plan de Protección* and other information. The SHyS representative may examine general laboratory conditions, engineering controls, work practices, chemical storage, use of personal protective clothing and equipment, signs and postings, documents such as MSDSs, and preferably, the Manual de Seguridad del Laboratorio. Laboratory workers may be interviewed. Inspection findings are detailed in a report forwarded to the principal investigator.

4.0 GENERAL FCEN EMERGENCY INFORMATION

4.1 Where to Find Specific Information

This section provides general information about the FCEN's emergency response programs.

- For detailed emergency notification procedures and other general emergency information, including fire safety, see your laboratory or departmental Manual de Seguridad.
- For emergency information relating to chemical spills and exposures, see Section 6.0.
- For emergency information relating to biological spills and exposures, see Section 7.0.
- For emergency information relating to exposure to bloodborne pathogens, see the *Bloodborne Pathogens Program*.

Call for assistance when needed. In FCEN buildings, **always** call the Departamento de Seguridad y Control at **int. 311** if there is an explosion, fire, injury, or spill-related evacuation.

Each FCEN employee (research and nonresearch personnel) receives an *Employee Safety Handbook* during Human Resources new employee orientation. SHyS produce this publication. This reference booklet also summarizes important phone numbers, emergency procedures, medical treatment procedures, safety inspection information, and hazard communication program elements. It further explains the duties and activities of the various emergency response service organizations. It is intended to give you thorough emergency information in an easily accessible overview. If you do not have your own copy of the handbook, contact the Human Resources Training Division or SHyH.

4.2 FCEN Emergency Response Plan

The Safety and Loss Prevention Division of the SHyS maintains the FCEN's Emergency Response Plan for emergencies. The Emergency Response Plan formalizes responses to all classes of emergencies, from small events to catastrophes. In emergency situations, the role of SHyS is to investigate the situation, provide site security, implement the emergency plan, and establish communications. SHyS will advise and assist with hazardous-material spill control and cleanup. When the ability to respond adequately to an emergency is beyond the capability of FCEN personnel, SHyS will call the local fire department or local hazardous materials response team. SHyS may make this call.

4.3 Building Emergency and Evacuation Plans

La máxima autoridad de la Facultad presente is authorized to initiate evacuation of buildings. The FCEN Emergency Response Plan requires that department heads cooperate to establish building safety committees and appoint building safety managers and alternates. The building safety committees shall develop evacuation plans for each building. The plans shall include a telephone tree for notifying key persons in case of emergency. All building occupants shall receive training in their respective evacuation plan. Safety wardens shall be appointed for each building.

In the event of a fire, hazardous material release, or other hazardous situation requiring emergency response in a safety warden's zone, the warden will:

- Activate the fire alarm, if needed
- Call Departamento de Seguridad y Control and report the incident
- Notify occupants to evacuate the zone
- Assist emergency personnel by providing information regarding location of the incident, origin, and persons involved

The warden shall not be placed in imminent danger.

4.4 Power Failure

In the event of a power failure in a FCEN research building, the building shall be evacuated. Evacuation is required because the ventilation system will cease to function. Although an emergency generator will maintain emergency lighting, air supply diffusers and chemical fume hoods will not operate.

Expect a delay between power outage and generator start-up; there will be a period of darkness before the emergency lights are turned on. Be prepared by keeping flashlights in the work area.

Once there is adequate emergency lighting, cap any open chemical containers and close gas cylinders, perform an orderly shutdown of equipment and processes, and close the chemical fume hood sash. If refrigerators, freezers, or cold rooms contain heat-sensitive materials, consider using dry ice to keep these materials cold. Leave immediately when the area has been secured and can be left unattended. Contact SHyS if there is a possibility of an uncontrolled reaction in a process that cannot be shut down.

Do not depend on safety showers or eyewashes. This safety equipment relies on a booster pump that will not be operational. Emergency telephones and manual pullbox stations should continue to operate properly.

4.5 Incident (Accident) Reporting

All laboratory incidents shall be reported to SHyS, including minor spills, fires, or injuries. Laboratory incidents shall be investigated. SHyS requires that an *Incident Report* be completed by the person(s) involved in the incident. The person's supervisor is expected to sign the completed form and state what steps will be taken to prevent future such incidents from occurring. The form is then submitted to SHyS for subsequent review by the Comite de Seguridad. The supervisor shall be responsible for ensuring that corrective action to prevent repeat incidents is undertaken.

SHyS may also prepare an investigation report. Investigations are made and reports written not only to satisfy certain laws but also to learn the cause of the problem and what changes in procedures, equipment, or training should be made to avoid other accidents.

Fires or injuries not requiring outside assistance shall also be reported to Departamento de Personal.

4.6 SHyS Assistance

SHyS will respond to chemical and biological spills. However, if the spilled material is not volatile and there is no immediate fire or toxic hazard, cleanup may be done by laboratory employees (under direction of the principal investigator or SHyS). SHyS will provide cleanup supplies and equipment, personal protective equipment, and cleanup instructions. In situations involving a fire or toxic hazard, SHyS will advise on evacuation or other precautions to protect persons or property in the immediate area.

4.7 Personal Injury

The CS and SHyS both recommend that at least two members of each lab group receive first aid and CPR training. PIs/supervisors must determine whether to arrange for and/or sponsor first aid and CPR training for their staffs.

4.7.1 Burn from Fire. If your clothing catches fire, decide very quickly how to put out the fire and minimize burns. The following methods are in order of preference:

1. Get under a safety shower or other water source if one is immediately at hand.
2. If a safety shower is not immediately available, stop, drop, and roll to extinguish the fire, holding your hands over your face to shield your face and eyes.
3. Roll up in a fire blanket if one is nearby. If a fire blanket is used, remove it immediately after the flames are extinguished to prevent further injury from heat buildup.

   Assess the condition of the skin's burn area. If skin is not broken, run water over the burn area to remove heat. If skin is broken, apply a dry, sterile dressing over the wound. Seek medical attention as soon as possible.

4.7.2 Inhalation. A person exposed to smoke or fumes shall be removed to uncontaminated air. Any victim overcome by smoke or fumes shall be treated for shock (see Section 4.7.3). Give cardiopulmonary resuscitation (CPR) if necessary and if trained personnel are available. If a person needs to be rescued from a contaminated area, evaluate the possibility of harm to the rescuer before anyone enters or remains in the contaminated area without proper protective equipment. If an MSDS is available for the material inhaled, it should accompany the victim to the medical treatment facility.

4.7.3 Shock. Shock is likely to develop in any serious illness or injury. Shock is a condition in which the circulatory system fails to deliver blood to all parts of the body. When the body's organs do not receive adequate blood supply, they fail to function properly.

The following signals are indicators that the victim is suffering from shock.

- Restlessness or irritability (often the first sign that the body is experiencing a significant problem)
- Altered consciousness
- Pale, cool, moist skin
- Rapid breathing

- Rapid pulse

In caring for shock, have the victim lie down. Help the victim rest as comfortably as possible to minimize pain and thereby slow the progression of shock. Control any external bleeding. Help the victim maintain a normal body temperature and avoid chilling. Elevate the victim's legs about 12 inches unless you suspect broken bones or possible head, neck, or back injuries. If in doubt, leave the patient lying flat.

Do **NOT** give the victim anything to eat or drink although (s)he may complain of thirst. Obtain medical assistance promptly since shock cannot be managed by first aid alone.

4.7.4 Ingestion. If a person ingests a toxic chemical, determine, if possible, what was ingested and notify the emergency medical personnel.

Inform the hotline personnel of the first aid treatment shown on the container label or the MSDS. The MSDS should accompany the victim to the medical treatment facility.

4.7.5 Puncture or Cut. When treating a victim with a puncture wound or cut, wear personal protective equipment (e.g., gloves) to minimize exposure to human blood, body fluids, or other chemical or biological contamination. Apply a pressure pad or clean cloth firmly to the wound. Raise the wounded area above the level of the heart to slow the bleeding. For severe bleeding or spurting, very firmly press the pressure pad directly on the wound and apply pressure at the applicable body pressure point above the wound to stop the flow of blood. In a severe injury, keep the victim warm, calm, and oriented to prevent shock.

4.7.6 Needlestick. Needlesticks or other accidents involving skin punctures by a chemical or biological agent shall be reported to the supervisor immediately. Appropriate medical testing, treatment, and follow-up may be indicated and shall be provided as appropriate. When a needlestick occurs, do not wait to report the incident and obtain medical attention. See the *Bloodborne Pathogens Program* for more information on needlestick exposures to human blood and other potentially infectious human materials.

4.7.7 Dermal Contact. If a chemical spills on a person, the first goal is to remove the chemical from the person's skin as soon as possible, without spreading it onto yourself. For chemicals that can cause burns, the stronger the chemical and the longer the contact, the worse the burn. The chemical continues to burn as long as it remains on the skin. For all chemicals except hydrofluoric (HF) acid, flush the skin under a safety shower for at least 15 minutes. For limited skin exposure on a small area, a drench hose may be adequate for flushing. HF burns should only be flushed with water for at most five minutes. Flushing after HF exposure shall be followed immediately with treatment as discussed below.

Remove contaminated clothing while the person is under the shower stream, taking care not to spread contamination from the clothing onto more of the person's skin. If the clothing must be pulled over the head or down along the legs to be removed, cut it away with first aid kit scissors instead. Many safety showers are equipped with curtains to give privacy to the victim. Don't let modesty keep you from removing contaminated clothing that remains against skin.

Do not treat the burn. Do not puncture any blisters that may develop. Allow trained medical personnel to administer treatment after flushing is complete. Your first aid kit will probably contain antibiotic ointment and sterile gauze for burns. These are intended only for minor burns such as those you might encounter in your household, e.g., small burns from cooking at a stove and sunburns.

In the special case of hydrofluoric (HF) acid exposure, you will be expected to provide treatment. That explains why flushing with water is curtailed. There should be minimal delay between exposure and treatment. Once the spill area has been thoroughly flushed, apply calcium gluconate antidote gel immediately. This application cannot wait for emergency personnel to respond. The gel must be administered quickly to prevent severe damage to bone and tissue or potential fatality. Refer to the *First Aid Kit Policy and Guidelines for Laboratories* for further information concerning proper gel application and purchasing. Any lab working with HF shall maintain a stock of gel.

4.7.8 Eye Contact. Should a chemical enter a person's eye(s), wash the eye(s) with water for at least 15 minutes, while waiting for medical help to arrive. Keep the affected eye (if only one has been contaminated) lower than the unaffected eye to prevent the spread of contamination. For HF splashes in the eye, flush with water for five minutes and then irrigate with a 1% solution of calcium gluconate gel. See also the *First Aid Kit Policy and Guidelines for Laboratories* for first aid information.

Be aware that particulates and liquids can become trapped in the conjunctiva where they may continue to cause damage. The entire interior of the eye must be flushed as well as the exposed cornea. Irrigator loops are available that can ensure flushing under the eyelids. A "buddy" in the lab is vital to the injured person to help find the eyewash, call for help, keep the eyes open under the water stream, and prevent the person from rubbing the eye(s) and aggravating the damage.

MEDICAL EMERGENCY PROCEDURES

In the event you are injured or exposed to a hazardous substance, follow these procedures to obtain medical care and establish any Workers' Compensation benefits to which you may be entitled. All work-related injuries and illnesses must be reported. The claims manager of the ART is responsible for processing reports and conducting investigations of employee injuries and work-related illnesses.

A. **Ambulatory victims (able to walk)**
   A. Inform your supervisor or designated departmental employee of your injury or illness. The supervisor will contact the ART at Dirección de Personal.
B. B. Proceed to Servicio Médico ubicado en el subsuelo del Pabellón II.If the injury or illness occurs after 8:00 p.m., before 9:00 a.m., or on a weekend or holiday, llame al Departamento de Seguridad y Control.
C. Following treatment, fax a copy of your "Duty Status Report" to the ART at xxx-xxxx. Do not pay for treatment. Forward all bills and other related documentation to the ART. Also send receipts for any prescriptions or other related medical costs to the ART for reimbursement.

II. Nonambulatory victims (unconscious or unable to walk)

A. Call int..
B. Report the injury, victim's name, and location (building, floor).
C. Ask Seguridad y Control to send an ambulance to the location.
D. The victim's supervisor or designated departmental employee should then call the ART to report the accident so that a Workers' Compensation report can be initiated.

5.0 GENERAL LABORATORY SAFETY

Working safely in a laboratory requires having the proper containment equipment and engineering controls, wearing appropriate personal protective equipment, using proper work practices, knowing safety information for the materials and equipment used, and following safety instructions and laboratory protocols.

The general safety information in this section is provided to assist investigators and supervisors in planning work and guiding those actually carrying out procedures.

Because each laboratory situation is different, judgment is required in interpreting general concepts for individual settings. The *Safety Plan* provides specific information for individual laboratories. If you have questions or concerns about implementing general safety concepts or specific safety procedures, consult SHyS.

Some laboratories contain more than one type of hazardous material. For example, biochemistry laboratories may work with chemicals, biological agents, and radioactive materials. In such cases, the protective equipment and work practices to be used are those that provide protection against the most hazardous agent or meet the most stringent legal requirement.

5.1 Personal Hygiene

Personal hygiene is extremely important to persons working in a laboratory. Contamination of food, beverages, or smoking materials is a potential route of exposure to toxic chemicals or biological agents through ingestion. Thus, **laboratory personnel shall not prepare, store, or consume food or beverages; pipette by mouth; smoke; apply lip balm or cosmetics; or handle contact lenses in the work area**. This familiar elementary safety rule shall be followed by everyone working in or visiting a laboratory.

Handwashing is a primary safeguard against inadvertent exposure to toxic chemicals or biological agents. Always wash your hands before leaving the laboratory, even though you use gloves. Wash your hands after removing soiled protective clothing, before leaving the laboratory, and before eating, drinking, smoking, or using a rest room.

Wash your hands periodically during the day at intervals dictated by the nature of your work. Wash with soap and running water, with hands held downward to flush the contamination off the hands. Turn the tap off with a clean paper towel to prevent recontamination, and dry your hands with clean towels.

Confine long hair and loose clothing when in the laboratory to keep them from catching fire, dipping into chemicals, or becoming entangled in moving machinery. Avoid wearing finger rings and wrist watches which may become contaminated, react with chemicals, or be caught in the moving parts of equipment.

Remove laboratory coats and gloves before you leave the laboratory to prevent spreading contamination to other areas. Keep a clean spare coat to wear outside the laboratory. Do not wear gloves outside the laboratory.

5.2 Personal Protective Clothing and Equipment

Personal protective clothing and equipment protects you from injury due to absorbing, inhaling, or coming into physical contact with hazardous materials. Some protection is afforded by ordinary clothing and eyeglasses. You have a responsibility to dress sensibly for laboratory work. Laboratory clothing protects workers' own clothing. You are responsible for using special protective clothing and equipment when they are required for safety. Protective wear may include laboratory coats, wraparound gowns, cloth masks, coveralls, aprons, gloves, shoe covers, and respirators. Select garments and fabric based on the nature of the hazardous agent.

Personal protective clothing and equipment shall be used and maintained in a sanitary and reliable condition and shall be cleaned regularly to avoid spreading contamination. Noncontaminated laboratory coats can be cleaned by any laundry service/dry cleaner. If you have contaminated coats contact the SHyS.

Laboratory coats shall never be washed at home. Regular clothing that is suspected of being contaminated shall be evaluated by SHyS for a proper decontamination or disposal method. It shall not be washed with or come into contact with other personal laundry.

5.2.1 Clothing. Cover unprotected skin whenever possible. Suitable clothing shall be worn in the laboratory; shorts are not appropriate. Clothing may absorb liquid spills that would otherwise come in contact with your skin. Long sleeves protect arms and shall fit snugly, especially when you are working around machinery. Wool affords more protection from flash burns or corrosive chemicals than cotton or synthetic fabrics. Synthetic fabrics may increase the severity of injury in case of fire. Cotton is less prone to static electricity buildup than nylon or other synthetics.

Wear substantial leather shoes in the laboratory to protect against chemical splashes or broken glass. Do not wear sandals, cloth sport shoes, perforated shoes, or open-toed shoes. If you clean up a spill from the floor, you may need the added protection of rubber boots or plastic shoe covers. Steel-toed shoes are required for handling heavy items, such as gas cylinders or heavy equipment components.

Aprons, laboratory coats, gloves, and other protective clothing, preferably made of chemically inert material, shall be readily available and used. Laboratory coats are essential to protect street clothing from biological agent aerosols or chemical splashes and spills, vapors, or dusts. For work involving carcinogens, disposable coats may be preferred. For work with mineral acids, acid-resistant protective wear is desirable. See Table 5.1 for properties of protective clothing materials.

When the potential for fire exists, consider wearing a laboratory coat specifically designed to be flame retardant. Several types of flame-resistant clothes are available from safety suppliers. A low-cost option is a disposable cotton coat that has been treated with a flame-resistant material. The treatment slows combustion and provides an additional level of protection from fire and heat. However, repeated washing degrades the chemical treatment and compromises fire protection.

More durable flame-resistant cotton laboratory coats are also available. One brand, Indura, employs a special finishing process that improves washability over standard fire-resistant cotton fabrics. A fabric known as Nomex provides the best protection against flame hazards. This material has a structure that thickens and carbonizes when exposed to heat. This unique characteristic gives Nomex lab coats excellent thermal protection. Because the characteristics of the material are inherent to the fiber, repeated laundering does not change the thermal protection capabilities. The drawback is that these coats are very expensive relative to treated and untreated cotton coats.

5.2.2 Eye Protection. Eye protection is mandatory in laboratories because of the obvious hazards of flying objects, splashing chemicals, and corrosive vapors. Eyes are very vascular and can quickly absorb many chemicals. Regulations require protective eye and face equipment where there is a reasonable probability that using them can prevent injury. Eye protection shall be required in all laboratories where chemicals are used or stored. Eye protection is not interchangeable among employees and shall be provided for each individual unless disinfected after use.

Safety glasses with clear side shields are adequate protection for general laboratory use. Goggles shall be worn when there is danger of splashing chemicals or flying particles, such as when chemicals are poured or glassware is used under elevated or reduced pressure. A face shield with goggles offers maximum protection (for example, with vacuum systems that may implode).

Corrective lenses in spectacles do not in themselves provide sufficient protection. Regulations require that persons whose vision requires corrective lenses, and who are required to wear eye protection, shall wear goggles over their eyeglasses, prescription safety glasses, or goggles with prescription lenses. These options are also recommended for persons who customarily wear contact lenses. If contact lenses are worn, they should not be handled in the laboratory and shall be worn with regularly required eye protection, such as plastic goggles.

Wearing of contact lenses in laboratories. Recent studies have produced varying views on the issue of contact lens use in laboratories. Traditional safety lore claimed that contaminated aerosols or particulate matter would concentrate behind contact lenses and cause permanent eye damage. In contradiction to this assumption, some researchers have found that contact lenses may minimize injuries to the eye from metal particles, paint fumes, and chemical splashes from solvents and acids.

Table 5.1 Properties of Protective Clothing Materials*

Materials	Properties					
	Strength	Chemical Resistance	Flammability	Static Properties	Comfort	Uses
Cotton	Fair durability	Degraded by acids; binds	Special treatment for flame	No static problems	Comfortable, lightweight	Lab coats
Modacrylic	Resistant to rips and tears but less so than polyamide fibers; abrasion-resistant but less so than nylon or polyester	Resistant to most chemicals	In direct flame, fabric shrinks to resist flame penetration; will not melt or drip; self-extinguishing; rapidly dissipates when source of ignition is removed	Has antistatic properties	Comfortable, soft, and resilient; easy to clean; has soil release properties	Lab coats
Nylon	Exceptionally strong and abrasion resistant	Not water absorbent	Melts when heated; requires flame retardant	Static buildup possible; requires antistatic agent	Lightweight	Lab coats
Plastic	Usually reinforced at points of strain;	Resistant to corrosive	Can be ignited by flammable	Accumulates considerable	Lightweight	Aprons, sleeve

	will not stick together, peel, crack, or stiffen	chemicals	solvents and others in event of static discharge	charge of static electricity		protectors, boots
Polyolefin	Resistant to rips and tears	Excellent chemical resistance; low binding for chemicals	High melting point; flame-resistant	Good static dissociation	Lightweight; good permeability; limited moisture absorbency; wearer perspiration may cause discomfort	Bouffant caps
Polypropylene	Strong	Resistant to most chemicals; oxygen and light-sensitive	Low melting point; requires flame retardant	Static buildup; requires antistatic agent	Lightweight	Aprons
Rayon	Fairly durable			Degraded by acids; binds some chemicals		Lab coats

*Based on manufacturer's claims.

From *Chemical Safety Manual for Small Businesses*, American Chemical Society, second edition, 1992.

It was once thought that chemicals are absorbed into the lens and concentrated, causing more significant irritation and possible burns. Instead, new information indicates that eyelid spasm seals off the area of the cornea under the lens. Also, contact lenses are probably beneficial because they provide far superior vision correction than spectacles. They give the same field of vision as the normal eye whereas spectacles reduce it. Theoretically, better sight may result in fewer accidents since distorted vision would be less of a potential factor.

An unresolved controversy rages among safety professionals, though it seems that evidence on the side of lens use acceptability is growing. In 1998, the American Chemical Society removed its prohibition against the wearing of contact lenses in labs. The FCEN's policy is to allow each individual principal investigator or laboratory supervisor to enforce the rule which (s)he supports. PIs may choose to ban contact lens use from the lab or allow use of contacts with appropriate eye protection such as safety glasses or goggles.

If contact lenses are to be permitted, lab personnel shall be trained to understand that lenses may be difficult to remove in the case of a splash. Training should include the following warnings:

- Copiously irrigate the eye with water, as you would for any splash.
- Hold the eyelids apart and keep the eye open as wide as possible.
- Do not worry about losing the lens!
- If the lens cannot be removed quickly, use a suction-type contact lens remover.

PIs should consider having the suction removers available in the lab's first aid kit.

5.2.3 Gloves. Gloves are worn to prevent contact with toxic or biological agents, burns from hot or extremely cold surfaces or corrosives, or cuts from sharp objects. Skin contact is a source of exposure to infectious agents and toxic chemicals, including carcinogens. Many gloves are made for specific uses. For adequate protection, select the correct glove for the hazard in question.

A leather glove provides good protection for picking up broken glass, handling objects with sharp edges, and inserting glass tubing into stoppers. However, because they absorb liquid, leather gloves do not provide protection from chemicals, nor are they adequate for handling extremely hot surfaces. Gloves designed to insulate against hot surfaces and dry ice are not suitable for handling chemicals.

Inspect gloves for punctures or tears before putting them on. To prevent contamination of your hands or work surfaces, wash rubber or plastic gloves thoroughly with water before removing them. Pull off

disposable gloves inside out and dispose of them according to the contamination hazard. Always remove contaminated gloves before leaving the laboratory. Always wash your hands after removing gloves, **before** leaving the work area, and before eating, drinking, smoking, or applying cosmetics.

The chemical resistance of rubber or plastic gloves varies greatly according to the glove material and the chemical handled. Consult SHyS for information before selecting and using laboratory gloves or see the sources listed below.

Specific information pertaining to resistance can be found in *The Chemical Protective Clothing Performance Index Book* by Forsberg and Keith (John Wiley and Sons, 1989) or the Instant GLOVES + CPC© computer database, accessible through the SHyS server.

Chemicals can eventually permeate all glove materials. Select glove materials resistant to the chemical being used, and change gloves periodically to minimize penetration. The chemical resistance of common glove materials varies according to the glove manufacturer, as manufacturers may vary the thicknesses and formulations of materials. Call the manufacturer to verify that a particular glove material is suitable for the chemical in use.

Latex Gloves. In practice, most labs tend to rely on latex as the staple for glove supplies for general laboratory use. Due to the prevalence of allergies to natural latex proteins, SHyS recommends substitution of latex gloves with nitrile or neoprene ones. Although these alternate glove materials may vary from latex in the range of typical lab chemicals to which they are rated as resistant, they do exhibit longer breakthrough times for those chemicals to which all three are acceptable. This is an added benefit to the avoidance of allergies.

Be aware that there are notable exceptions in performance between these gloves. Nitrile offers no protection for acetone use but is the preferred protection over latex for ethanol, formaldehyde, and mineral oil. This variability is a convincing argument as to why it is important to carefully check resistance charts for specific gloves.

See the SHyS publication "*Allergic Reactions to Latex Gloves*" at latex.htm for more information about latex allergies.

5.2.4 Respirators. When feasible, engineering controls shall be provided to minimize airborne hazards. If accepted engineering control measures are not available to prevent or protect against harmful levels of airborne contaminants, employers are required to provide respirators at no cost to employees and employees are required to wear them. Respirators are considered a last resort of protection against exposure to inhalation hazards after all practicable engineering options have been exhausted.

Persons desiring to use a respirator shall inform SHyS and obtain information on the requirements. These requirements are mandated by the National Regulations and are described in the FCEN's *Respiratory Protection Program*.

A hazard evaluation shall be conducted to determine whether the employee or student is required to wear a respirator or whether engineering controls can eliminate the hazard. If the need for a respirator is established, the wearer must register with SHyS.

The potential respirator wearer must meet certain qualifications before being allowed to wear a respirator. El Médico Laboral (ML) shall review an annual, confidential medical questionnaire submitted by the wearer. Based on the questionnaire, the ML may recommend a physical examination. A medical history of respiratory or heart disease could preclude the use of a respirator.

SHyS will select an appropriate respirator for protection against a given contaminant and evaluate it in terms of the range of contaminants to which an employee is exposed during a particular procedure. It is the PI or supervisor's responsibility to provide and pay for the respirator. Employees are prohibited from purchasing their own respirator.

Fit testing is required before the employee or student first wears the respirator and annually thereafter. Fit testing is necessary to establish that the chosen respirator seals to the face properly to prevent

inward leakage of contaminants. Respirator wearers shall receive interactive training in respirator use, limitations, and care. The respirator shall be cleaned and disinfected on a regular basis and inspected before and after each use.

Respirators shall not be worn when conditions prevent a good facepiece-to-face seal, as with beard growth, sideburns, or dentures. With full-face respirators, temple bars on eyeglasses interfere with the sealing edge of the facepiece.

5.3 General Laboratory Protocol

All laboratory protocols shall include basic safety precautions. These include personal hygiene, work practices, and the appropriate personal protective clothing and equipment needed to protect you from exposure to chemicals or biological agents. Each situation is unique, and safety aspects shall be assessed individually as described in your laboratory's *Plan de Protección*. Some of the fundamental principles of laboratory operation are described below.

5.3.1 Housekeeping. Keeping things clean and organized helps provide a safer laboratory. Keep drawers and cabinet doors closed and electrical cords off the floor to avoid tripping hazards. Keep aisles clear of obstacles such as boxes, chemical containers, and other storage items that might be put there even temporarily. Avoid slipping hazards by cleaning up spilled liquids promptly and keeping the floor free of stirring rods, glass beads, stoppers, and other such items. Never block or even partially block the path to an exit or to safety equipment such as a fire extinguisher or safety shower.

Put ordinary wastepaper in a wastepaper basket separate from chemical wastes. Broken glass and other sharp items shall be disposed of in rigid, puncture-resistant containers to protect persons collecting the waste materials. Needles and syringes that are not contaminated may be sealed in a rigid, puncture-resistant container and placed in a regular waste receptacle. When discarding empty boxes or other containers bearing hazardous materials labels, the labels shall be defaced or removed before disposal. Contaminated boxes or containers shall not be disposed of in the regular trash.

Chemical wastes and unwanted chemicals shall be disposed of promptly and not left to clutter a laboratory. The procedure is described in Section 6.0. Infectious waste management is described in Section 7.0. Additional information on disposal of human body fluids or other potentially infectious materials appears in the *Bloodborne Pathogens Program*.

5.3.2 Cleaning Glassware. When cleaning laboratory glassware, wear appropriate gloves that have been checked for tears or holes. Avoid accumulating too many articles in the cleanup area around the sink; space is usually limited, and piling up glassware leads to breakage. Do not clean food containers in a sink that is used for cleaning contaminated glassware.

Many fingers have been badly cut by broken glass from glassware that was intact when put into the sink water. Handle glassware carefully and watch out for broken glass at the bottom of the sink. A rubber or plastic mat in the sink will help minimize breakage.

Avoid using strong cleaning agents such as nitric acid, chromic acid, sulfuric acid, strong oxidizers, or any chemical with "per" in its name (perchloric acid, ammonium persulfate, etc.) unless no alternatives are available. The prefix "per" signifies a state of completeness or extremity. In a chemical name, it denotes 1) a compound containing an element in its highest state of oxidation, such as perchloric acid; 2) the presence of the peroxy group (-O-O-), as in peracetic acid; or 3) exhaustive substitution or addition, as in perchloroethylene.

If you must use these substances for cleaning, you should be thoroughly familiar with their hazardous characteristics and use appropriate protective equipment. Flammable solvents such as acetone should be used in minimum quantities for cleaning and with appropriate precautions taken during their use. Acids and solvents shall not be rinsed down the drain during cleaning but shall be collected for proper treatment and disposal.

5.3.3 Laboratory Animals. National regulations require that the Animal Care and Use Committee review and approve the use of animals in research. The Bioterio administers all activities related to the care and use of animals.

Laboratory animals may be potential sources of hazardous chemical exposure from metabolic products, wastes, cage litter, and contaminated cages. The preparation of food and water containing toxic substances under investigation shall be done with all precautions ordinarily taken to protect the health and safety of personnel. The Bioterio Laboratory Standard guidelines for animal work with chemicals of high chronic toxicity shall be followed. The guidelines cover administration of the toxic substance, aerosol suppression, personal protection, and waste disposal. Contact SHyS for the text of the guidelines.

Another possible concern in handling laboratory animals is the potential for exposure to inherent biological hazards. Aside from the biological agents to which the animals are deliberately exposed, lab animals may harbor indigenous pathogens that can be transmitted to humans. This is of particular concern with nonhuman primates.

In the case of macaque monkeys, animal handlers may contract *Cercopithecine herpesvirus* ([CHV-1], commonly referred to as *Herpesvirus simiae* or "B-virus") infection that can be deadly. The virus is primarily transmitted through bites, scratches, or other contamination of broken skin; however, a fatality due to a splash of a macaque's body fluid in the eye has been reported. The high risk of infection places particular importance on the wearing of personal protective equipment to prevent exposure. Animal handlers working with macaques and other nonhuman primates shall always don appropriate gloves, surgical masks, splash goggles, and lab coats or other suitable covering that leaves no exposed skin or mucous membranes.

5.3.4 Relocating or Closing a Laboratory. Guidelines are available from SHyS to assist you in safely relocating laboratory chemicals or biological agents within the FCEN.

All chemicals that will not be relocated shall be listed on a *Surplus Chemical Collection Form*. The form shall be completed before the principal investigator relinquishes possession of the vacated laboratory. Disposition of all unwanted chemicals is the responsibility of the principal investigator. The department of record is responsible for the safe and lawful cleanup and disposition of all chemicals and biological materials that are abandoned. All biological materials shall be autoclaved or chemically disinfected and disposed of before the laboratory is vacated.

The principal investigator is responsible for ensuring that surfaces and equipment potentially contaminated with hazardous chemicals or biological agents are decontaminated before the laboratory is vacated. Accessible surfaces (chemical fume hoods, sinks, benchtops) should be cleaned, when practical, by the principal investigator and staff. If this is not possible, an outside contractor specializing in the testing and cleaning of contaminated laboratory equipment should be contacted. The principal investigator shall provide the contractor with thorough and accurate information pertaining to the past uses of the equipment.

To confirm that a vacated lab is properly emptied of hazardous materials, decontaminated, and ready for new occupants, the principal investigator or laboratory supervisor shall prepare the *Laboratory Closeout Checklist*. This form is available from SHyS or on the Web and shall be signed by the respective department head (or designee). Should the principal investigator fail to complete the items required on the form, the department becomes financially and administratively responsible for the safe disposition of the hazardous materials and the decontamination of work surfaces.

SHyS offers a laboratory survey to any principal investigator vacating a lab to assist in identifying the tasks that must be finished for clearance of the space. SHyS will require a completed *Laboratory Closeout Checklist* when performing final services such as chemical waste removal for the lab.

5.3.5 Transportation of Hazardous Materials. A personal vehicle shall not be used to transport hazardous materials. The National laws requires that a licensed hazardous materials transporter be employed if hazardous materials are transported on a public highway or by air or water. It is also requires that all individuals offering a hazardous material for transport receive training. The material to be shipped shall be properly packaged in accordance with all applicable regulations and appropriate shipping papers shall be provided.

Biological materials shall be shipped in compliance with National Lwas.

5.3.6 Laboratory Doors. Fire and life safety codes as well as FCEN policy require that laboratory doors be kept closed at all times. Keeping doors closed also helps ensure that ventilation systems work properly and maintain contaminant-containing pressure differentials between labs and corridors.

5.3.7 Visitors to Laboratories. Do not allow visitors, including children and pets, in laboratories where hazardous substances are stored or are in use or hazardous activities are in progress. Students from primary and secondary schools occasionally may enter laboratories as part of educational programs under carefully controlled and supervised conditions. Colleagues, prospective students, and others may be invited into laboratories for legitimate academic and research purposes. Each individual working in a laboratory should prudently evaluate the risks to visitors, especially to persons of increased risk such as children and immunosuppressed individuals. This may be especially important in facilities such as animal quarters.

5.4 General Laboratory Techniques

5.4.1 Laboratory Ventilation. Laboratories shall be provided with general ventilation adequate for employee comfort and sufficient to supply air for chemical fume hoods and other local ventilation devices. Because the general air supply is not adequate for manipulating hazardous materials on an open lab bench, volatile or toxic chemicals shall be handled in a chemical fume hood or other appropriate containment device.

Laboratory ventilation shall change the air at least 10 times per hour, depending on the nature of the laboratory work. Except in special circumstances approved by SHyS, air in laboratories shall be at a negative pressure with respect to the rest of the building. Air diffusers or grilles shall be so designed and located as to direct the air over the laboratory personnel and sweep the contaminated air away from their breathing zone. To promote uniform distribution and mixing of air in large laboratories, the supply registers shall deliver the air in all directions, at a typical velocity of 20 linear feet per minute.

Problems with general ventilation shall be reported promptly to Secretaría Técnica. Adjustments or alterations to the general ventilation equipment of a laboratory shall be performed only under the supervision of Secretaría Técnica.

On occasion, Secretaría Técnica will issue notices of intent to perform maintenance work on the ventilation system. These notices shall be heeded and chemical fume hoods shall not be used when Secretaría Técnica is involved in repairing or adjusting the ventilation system. The supervisor of the laboratory is responsible for ensuring that the Secretaría Técnica crew is informed of the hazards in the area. The chemical fume hood shall be cleared of toxic materials and properly decontaminated before the work begins. Facilities Management will likely request SHyS to inspect the chemical fume hood prior to maintenance or repair work. Be prepared to supply a detailed history of chemical and biological agent use in the chemical fume hood for safety evaluation purposes.

5.4.2 Chemical Fume Hoods. A chemical fume hood is an important engineering control for preventing exposure to hazardous materials. In conjunction with sound laboratory techniques, a chemical fume hood serves as an effective means for capturing toxic, carcinogenic, offensive, or flammable vapors or other airborne contaminants that would otherwise enter the general laboratory atmosphere. With the sash lowered, the chemical fume hood also forms a physical barrier to protect workers from hazards such as chemical splashes or sprays, fires, and minor explosions. Chemical fume hoods may also provide effective containment for accidental spills of chemicals, although this is not their primary purpose.

The deliberate release and venting of chemicals (i.e., evaporation) in chemical fume hoods shall **never** be used as a means of disposal.

Turbulence is the greatest enemy to proper chemical fume hood operation. It can lead to backspill of contaminants out of the chemical fume hood. The operator has significant control over the factors that cause turbulence and, consequently, the chemical fume hood's capture efficiency.

For example, chemical fume hoods are not meant for storage of chemicals. Storing chemical containers and equipment in a chemical fume hood impairs its performance. The containers and

equipment create turbulence as airflow is diverted around them. Volatile and odorous chemicals and highly toxic gases shall be stored in ventilated cabinets.

If chemical containers or bulky devices must be maintained in the chemical fume hood during an experiment, they should be elevated two to three inches above the interior work surface using jacks, apparatus scaffolding, support stands, ring stands, metal bars or stilts, etc. Materials remaining directly on the work surface block the incoming air and propel it back toward the chemical fume hood face. The elevation of materials in the chemical fume hood allows air to pass unimpeded to the bottom exhaust opening at the chemical fume hood's back wall.

Turbulence is also created at the face of the chemical fume hood when obstacles to airflow such as containers and equipment are too close to the sash. Containers and equipment should always be moved six inches back from the inner edge of the air sill. This practice can reduce vapor concentrations at the chemical fume hood face by about 90 percent.

Even the movement of one's hands can interrupt airflow patterns and disturb proper circulation of exhaust air. When reaching into the chemical fume hood, take care to move your hands slowly with smooth gestures and no jerking. If working at a chemical fume hood with a horizontal sash, use one of the panes as a barrier to splashes. Position the pane directly in front of you and move your hands on opposite sides of the pane.

Apparatus in chemical fume hoods shall be fitted with traps, condensers, or scrubbers to remove toxic fumes, gases, vapors, or dusts before venting to the atmosphere. Chemical fume hood performance is also dependent on the room's air flow pattern, including airflow generated by drafts and persons walking by. Minimize traffic and opening and closing of doors near the chemical fume hood. When the chemical fume hood is in use, the sashes should be pulled down as far as workable for minimal external airflow interference and maximum barrier protection.

Chemical fume hoods used for hazardous chemicals shall have an average face velocity of 80 to 100 feet per minute at a minimum sash height of twelve inches. Face velocity shall not exceed 120 fpm at the working sash height.

Compounds such as perchloric acid or aqua regia are likely to cause chemical fume hood corrosion. Please refer to Section 6.7 for further information with respect to perchloric acid.

Chemical fume hoods shall be evaluated for performance upon installation and following any alterations. SHyS monitors chemical fume hoods annually. The fans and duct systems are maintained and inspected by Secretaría Técnica. Any problems with hood ventilation or air flow should be reported to SHyS or Secretaría Técnica for inspection and evaluation.

Refer to *The Chemical Fume Hood Handbook* for further information regarding optimum hood operation and an understanding of ventilation principles.

5.4.3 Safety Showers. Safety showers shall be installed in all areas where employees may be exposed to splashes or spills of materials that may be injurious to the eyes and body. Showers shall be placed as close to the hazard as possible, but in no case more than 10 seconds' travel time from the hazard. Department heads shall ensure that safety showers are installed in the department where needed.

Every laboratory employee shall be instructed in the location(s) and use of a safety shower. Ideally, a person should be able to find the shower with his or her eyes closed. Safety showers shall provide a minimum of 20 gallons of water per minute and deliver the volume at low velocity; a high-velocity shower could further damage injured tissue.

Ideally, the water temperature of the shower should be tepid to prevent pain or shock to a person standing under it for 15 minutes. Safety showers shall have quick-opening valves requiring manual closing so that a person does not have to hold the valve open while trying to undress or wash off. The pull handle shall be a delta bar or large ring within easy reach but not so low as to be in the way.

Because not all laboratories have safety showers, a "Safety Shower" sign shall be placed outside each room that has a shower. Flammable-liquid cabinets or other hazardous equipment or material shall not

be placed near a safety shower, and access to the shower or the activating handle shall not be impeded. The floor shall be clear in a 34-inch-diameter area under the shower.

Safety showers shall be tested and inspected at least annually. Inspection includes a visual check of visible plumbing and verification of proper operation. Secretaría Técnica conducts the annual tests and maintains related records. Contact Secretaría Técnica to schedule safety-shower testing if the shower you intend to use in an emergency has not been tested in the last 12 months.

5.4.4 Eyewash Fountain. An eyewash providing a continuous, low-pressure stream of aerated water shall be provided as close to the hazard as possible, but in no case more than 10 seconds' travel time from the hazard. The eyewash shall be easily accessible from any part of the laboratory. If possible, the eyewash should be located near the safety shower so that, if necessary, the eyes can be washed while the body is showered.

Eyewash fountains shall supply 0.4 gallons of water per minute for 15 minutes. The three basic kinds of eyewash fountains are the fixed-base shower, much like a drinking fountain, with arm or foot-pedal operation, faucet-mounted units, and the handheld-hose type, with aerating nozzle(s) and lever-operated valve. The main criteria are that, whichever eyewash chosen:

- it shall activate within one second
- it shall provide hands-free continuous operation once activated
- the flushing streams shall rise to approximately equal heights and the flushing fluid will wash both eyes simultaneously.

Contact SHyS for information on the types of eyewashes available.

Gravity-feed eyewash devices (wall-mounted or on mobile carts) are not recommended unless they provide adequate water supply for 15 minutes of eye washing and the stored water is treated so that it does not become microbially contaminated. For such units, a documented monthly maintenance program shall be established to ensure that the water supply remains in satisfactory and usable condition. Bottle-type portable eyewashes are not acceptable, as they do not have the capacity to deliver 0.4 gallons of water per minute.

Principal investigators are responsible for ensuring that eyewash fountains in their labs are tested monthly to ensure that the valves operate properly, the required volume and aerated stream are available, and the pipes or hose are cleared of sediment that might collect.

5.4.5 First Aid Kits. Principal investigators are responsible for supplying at least one first aid kit for their lab groups. This kit shall not be shared between lab groups. The kit should be stored in the main lab and be easily accessible to any other lab locations that belong to a particular group. If the same group occupies labs that are not in immediate proximity (i.e., labs in different buildings or on different floors), a first aid kit shall be available for each set of adjacent labs. Each lab member shall be trained to know where the kit is located.

The first aid kit should contain the items recommended in the *First Aid Kit Policy and Guidelines for Laboratories*, available from SHyS or on the Web. It shall be inspected monthly to ensure that no items are missing and that none of the remedies (e.g., saline solution, ointment) in the kit have expired. The inspections shall be documented (an inspection record is included in the policy).

The SHyS and CS recommend CPR and first aid training for at least two lab members in each lab group. Such training can be arranged through the SHyS.

5.4.6 Laboratory Sinks and Drain Traps. Every laboratory using chemical or biological agents shall have at least one sink, preferably located near the room exit, available for handwashing. The sink shall be cleaned regularly to eliminate contamination, and soap shall be supplied for handwashing. Antimicrobial soaps are not necessary. They tend to dry the user’s skin by stripping natural oils.

Drain traps in sinks, floors, and other places will dry out if they are not used regularly, allowing odors and contamination to back up into the room. Drain traps shall be kept filled with water to prevent backup. Also fill cup sinks on benches and in chemical fume hoods.

5.4.7 Electrical Equipment. Electrical currents of very low amperage and voltage may result in fatal shock under certain circumstances. Voltages as low as 24 volts AC can be dangerous and present a lethal threat. Low-voltage DC circuits do not normally present a hazard to human life, although severe burns are possible. The duration of contact with a live circuit affects the degree of damage, especially with regard to burns.

All electrical switches shall be labeled, including circuit breakers in the service panels, and all laboratory personnel shall know where these controls are and how to shut off circuits or equipment in case of fire or other accident. Any electrical equipment that is not operating properly or seems to be overheating shall be turned off immediately and inspected by a qualified technician.

Electrical equipment should be inspected periodically to confirm that the cords and plugs are in safe condition. Circuit diagrams, operating instructions, descriptions of hazards, and safety devices are usually provided by the manufacturer and should be kept on file for reference.

Only three-wire grounded, double insulated, or isolated wiring and equipment shall be used in 220V AC applications. All wiring and equipment shall comply with the IRAM Code. In specifically designated laboratories, cold rooms, or storage rooms or other locations where concentrations of flammable vapor-air mixtures are likely to occur, certified explosion-proof wiring and equipment, including light fixtures, switches, refrigerators, and telephones, shall be used. If you have any questions with regard to the code, contact the SHyS.

Series-wound motors with carbon brushes, typically found in household appliances such as blenders and mixers, are not spark-free and shall not be used in laboratories where flammable vapors accumulate. Equipment manufactured for use in laboratories generally contains induction motors.

Electrical extension cords should be avoided, where practical, by installing additional electrical outlets. Only electricians from Secretaría Técnica are permitted to make electrical modifications in FCEN properties. When extension cords are used, the wire gauge shall be equal to or larger than the size of the cord being supplied by them. Electrical cords on equipment shall be discarded or repaired if frayed or damaged. Cords should be kept as short as practical to avoid tripping hazards and tangles.

Place electrical equipment so as to minimize the possibility that water or chemicals could spill on it or that water could condense and enter the motor or controls. In particular, place such equipment away from safety showers. In cold rooms, condensation can be minimized by mounting electrical equipment on walls or vertical panels.

Only qualified individuals are permitted to make electrical repairs to any kind of electrical equipment. All electrical equipment shall be deenergized and tagged or locked out according to SHyS requirements before repairs are made. If adjustments or other contact are to be made with energized electrical equipment, a second person shall be present. Be sure you are not on a damp surface or touching a potential grounding surface. Use insulated tools, keep your hands dry, and wear safety glasses to prevent injury from sparks.

If a worker receives an electrical shock and is in contact with the energized device, use nonconductive gloves or a nonconducting device to pull or push the victim free from the electrical source. Help victims only if you are certain that you will not endanger your own safety. Turn off or disconnect the power source if possible. Call Departamento de Seguridad y Control en el 311 Pab II o 507 Pab I. If a trained person is available, start CPR if necessary. Get medical assistance at once.

5.4.8 Static Electricity. Static electricity may be generated whenever two surfaces are in contact with one another. Examples are processes such as evaporation, agitation, pumping, pouring of liquids, or grinding of solids or powders. Equipment used in these operations shall be bonded and grounded to prevent static charges from accumulating on the containers. Blanketing with inert gas may also prevent sparks in equipment where flammable vapors are present. Static electricity is increased by low absolute humidity, as is likely in cold weather. Some common potential sources of electrostatic

discharges are ungrounded metal tanks and containers; metal-based clamps, nipples, or wire used with nonconducting hoses; high-pressure gas cylinders upon discharge; and clothing or containers made of plastic or synthetic materials.

5.4.9 Centrifuges. If a tabletop centrifuge is used, make certain that it is securely anchored in a location where its vibration will not cause bottles or equipment to fall. Ensure that the disconnect switch is working properly and shuts off the equipment when the top is opened. Centrifuge rotors shall be balanced each time they are used. Securely anchor and shield each unit against flying rotors. Regularly clean rotors and buckets with noncorrosive cleaning solutions.

Always close the centrifuge lid during operation, and do not leave the centrifuge until full operating speed is attained and the machine appears to be running safely without vibration. Stop the centrifuge immediately and check the load balances if vibration occurs. Check swing-out buckets for clearance and support.

5.4.10 Vacuum Pumps. If vacuum pumps are used with volatile substances, the input line to the pump shall be fitted with a cold trap to minimize the amount of volatiles that enter the pump and dissolve in the pump oil. The exhaust from evacuation of volatile, toxic, or corrosive materials shall be vented to an air exhaust system. A scrubber or trap may also be required.

If pump oil becomes contaminated with toxic chemicals, it will exhaust the chemicals into the room air during future use. Pump oil shall be changed if it becomes contaminated. Dispose of used pump oil with SHyS.

Before using the vacuum pump, ensure that the moving parts have been properly guarded and that there are no exposed points of operation (i.e., exposed belt) that could nip a finger or catch hair or clothing. Wear eye protection when working with a vacuum pump or setting up the cold trap assembly.

5.4.11 Drying Ovens and Furnaces. Volatile organics shall not be dried in ovens that vent to the room air. Glassware rinsed with organics should not be oven dried unless it is first rerinsed with water. Bimetallic strip thermometers rather than mercury thermometers are recommended for measuring oven temperatures. If a mercury thermometer breaks in an oven, the oven shall be turned off and cooled before cleanup is attempted. See Section 6.0 for information regarding cleanup of mercury spills, or contact SHyS.

Wear heat-resistant gloves and appropriate eye protection when working at ovens or furnaces. ANSI-approved eyewear (i.e., heat-absorbing, reflective goggles) offers protection against projectiles and infrared radiation.

5.4.12 Syringes and Scalpel Blades. Syringes used with hazardous agents shall have needle-locking or equivalent tips to assure that the needles cannot separate during use. Disposal of needles and syringes contaminated with infectious agents is described in Section 7.0. **Do not recap needles after use**. Recapping of needles potentially contaminated with human blood, blood products, or other potentially infectious materials is prohibited.

Syringes, needles, or scalpels shall be disposed of immediately after use in sealable, puncture-resistant, disposable containers that are leakproof on the sides and bottom. The containers shall be appropriately labeled as to the chemical or biological hazard. Sharps containers shall be easily accessible to personnel in the immediate area of use.

5.4.13 Facility Cleaning and Maintenance. A custodial service has been contracted to wet-mop floors (including laboratory space) on a weekly basis. However, building services and custodial staff are prohibited from cleaning up chemical and biological materials (including spills), and custodians shall not be expected to mop any floors that have not been properly decontaminated after a spill.

In preparation for the cleaning service, the laboratory staff shall remove hazards that the custodians might encounter during their activities. Chemical containers on the floor and all containers of biohazardous waste shall be moved by laboratory occupants to a safe and secure location before custodians enter the lab. In the event that a supervisor does not wish a particular laboratory to be

disturbed, custodial floor cleaning can be suspended on request of the area occupants. To have the mopping discontinued, contact Secretaría Técnica and post a sign on the lab.

Likewise, if maintenance is required on any component of the laboratory, such as a sink or piece of equipment, the same principles of preparation apply. The supervisor shall ensure that the immediate area is decontaminated and any infectious agents or chemicals are removed to another secure area prior to initiation of work. The laboratory supervisor shall inform maintenance personnel of the presence of any hazardous materials to which they might become exposed.

Cleaning duties that are the specific responsibility of laboratory personnel shall be conducted on a regular basis to prevent accidental contact with hazards and to reduce clutter in the lab space. Laboratory equipment, including refrigerators, freezers, and work surfaces, shall be cleaned by laboratory staff. In laboratories using large amounts of powdered carcinogens, reproductive toxins, or acutely toxic materials, lab workers should avoid dry mopping or sweeping with a broom if this could cause the materials to become airborne.

Facility maintenance and custodial staff shall not handle or remove hazardous waste bags or other containers.

5.4.14 Glassware. Borosilicate glassware, such as Pyrex 7740, is the type preferred for laboratory experimentation, except in special experiments involving ultraviolet or other light sources or hydrofluoric acid, for which polypropylene containers are most appropriate. Measuring glassware, stirring rods, tubing, and reagent bottles may be ordinary soft glass. Vacuum or suction flasks shall be designed with heavy walls. Dewar flasks and large vacuum vessels shall be taped or otherwise screened or contained in metal to prevent glass from flying if they should implode. An ordinary thin-walled thermos bottle is not an acceptable replacement for a Dewar flask.

Because it can be damaged in shipping, handling, or storage, inspect glassware carefully before using it to be sure it does not have hairline cracks or chips. Even the smallest flaw renders glassware unacceptable and possibly dangerous. Flawed glassware shall be discarded in a rigid, puncture-resistant broken-glass bin. Where the integrity of glassware is especially important, it can be examined in polarized light for strains.

5.4.15 Assembling Apparatus. Operations that may generate airborne contaminants or that use flammable liquids or toxic, reactive, or odoriferous materials shall be conducted in a chemical fume hood or other appropriate containment enclosure. Whenever hazardous gases or fumes are likely to evolve, an appropriate trap, condenser, or scrubber shall be used to minimize release of material to the environment.

Apparatus should be set up well back from the edge of the work area, be it a bench or a hood. When assembled in a hood, apparatus should not obstruct the area. To avoid overflow, choose apparatus with at least 20 percent more capacity than would normally accommodate the volume of chemical planned for the operation. All parts of the apparatus shall be firmly balanced and supported. Tubing shall be fastened with wire or appropriate clamps.

Stirrer motors and vessels shall be positioned and secured to ensure proper alignment. Magnetic stirring is preferable, and nonsparking motors or air motors shall be used in any laboratory that might contain flammable vapors.

Funnels and other apparatus with stopcocks shall be firmly supported and oriented so that gravity will not loosen the stopcock plug. Use a retainer on the stopcock plug and lubricate glass stopcocks. Do not lubricate Teflon stopcocks.

Include a vent in apparatus for chemicals that are to be heated and place boiling stones in unstirred vessels. If a burner is to be used, distribute the heat with a ceramic-centered wire gauze. Insert a thermometer in heated liquids if dangerous exothermic decomposition is possible. This will provide a warning and may allow time to remove the heat and apply external cooling.

A pan under a reaction vessel or container will confine spilled liquids in the event of glass breakage.

If a hot plate is used, be sure that its temperature is less than the autoignition temperature of the chemicals likely to be released and that the temperature control device does not spark. Whenever possible, use controlled electrical heaters or steam in place of gas or alcohol burners.

5.4.16 Eliminating Mercury Thermometers. Metallic mercury is highly toxic by skin absorption, inhalation, and ingestion. Lab workers face limited potential exposure whenever they break mercury-filled thermometers. The mercury contamination may infiltrate cracks in benches and the floor or spread beneath equipment and instruments. The contamination is insidious and difficult to remove completely. The difficulty is magnified if the thermometer breaks in a water bath or sink.

One of the best methods for eliminating this hazard and metallic mercury in labs is to replace all mercury thermometers with nonmercury instruments. Alternatives to mercury thermometers are spirit-filled or digital units. SHyS strongly urges you to substitute nonmercury thermometers whenever possible.

5.4.17 Fire Extinguisher Policy. Fire extinguishers are provided by the FCEN in corridors, public areas, laboratories, and other locations where required by building and life safety code. Missing extinguishers should be reported to SHyS. SHyS will inspect and maintain all fire extinguishers, both inside and outside laboratories.

5.4.18 Special Precautions Against Ultraviolet Light. Germicidal lamps using ultraviolet light are common fixtures in biological safety cabinets, where they serve to destroy bacteria and molds. These lamps are considered a high-level source of UV radiation; exposure to the lamps without adequate personal protection could result in skin or eye injury.

Acute skin effects due to direct UV exposure vary with dose. Dermal effects include three types: erythema (sunburn), increase in pigmentation (suntanning), and hyperplasia (increase in epidermal cell growth, resulting in enlargement of tissue). UV radiation may also increase the cutaneous effects of certain solvents and photosensitizing chemicals.

Eye injuries attributable to UV exposure are most prevalent among welders. Laboratory applications are unlikely to achieve doses comparable to those in industrial settings, but a small amount of UV light may produce temporary eye injury, such as corneal inflammation and "sand-in-the-eye" sensation.

A great concern with UV eye exposure is that the victim is often unaware that damage is occurring. Usually, no pain develops from the eye injury until four to six hours after the exposure. The only way to prevent injury is to minimize eye exposure to UV light.

Appropriate protection against UV exposure includes long sleeves and laboratory gloves. For individuals particularly sensitive to UV light, suntan lotion on the exposed skin of the face is recommended. ANSI-approved shaded eye protection with side enclosures shall be worn in the vicinity of a UV light fixture not shielded by a physical barrier.

5.5 Signs and Labels for Laboratories

The following signs and labels are required for all laboratories in FCEN facilities:

- An "Emergency Information" sign shall be posted outside all laboratories, either on the outside of the door or on the wall beside the door. This sign provides information on specific hazards in the laboratory, special precautions, personal protective equipment, and telephone numbers of responsible faculty and staff. The information provided on these signs, as with all other signs, shall be updated as necessary.
- A red-bordered "Emergency Procedures for Laboratories" sign shall be posted in a prominent location inside the laboratory, near the door or telephone. This sign briefly describes what to do in case of an emergency.
- A label bearing the Departamento de Seguridad y Control emergency number shall be placed on each telephone in the laboratory.

Principal investigators and laboratory supervisors may request additional signs and labels as listed on the *Signs and Labels Request Form* available from SHyS or on the Web.

5.6 Training

Training is required under the National Laws. FCEN policy prohibits persons without appropriate training from working in laboratories and other areas where hazardous chemicals are used. National law mandates training at the time of initial assignment to a laboratory or work area where hazardous chemicals are present or exposure to bloodborne pathogens is possible. Additional training is required on introduction of a new chemical or biological exposure hazard or new or modified tasks and procedures which affect occupational exposure. Refresher training shall be conducted annually for persons working in areas of potential exposure to chemical hazards and bloodborne pathogens.

Principal investigators shall ensure that laboratory personnel are properly trained and shall certify training on the *Plan de Protección*. An agenda of required training for employees and students (including summer and work-study students) who handle hazardous chemicals appears in the *Hazard Communication Program*. Bloodborne pathogens training information may be found in the *Bloodborne Pathogens Program*.

Training materials to assist the principal investigator or department head are available from SHyS. In addition, SHyS can provide general safety seminars for laboratory or department groups. SHyS training is general in nature; principal investigators are required to provide specific safety training in the particular hazards of their laboratories.

6.0 CHEMICAL HAZARDS

> "What is it that is not poison? All things are poison, and nothing is without poison. It is the dose only that makes a thing not a poison."
> — Paracelsus (1493 - 1541)

6.1 Exposure to Chemicals

A thorough discussion of toxicity is beyond the scope of any single publication. Individuals who handle chemicals should supplement the information in this manual with specific details applicable to their laboratories. Such information is available in Material Safety Data Sheets (MSDSs) and other reference materials that are available at SHyS. The complex relationship between a material and its biological effect in humans involves considerations of dose, duration and frequency of the exposure, route of exposure, and many other factors, including sex, allergic factors, age, previous sensitization, and lifestyle.

6.1.1 Exposure Routes. Chemicals enter the body through the following routes:

- Inhalation — absorption through the respiratory tract by inhalation. This is probably the easiest way for chemicals to enter the body.
- Ingestion — absorption through the digestive tract by eating or smoking with contaminated hands or in contaminated work areas. Depending on particle or droplet size, aerosols may also be ingested.
- Skin or eye contact — absorption through the skin or eyes. Skin contact is the most common cause of the widespread occupational disease dermatitis. The eyes are very porous and can easily absorb toxic vapors that cause permanent eye damage.
- Injection — percutaneous injection through the skin. This can occur through misuse of sharp items, especially hypodermic needles.
- Toxic effects can be immediate or delayed, reversible or irreversible, local or systemic.

6.1.2 Acute and Chronic Toxicity. Toxicity is the measure of a poisonous material's adverse effect on the human body or its ability to damage or interfere with the metabolism of living tissue. Generally, toxicity is divided into two types, acute and chronic. Many chemicals may cause both types of toxicity, depending on the pattern of use.

Acute toxicity is an adverse effect with symptoms of high severity coming quickly to a crisis. Acute effects are normally the result of short-term exposures and are of short duration. Examples of acutely toxic chemicals are hydrogen cyanide and ammonia.

Chronic toxicity is an adverse effect with symptoms that develop slowly over a long period of time as a result of frequent exposure. The dose during each exposure period may frequently be small

enough that no effects are noticed at the time of exposure. Chronic effects are the result of long-term exposure and are of long duration. Carcinogens as well as many metals and their derivatives exhibit chronic toxicity.

Cumulative poisons are chemicals that tend to build up in the body as a result of numerous chronic exposures, leading to chronic toxicity. The effects are not seen until a critical body burden is reached. Examples of cumulative poisons are lead and mercury.

With substances in combination, such as exposure to two or more hazardous materials at the same time, the resulting effect can be greater than the combined effect of the individual substances. This is called a synergistic or potentiating effect. One example is concurrent exposure to alcohol and chlorinated solvents.

The published toxicity information for a given substance is general—human data may not be available—and the actual effects can vary greatly from one person to another. Do not underestimate the risk of toxicity. All substances of unknown toxicity should be handled as if they are toxic, with the understanding that any mixture may be more toxic than its most toxic component.

6.1.3 Carcinogenicity. A carcinogen is a chemical that causes malignant (cancerous) tumors. Individual carcinogens currently regulated are listed in Appendix A along with recognized and suspected carcinogens identified by other agencies. The use of carcinogens is regulated by the FCEN and requires submission of a *Plan de Protección*. Any chemical identified in Appendix A shall be handled as a known carcinogen.

6.1.4 Reproductive Toxins. Chemicals can affect both adult male and female reproductive systems. Chemicals may also affect a developing fertilized ovum, embryo, or fetus through exposure to the mother (teratogenic effects). Reproductive hazards affect people in a number of ways, including mental disorders, loss of sexual drive, impotence, infertility, sterility, mutagenic effects on cells, teratogenic effects on the fetus, and transplacental carcinogenesis. Consult the MSDS for information on possible reproductive hazards. The use of reproductive toxins is regulated by the FCEN and requires submission of a *Plan de Protección*.

6.1.5 Designated Area. Work involving selected carcinogens, reproductive toxins, and substances of high acute toxicity shall be conducted in a "designated area." This is a requirement of the FCEN Laboratory Standard. This area shall be so posted, and all employees working within the area shall be informed of the hazardous substances used there. The designated area may be a chemical fume hood, a part of a laboratory, or the entire laboratory.

6.1.6 Material Safety Data Sheets (MSDSs). MSDSs are the most basic source of chemical hazard information. The MSDS summarizes the chemical’s properties, the health and physical hazards, including the type of toxicity information discussed in the sections above, and related safety information required by emergency responders.Principal investigators or supervisors shall provide staff with easy access to MSDSs for each of the chemicals in use or storage in their labs. Contact SHyS for help in obtaining MSDSs.

6.1.7 Monitoring Airborne Concentrations of Contaminants. International Agencies has established permissible exposure limits (PELs) for airborne concentrations of selected materials. The PEL is defined as a time-weighted average (TWA) concentration of a particular substance for a normal eight-hour workday and a 40-hour workweek, a concentration to which nearly all workers may be exposed, day after day, without adverse effect.

Corollaries to the eight-hour PEL are the short-term exposure limit (STEL) and the ceiling exposure limit. The STEL is the time-weighted average concentration of a compound to which a worker may be exposed over a period of fifteen minutes without expecting symptoms of irritation, chronic or irreversible tissue damage, or narcosis. The ceiling is the concentration of a substance that should not be exceeded during any part of the working exposure. When instantaneous monitoring is not feasible, the ceiling limit is measured over a period of ten to fifteen minutes.

As the PELs were designed to protect workers in industrial settings, it is unlikely that these limits will be exceeded during the performance of laboratory procedures. Laboratory workers generally do not handle the same quantities of hazardous materials as do manufacturing and production employees

Nonetheless, exposure to airborne chemicals in laboratories shall not exceed PELs. If there is reason to believe that airborne concentrations may exceed PELs, contact SHyS for consultation on the need for air monitoring. PELs are listed on Material Safety Data Sheets, are available from SHyS, or may be found on the OSHA Web page (http://www.osha-slc.gov/OshStd_data/1910_1000_TABLE_Z-1.html). Please note that PELs have not been developed for all the compounds to which laboratory workers may be exposed. In all circumstances, caution shall be used in handling hazardous chemicals.

In addition to PELs, International Agencies has set action levels for specific compounds, such as formaldehyde, cadmium, and lead, for which individual standards have been promulgated. International Agencies has classified these compounds as potential carcinogens. The *Plan de Protección* discusses the specific requirements which apply to International Agencies-classified carcinogens. Action levels are concentrations of a chemical in air at which International Agencies regulations to protect workers take effect.

If monitoring of airborne concentrations reveals that levels are above the International Agencies action level, then levels shall either be immediately reduced by a procedural change or equipment modification or the department head and principal investigator shall comply with the requirements of the International Agencies standard for the chemical. International Agencies regulations govern periodic monitoring and termination of monitoring, as well as employee notification. Medical surveillance may be a requirement.

For chemicals without regulated action levels, the general rule is that half the PEL may be considered a de facto action level. Engineering controls shall be instituted to reduce exposure to the hazardous substance in question.

6.2 Guidelines for Handling Chemicals

The chemical handling guidelines described in this document are founded on several basic principles:

- Substitute less hazardous chemicals whenever possible
- Minimize chemical exposures
- Avoid underestimating risk
- Provide adequate ventilation

Since most chemicals are hazardous to some degree, it is prudent to minimize exposure to chemicals as a general rule, rather than implementing safety protocols only for specific compounds. Avoid skin contact with chemicals as much as possible. Assume that mixtures are more toxic than their components and that all substances of unknown toxicity are toxic. Do not work with a volatile or aerosolizing material without adequate ventilation from chemical fume hoods or other protective devices. Remember: Prepare yourself, then protect yourself.

6.2.1 General Guidelines. The following guidelines are applicable to nearly all uses of chemicals in laboratories. They apply to most hazardous chemicals, such as acids, bases, and flammable liquids. They are also applicable to chemicals that display low carcinogenic potency in animals and are not considered carcinogens.

The general guidelines are not, by themselves, adequate for chemicals with high acute toxicity or high chronic toxicity such as heavy metals, chemical carcinogens, or reproductive toxins.

1. Wear eye protection at all times where chemicals are used or stored.
2. Wear a lab coat or other protective clothing (e.g., aprons).
3. Wear gloves selected on the basis of the hazard. Inspect them before use. Wash reusable gloves before removal. Turn disposable gloves inside out carefully when removing to avoid contaminating hands.

4. Wash hands immediately after removing gloves, after handling chemical agents, and before leaving the lab, even though you wore gloves.
5. Lab coats and gloves are worn only in the lab. They are not taken outside the lab to lunch rooms or offices nor are they worn outdoors. Lab coats shall be cleaned frequently.
6. Confine long hair and loose clothing.
7. Wear sturdy shoes that cover feet completely.
8. Do not store or prepare food, eat, drink, chew gum, apply lip balm or cosmetics, or handle contact lenses in areas where hazardous chemicals are present.
9. Check with your supervisor regarding contact lens policy in your lab. If wearing them is acceptable, take appropriate precautions such as informing other lab occupants and having a suction-type removal device in your first aid kit.
10. Food is stored in cabinets or refrigerators designated for such use only.
11. Never pipette or start a siphon by mouth.
12. Label all chemical containers (see Section 6.5.1).
13. Chemical storage is by hazard class (see Section 6.7). Chemicals are not stored merely by alphabetical order (see Section 6.5).
14. Never smell or taste chemicals. Again, label containers properly to avoid confusion about contents.
15. Keep work areas clean and uncluttered.
16. Keep personal belongings away from chemicals.
17. Obtain an MSDS for each chemical, and consult the MSDS before you use a chemical.
18. Know the emergency procedures for the building, the department, and the chemicals being used.
19. Vent into local exhaust devices any apparatus that may discharge toxic vapors, fumes, mists, dusts, or gases. Never release toxic chemicals into cold rooms or warm rooms that have recirculating atmospheres.
20. Use chemical fume hoods or other engineering controls to minimize exposure to airborne contaminants.
21. Properly handle, collect, and dispose of surplus and waste chemicals (see Section 6.8).

6.2.2 Guidelines for Working with Chemicals of Acute Toxicity. Chemicals of acute toxicity are defined by OSHA as those that cause rapid effects as a result of a short-term exposure-generally sudden and severe, as in the case of a leak from equipment. Acute toxic effects include irritation, corrosion, sensitization, and narcosis.

To illustrate, hydrofluoric acid (HF) is a chemical of high acute toxicity because of its destructive effect on skin and bone tissue. Arsine and other hydrides may be lethal at low concentrations because of red blood cell hemolysis. Inhalation of high concentrations of carbon monoxide can cause immediate poisoning and death, as the gas directly interferes with oxygen transport in the body by preferentially binding to hemoglobin. Hydrogen cyanide inhalation inhibits enzyme systems vital to cellular uptake of oxygen.

When working with significant quantities of such chemicals, the aim is to minimize exposure to the material. Special care should be taken in the selection of protective clothing to ensure it is appropriate for the hazard. Personal hygiene and work practices should also be carefully evaluated to minimize exposure. The following guidelines should be practiced *in addition* to the general guidelines for handling chemicals.

1. When performing procedures that may result in the release of airborne contaminants, use a chemical fume hood.
2. Trap or treat effluents to remove gases, fumes, vapors, and particulates before discharging them to facility exhaust.
3. Restrict access to the laboratory or work area.
4. Establish and label a "designated area" for work with acutely toxic chemicals. Keep materials within the designated area.
5. Use plastic-backed paper or trays under work areas. Replace the paper when contaminated.
6. Develop and know special emergency procedures. Keep emergency supplies at hand for immediate use. When hydrofluoric acid is in use, the first aid kit should contain HF antidote

gel. See the First Aid Kit Policy and Guidelines for Laboratories for purchasing and application information.

6.2.3 Guidelines for Chemicals with High Chronic Toxicity, Carcinogens, and Reproductive Toxins. In addition to the general guidelines for handling chemicals, use the following guidelines for handling chemicals with high chronic toxicity, which include most heavy metals, chemicals displaying moderate to high carcinogenic potency in animals, and reproductive toxins.

1. For carcinogens, determine if the chemical is regulated by International Agencies in a substance-specific standard. If so, the principal investigator or lab supervisor shall document a hazard evaluation. See your *Plan de Protección*.
2. Designated work and storage areas shall be established for carcinogens, chemicals with high chronic toxicity, and reproductive toxins. Materials shall be kept within the designated area to the extent possible.
3. Designated work and storage areas for chemical carcinogens, including chemical fume hoods and refrigerators, shall be labeled "Chemical Carcinogen." The outer door to the laboratory shall also be labeled "Chemical Carcinogen."
4. Designated work and storage areas used for chemicals with high chronic toxicity or reproductive toxins shall be labeled "Toxic Chemical" or "Toxic Substance."
5. Access procedures shall be used if work involves moderate or greater amounts of carcinogens or moderate to lengthy procedures. These procedures may include:
    - closed doors
    - restricted access-only authorized personnel permitted
    - written access procedures posted on the outer door.
6. Cover laboratory surfaces, including chemical fume hood surfaces, with plastic-backed paper or protective trays. Inspect work surfaces following procedures, and remove the paper if contamination is present. Dispose of the used paper as hazardous waste.
7. Disposable gloves shall be disposed of as hazardous waste. Wash reusable gloves before removing them. Contact SHyS prior to washing to determine if the wash water must be collected for disposal as a hazardous waste.
8. Transport highly toxic or carcinogenic materials through public areas, such as hallways, in closed containers within unbreakable outer containers. Sealed plastic bags may be used as secondary containment in many cases.
9. To avoid potential inhalation hazards, handle powdered carcinogens and toxins in a chemical fume hood, even during weighing procedures. Inside the chemical fume hood, measure the powder with a spatula into a preweighed vessel then seal or cover the vessel, remove it from the chemical fume hood, and take it to the balance to be weighed. If more or less material is needed, return the container to the chemical fume hood for addition or subtraction of material. Close the container again and reweigh it. Repeat these steps until the desired amount is obtained. This procedure eliminates contamination of the air, the work bench, and the scale. Procedures generating either solid or liquid airborne contaminants or involving volatile chemicals are always to be performed in a chemical fume hood.
10. Vacuum pumps shall be protected against contamination (e.g., traps and filters in lines) and vented into direct exhaust ventilation. Pumps and other equipment and glassware shall be decontaminated before they are removed from the designated area. The designated area shall be decontaminated before other normal work is conducted. Vacuum pump oil shall be collected as a contaminated waste and disposed of through SHyS.
11. Water vacuum lines shall be equipped with traps to prevent vapors from entering the wastewater stream.
12. Floors shall be wet-mopped or cleaned with a high-efficiency particulate air filter (HEPA) vacuum cleaner if powdered materials are used.

6.3 Chemical Emergency Procedures

6.3.1 Procedures for Spills of Volatile, Toxic, or Flammable Materials.

1. Warn all persons nearby.
2. Turn off any ignition sources such as burners, motors, and other spark-producing equipment.
3. Leave the room and close the door if possible.

4. Call al Departamento de Seguridad y Control Int. 311 Pab II o 507 Pab. I to report the hazardous material spill. El Departamento de Seguridad y Control will contact SHyS emergency response personnel at anytime to respond to hazardous material spills.
5. **Small spills** can be absorbed with paper towels or other absorbents. However, these materials can increase the surface area and evaporation rate, increasing the potential fire hazard if the material is flammable and airborne concentration reaches the flammability level.

6.3.2 Procedures for Chemical Spill on a Person.

1. Know where the nearest eyewash and safety shower are located.
2. For small spills on the skin, flush immediately under running water for at least fifteen minutes, removing any jewelry that might contain residue. If there is no sign of a burn, wash the area with soap under warm running water. Exception: only five minutes of flushing for HF burns. Proceed to aggressive antidote gel application as soon as possible. The antidote is the best hope of preventing permanent bone or tissue damage.
3. If pain returns after the fifteen-minute flooding, resume flooding the area (but not for HF spills). When providing assistance to a victim of chemical contamination, use appropriate personal protective equipment.
4. For a chemical splash in the eyes, immediately flush the eyes under running potable water for fifteen minutes, holding the eyes open and rotating the eyeballs. This is preferably done at an eyewash fountain with tepid water and properly controlled flow. Hold the eyelids open and move the eye up, down, and sideways to ensure complete coverage. Use an irrigator loop to thoroughly flush the conjunctiva under the upper eyelid, if available in your first aid kit. If no eyewash fountain is available, put the victim on his or her back and gently pour water into the eyes for fifteen minutes or until medical personnel arrive. If HF is splashed in the eye, flush for five minutes and then irrigate the eye with a 1% solution prepared from the calcium gluconate antidote gel.
5. For spills on clothing, immediately remove contaminated clothing, including shoes and jewelry, while standing under running water or the safety shower. When removing shirts or pullover sweaters, be careful not to contaminate the eyes. Cutting off such clothing will help prevent spreading the contamination. To prepare for emergencies, shears (rounded-tip scissors) should be available in the first aid kit to allow safe cutting of contaminated clothing.
6. Consult the MSDS to see if any delayed effects should be expected, and keep the MSDS with the victim. Call al Departamento de Seguridad y Control to have the victim taken to the emergency room for medical attention. Be sure to inform emergency personnel of the decontamination procedures used prior to their arrival (for example, flushing for fifteen minutes with water). Be certain that emergency room personnel are told exactly what the victim was contaminated with so they can treat the victim accordingly.

6.3.3 Procedure for Cryogenic Liquid Spill on a Person. Contact with cryogenic liquids may cause crystals to form in tissues under the spill area, either superficially or more deeply in the fluids and underlying soft tissues. The first aid procedure for contact with cryogenic liquids is identical to that for frostbite. Rewarm the affected area as quickly as possible by immersing it in warm, but not hot, water (between 102° and 105° F). Do not rub the affected tissues. Do not apply heat lamps or hot water and do not break blisters. Cover the affected area with a sterile covering and seek assistance as you would for burns.

6.3.4 Incidental Spills—Procedure for Small, Low-Toxicity Chemical Spills. Be prepared. Keep appropriate spill-containment material on hand for emergencies. Consult with SHyS to determine which materials are suitable in a particular lab.

Laboratory workers must receive training to distinguish between the types of spills they can handle on their own and those spills that are classified as "MAJOR." Major spills dictate the need for outside help.

Laboratory workers are qualified to clean-up spills that are "incidental." International Agencies defines an incidental spill as a spill that does not pose a significant safety or health hazard to employees in the immediate vicinity nor does it have the potential to become an emergency within a short time frame. The period that constitutes a short time is not defined. Laboratory workers can

handle incidental spills because they are expected to be familiar with the hazards of the chemicals they routinely handle during an "average" workday. If the spill exceeds the scope of the laboratory workers' experience, training or willingness to respond, the workers must be able to determine that the spill cannot be dealt with internally.

Emergency assistance is provided by SHyS or an outside agency. Spills requiring the involvement of individuals outside the lab are those exceeding the exposure one would expect during the normal course of work. Spills in this category are those which have truly become emergency situations in that laboratory workers are overwhelmed beyond their level of training. Their response capability is compromised by the magnitude of the incident.

Factors that clearly indicate a major spill are:

- the need to evacuate employees in the area
- the need for response from outside the immediate release area
- the release poses, or has potential to pose, conditions that are immediately dangerous to life and health
- the release poses a serious threat of fire and explosion
- the release requires immediate attention due to imminent danger
- the release may cause high levels of exposure to toxic substances
- there is uncertainty that the worker can handle the severity of the hazard with the PPE and equipment that has been provided and the exposure limit could be easily exceeded
- the situation is unclear or data is lacking regarding important factors.

The following steps shall be followed for **incidental spills**:

1. Alert persons in the area that a spill has occurred.
2. Evaluate the toxicity, flammability, and other hazardous properties of the chemical as well as the size and location of the spill (for example, chemical fume hood or elevator) to determine whether evacuation or additional assistance is necessary. Large or toxic spills are beyond the scope of this procedure.
3. Contain any volatile material within a room by keeping doors closed. Increase exhaust efficiency by minimizing sash height of the chemical fume hood or activating the emergency purge, if available.
4. Consult your MSDS, the laboratory emergency plan, or procedures in this document, or call SHyS for correct cleaning procedures.
5. Obtain cleaning equipment and protective gear from SHyS, if needed.
6. Wear protective equipment such as goggles, apron, laboratory coat, gloves, shoe covers, or respirator. Base the selection of the equipment on the hazard.
7. First, cordon off the spill area to prevent inadvertently spreading the contamination over a much larger area.
8. Absorb liquid spills using paper towels, spill pillows, vermiculite, or sand. Place the spill pillow over the spill and draw the free liquid into the pillow. Sprinkle vermiculite or sand over the surface of the free liquid.
9. Place the used pillows or absorbent materials in plastic bags for disposal along with contaminated disposable gear, such as gloves.
10. Neutralize spills of corrosives and absorb, if appropriate. Sweep up waste and place in plastic bags for disposal.
11. Complete a *Surplus Chemical Collection Form*. SHyS will pick up the wastes.
12. Complete an *Incident Report* describing the spill and send a copy to SHyS. A copy may be kept by the department head, if required.

Note: Information for specific chemicals may be found in Table 6.1, "Quick Reference for Spill Cleanups," and Section 6.3.5, "Mercury Spill Procedure." Consult the MSDS and your laboratory's Safety Plan, which has specific information on spill procedures for your workplace.

6.3.5 Mercury Spill Procedure. Mercury is a high-density, low-viscosity liquid at room temperature. During a spill, it can form tiny droplets that adhere to surfaces and enter cracks and crevices. SHyS

has a mercury vacuum and mercury vapor analyzer available to assist with large or difficult-to-clean mercury spills. In the case of small mercury spills (e.g., mercury-containing thermometers), laboratory personnel should be able to handle the cleanup. Cleanup kits are available from SHyS.

To minimize the spill hazard, place a splash plate beneath all mercury-containing equipment.

Procedures for small mercury spills:
Equipment needed – Mercury Spill Kit from SHyS

Mercury vacuum pump, eyedropper, water or vacuum drive aspirator (optional)
Chemical amalgam
Laboratory coat
Gloves
Shoe protectors
Glass or plastic collection container
Plastic bags
Wipes or paper towels
Barricade tape

1. Before entering the contaminated area, put on protective clothing.
2. Establish a cleanup area and section it off to avoid spreading mercury.
3. Draw all visible mercury into a glass or plastic collection container.
4. Sprinkle the contaminated area with chemical amalgam. Wet with a little water.
5. Wipe up the powder from the contaminated area with a wet towel or a damp sponge impregnated with chemical amalgam. Repeat steps 4 and 5.
6. Sprinkle a very light coating of chemical amalgam into the cracks and crevices.
7. Dispose of the contaminated solid waste material (such as boots, gloves, wipes, or thermometer glass) in a plastic bag and seal tightly.
8. Dispose of the collected mercury and the bags of waste through SHyS. Do not bring the waste bag to SHyS; it will be picked up from your laboratory. Store the bag in a chemical fume hood until it is collected by SHyS.
9. The principal investigator shall ensure that an *Incident Report* is completed and sent to SHyS.

6.4 Medical Surveillance

6.4.1 When is Medical Surveillance Required?

Signs and Symptoms. Whenever an employee or student develops signs or symptoms associated with a hazardous chemical exposure, that person shall be provided an opportunity to receive an appropriate medical examination.

Exposure Monitoring. If exposure monitoring reveals that the airborne concentration of a chemical is above the action level or the permissible exposure limit (if no action level is set) for a chemical regulated by International Agencies, medical surveillance shall be implemented for affected persons as prescribed in the International Agencies standard for the material.

Spills, Leaks, and Other Releases. If a spill, leak, explosion, or other occurrence results in the likelihood of a hazardous chemical exposure, affected employees shall be provided an opportunity for a medical consultation. The consultation will determine whether there is a need for a medical examination.

6.4.2 Medical Consultation and Evaluation. Medical consultation and evaluation shall be performed buy the ART.

The principal investigator or laboratory supervisor shall ensure that the following information is provided to the physician: the identity of the chemical involved in the exposure, a description of

conditions relating to the exposure, any quantitative data available regarding the exposure, and a description of signs and symptoms experienced by the affected person.

The principal investigator or laboratory supervisor shall ensure that the following information is obtained from the physician in writing:

- Recommendation for medical follow-up.
- Results of the medical examination and associated tests.
- Any medical condition revealed in the course of the examination that may place the affected person at increased risk as a result of the exposure.
- A statement that the physician has informed the affected person of the results of the consultation or examination and any medical condition that may require further treatment.
- The physician shall not reveal specific findings or diagnoses unrelated to the chemical exposure. All medical records shall be kept as part of an employee's or student's permanent file.

Table 6.1 Quick Reference for Spill Cleanups

Chemical Spilled	Cleanup
Acids, organic	Apply sodium bicarbonate. Absorb with spill pillow or vermiculite.
Acids, inorganic	Apply sodium bicarbonate/calcium oxide or sodium carbonate/calcium oxide. Absorb with spill pillow or vermiculite. **Note:** Hydrofluoric acid is an exception to this general practice; see below.
Acid chlorides	Do not use water. Absorb with sand or sodium bicarbonate.
Aldehydes	Absorb with spill pillow or vermiculite.
Aliphatic amines	Apply sodium bisulfite. Absorb with spill pillow or vermiculite.
Aromatic amines	Absorb with spill pillow or vermiculite. Avoid skin contact or inhalation.
Aromatic halogenated amines	Absorb with spill pillow or vermiculite. Avoid skin contact or inhalation.
Azides (potential explosives)	Absorb with spill pillow or vermiculite. Decontaminate with 10% ceric ammonium nitrate solution.
Bases (caustic alkalis)	Neutralize with acid or commercial chemical neutralizers and absorb with spill pillow or vermiculite.
Carbon disulfide (flammable and toxic)	Absorb with spill pillow or vermiculite.
Chlorohydrins	Absorb with spill pillow or vermiculite. Avoid skin contact or inhalation.
Cyanides	Wet or mist solids before sweeping, or use a HEPA filter vacuum to collect the solids. Absorb liquids with spill pillow or vermiculite.
Halides, organic or inorganic	Apply sodium bicarbonate.
Halogenated hydrocarbons	Absorb with spill pillow or vermiculite.
Hydrazine	Absorb with spill pillow or vermiculite. Avoid organic matter.
Hydrofluoric acid	Absorb with calcium carbonate (or calcium oxide) rather than sodium bicarbonate. The use of sodium bicarbonate will lead to the formation of sodium fluoride, which is considerably more toxic than calcium fluoride. Be careful in the choice of spill pillows used to absorb the acid. Certain pillows contain silicates that are incompatible with hydrofluoric acid.
Inorganic salt solutions	Apply soda ash.
Mercaptans/organic sulfides	Neutralize with calcium hypochlorite solution. Absorb with spill pillow or vermiculite.
Nitriles	Sweep up solids. Absorb liquids with spill pillow or vermiculite.
Nitro compounds, organic nitros	Absorb with spill pillow or vermiculite. Avoid skin contact or inhalation.
Oxidizing agents	Apply sodium bisulfite.
Peroxides	Absorb with spill pillow or vermiculite.
Phosphates, organic and related	Absorb with spill pillow or vermiculite.
Reducing substance	Apply soda ash or sodium bicarbonate.
Reference: *Reagent Chemicals*, MCB Manufacturing Chemists, Inc., 1981, pp. 359-402.	

6.4.3 Medical Surveillance for Chemicals of High Chronic Toxicity. Routine medical surveillance may be warranted for individuals working with chemicals of high chronic toxicity, including carcinogens.

Although no restriction of hiring can be made, candidates for work with carcinogens shall be informed of the possibility of increased risk associated with these conditions:

- Strong family history of cancer, comprising at least two first-generation relatives from maternal and paternal ancestry or a specific pattern of cancer incidence that can be recognized as a genetic trait.
- A precancerous condition or past history of cancer.
- A history of exposure to therapeutic doses of radiation.
- A history of treatment with cytotoxic drugs.
- A history of impaired immunity or current use of therapeutic doses of steroids or other immunosuppressive drugs.
- Concurrent pregnancy or likelihood of pregnancy during employment.

Job tasks for certain workers using chemicals of high chronic toxicity should be evaluated to determine whether these workers should be temporarily excluded from work or reassigned to less hazardous activities. This is particularly appropriate for pregnant women or persons receiving immunosuppressive drugs or therapy.

6.5 Chemical Storage

6.5.1 Chemical Labels. Label all containers of hazardous chemicals in accordance with the Internatonal Agencies Hazard Communication Standard. Each container of and/or apparatus with hazardous chemical contents in the lab shall be labeled with the following information:

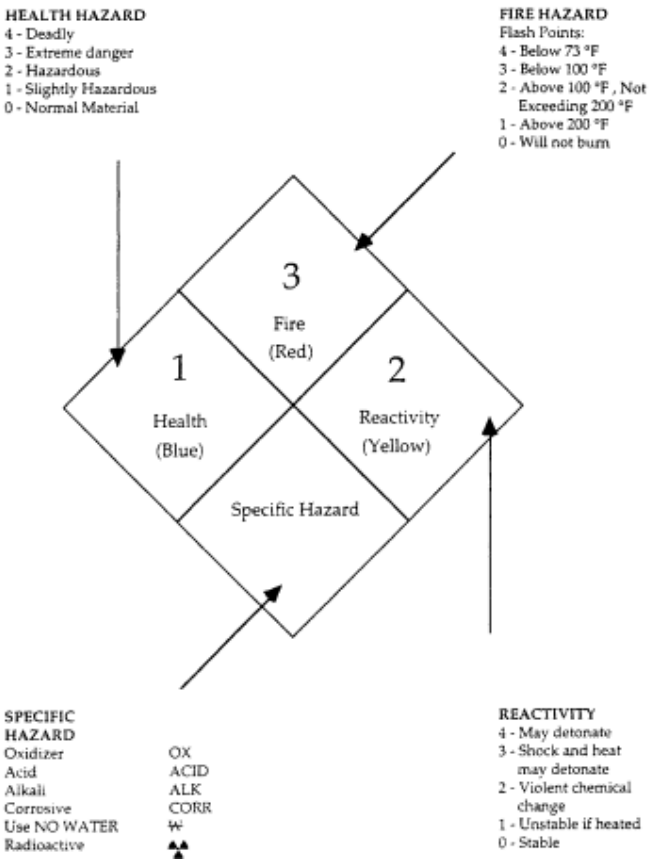
- identity of the hazardous chemical(s)
- hazard warnings in words, pictures, symbols, or a combination thereof, which provide at least general information regarding the hazards of the chemical(s)

See the *Hazard Communication Program* for further labeling guidance.

6.5.1.1 Sistema Adoptado por la FCEN

El sistema adoptado por la FCEN, conocido como NFPA 704, is one of the most widely used marking systems. Be prepared to recognize these markings on containers received from vendors. Be aware that this labeling system does not in itself meet the requirements of the Hazard Communication Standard.

The system was originally devised for industry to use on such facilities as storage tanks or buildings so that firefighters could assess the hazard from a safe distance and better evaluate what fire-fighting techniques to employ. The system can also be useful in situations other than fires when used on container labels or room doors so that a person



working in the room or area can quickly determine the degree of hazard of a particular chemical. Several kinds of kits with pressure-sensitive diamonds and separate numbers in several sizes can be purchased from safety supply distributors.

The system does not provide any detailed hazard information and does not supersede the need for posting the other required information (such as the name of the chemical and the name of the manufacturer) on a portable container label. The diamond-shaped label shown identifies three categories of hazards in three squares of different colors. The blue square at the left indicates health hazard, the red square at the top indicates flammability, and the yellow square at the right indicates reactivity.

The degree of severity under fire conditions is indicated numerically by five divisions ranging from 0 to 4, with 0 indicating no hazard and 4 indicating severe hazard. Any special hazard, such as unusual reactivity with water, is indicated in a white square at the bottom of the diamond.

6.5.1.2 HMIS System

In addition to the NFPA 704, another frequently used marking system is that of the Hazardous Materials Identification System (HMIS). This system does not meet all the requirements of the Hazard Communication Standard.

HMIS uses the same numbering system as NFPA 704 for health, flammability, and reactivity hazards, but the label includes some additional information.

The identity of the chemical (chemical or trade name) is shown at the top of the label. Instead of the three colored diamonds used by NFPA 704, the HMIS uses colored bars (blue for health, red for flammability, yellow for reactivity), each with its separate numerical coding. As in NFPA 704, the degree of hazard is expressed in a numerical rating on a scale of 0 to 4, with 0 denoting a minimal hazard and 4 a severe hazard.

A white bar at the bottom of the label contains a letter representing one or more personal protective devices that must be used when handling that substance. The label also specifies chronic health hazards.

6.5.1.3 Chemical Dating

Chemicals shall be dated on receipt in the laboratory and on opening. This information provides a history of the chemicals in each container and guides future researchers as to potential quality of the chemicals stored in the laboratory. Providing container-opening dates is especially important for peroxide-forming chemicals such as ethers, dioxane, isopropanol, and tetrahydrofuran that could pose an explosion hazard. Solutions shall be labeled and dated when prepared. Chemicals shall be removed from the laboratory if they are past their expiration date.

6.5.2 Chemical Compatibility.

Chemicals shall be stored only with other compatible chemicals (see Table 6.2 for classes of incompatible chemicals). Do not store them alphabetically, except within a grouping of compatible chemicals. Chemical groupings are listed below, and their storage arrangement is shown in a picture of a laboratory below.

- Highly toxic (poisons) and habit-forming organic chemicals.
- Flammable organic chemicals and organic acids.
- Organic bases and other organic compounds.
- Inorganic (mineral) acids and inorganic oxidizers (some additional separation may be required because of the reactivity of these materials).
- Inorganic bases, reducers, and salts.

Take into account specific chemical incompatibilities in all storage of chemicals (see Table 6.3). For example, nitric and chromic acids are incompatible and shall not be stored together. Nitric acid and organic compounds together present a dangerous fire risk. Carcinogenic chemicals are to be stored with others of a similar grouping based on their properties.

6.5.3 Storage Facilities.

Highly toxic chemicals (such as cyanide, cacodylic acid), shock-sensitive chemicals (such as solid sodium azide or picric acid), and habit-forming chemicals (amyl nitrite) shall be stored in locked cabinets to prevent theft.

Peroxide-forming chemicals and those that may become **shock-sensitive** with long-term storage shall be stored separately and shall be labeled and dated. Peroxide-forming chemicals shall be stored in a cool, dark, dry place.

Flammable liquids shall be stored in flammable-liquid cabinets if the laboratory contains a total of 10 gallons or more, **including** flammable liquid wastes.

Volatile or highly odorous chemicals shall be stored in a well-ventilated area; a ventilated cabinet is preferable. Chemical fume hoods shall not be used for storage, as containers block proper air flow in the hood and take up work space.

Storage areas for **carcinogens** shall be labeled "Chemical Carcinogen." This requirement for cancer-warning labels applies even to chemicals that exhibit more than one hazard (e.g., carcinogenic and flammable).

6.5.4 Inspection of Stored Chemicals.

6.5.4.1 Storage Area

Chemical storage areas shall be inspected at least annually and any unwanted or expired chemicals shall be removed. During this inspection, the list of chemicals present in the laboratory shall be updated or verified and the date and name of the inspector recorded.

6.5.4.2 Inspections

Although the deterioration in storage of a specific compound cannot be predicted in detail, generalizations can often be made about the reaction characteristics of groups of compounds. Some general conclusions about the stability of classes of chemicals can be reached, and corresponding storage time spans can be identified. Visual inspection of stored chemicals is important in the disposal decision.

Chemicals showing any of the indications listed below shall be turned over to SHyS for safe disposal:

- Slightly cloudy liquids.
- Darkening or change in color.
- Spotting on solids.
- Caking of anhydrous materials.
- Existence of solids in liquids or liquids in solids.
- Pressure buildup in containers.
- Evidence of reaction with water.
- Corrosion or damage to the container.
- Missing or damaged (i.e., illegible) labels

6.5.5 Refrigerator Storage. Flammable liquids shall not be stored in ordinary domestic refrigerators. Refrigerator temperatures are almost universally higher than the flash points of flammable liquids, and ignition sources are readily available inside the storage compartment. Furthermore, the compressor and its circuits are typically located at the bottom of the units, where vapors (from flammable liquid spills or leaks, for example) may easily accumulate.

Some domestic refrigerators can be modified to become "explosion-safe," permitting storage of flammable liquids. The modifications to the units include relocation of manual temperature controls to the exterior of the storage

compartment, removal of light switches and assemblies, and replacement of positive mechanical door latches with magnetic door gaskets. The primary intent of these modifications is to eliminate ignition of vapors inside the storage compartment by removing ignition sources within the compartment. To inquire whether a particular domestic refrigerator can be modified, contact the manufacturer for possible conversion.

Ideally, labs requiring refrigerator storage for flammable liquids shall purchase explosion-safe models that require no modification. Under no circumstances should lab workers attempt to perform modification themselves. Modification may only be conducted by manufacturer representatives who will certify the safety of the work.

Please note that "explosion-safe" refrigerators are not "explosion-proof." "Explosion-proof" refers to refrigeration equipment that has been designed to protect against ignition of flammable vapors both inside and outside the storage compartment.

If refrigerators are not "explosion-safe" or "explosion-proof," they shall be labeled "Caution. Not approved for flammable liquid storage." Self-adhering stickers are available from SHyS. Flammable liquids shall not be stored in cold rooms that do not have explosion-proof wiring and fixtures. Such storage facilities pose explosion hazards because the various control switches and defroster heaters can spark and ignite flammable vapors.

Chemicals stored in refrigerators or cold rooms shall be sealed and labeled with the name of the person who stored the material, in addition to the labeling requirements under Section 6.0. Old chemicals shall be disposed of after a specified storage period.

Food shall not be stored in a refrigerator used for chemical storage. The refrigerator shall be labeled "Food Must Not Be Stored in This Refrigerator" or equivalent. Refrigerators used for food shall be marked "Food Only" or equivalent and shall not be in the work area.

CHEMICAL STORAGE SCHEMATIC

I - Poisons and Habit Formers	II - Inorganic Bases and Inorganic Reducers/Salts	III - Carcinogens	IV - Organic Bases and Organic Compounds	V - Inorganic Acids and Oxidizers	VI - Flammable Organics and Organic Acids
Storage: Locked cabinet or shelf segregated from less hazardous material.	**Storage:** Cabinets above or below eye level, separated from organics.	**Storage:** In any other storage areas, according to the carcinogen's chemical properties.	**Storage:** Cabinets above or below eye level, separated from inorganics.	**Storage:** Corrosive cabinets or shelving under benchtop.	**Storage:** Flammable cabinets or shelving under benchtop.
For extremely hazardous agents.	It is recommended that more hazardous chemicals be stored below eye level.	It is recommended that all such storage areas be labeled with "Cancer Hazard" signs.	It is recommended that more hazardous chemicals be stored below eye level.		

EXAMPLES OF CHEMICALS STORED BY HAZARD

Poisons and Habit Formers	Inorganic Bases and Inorganic Reducers/Salts	Carcinogens	Organic Bases and Organic Compounds	Inorganic Acids and Oxidizers	Flammable Organics and Organic Acids
Poisons: • Arsenic trioxide (carcinogen) • Sodium azide (solid may be shock-sensitive) • Sodium cacodylate (solid)	**Inorganic Bases:** • Ammonium hydroxide • Potassium hydroxide • Sodium hydroxide **Inorganic Reducers:**	• Acrylamide • Aflatoxins • Aniline • Benzene • Benzidine • Carbon tetrachloride • Chloroform • 3,3'-Diamino-benzidine • Ethidium bromide	**Organic Bases:** • Diaminopentane • Diethylamine • Hexamethyleneimine **Organic Compounds:** • Dextrose • Ethylenediaminetetraacetic acid (EDTA)	**Inorganic Acids:** • Chromic acid (separate from nitric) • Hydrochloric acid • Hydrofluoric acid • Nitric acid (separate from	**Flammable Organics:** • Acetone • Benzene (carcinogen) • Diethyl ether (peroxide-former) • Ethanol • Pyridine • Tetrahydrofuran (peroxide-

• Sodium nitroprusside • Strychnine • Tetrodotoxin **Habit Formers:** • Amyl nitrite • Sodium pentobarbital	• Sodium sulfite **Inorganic Salts:** • Calcium chloride • Lithium carbonate • Sodium silicate	bromide (mutagen) • Hydrazine • Nitrosodiethyl-amine • Urethane	• Formaldehyde (carcinogen) • Formamide • Isoleucine • Naphthol	from chromic) • Perchloric acid **Inorganic Oxidizers:** • Ammonium persulfate (separate from sodium nitrite) • Chromium trioxide • Hydrogen peroxide • Silver nitrate • Sodium nitrate	(peroxide-former) • Xylene(s) **Organic Acids:** • Acetic acid • Formic acid

TABLE 6.2 CLASSES OF INCOMPATIBLE CHEMICALS

A Incompatible with	B
Alkali and alkaline earth Carbides Hydrides Metals Oxides Peroxides	Water Acids Halogenated organic compounds Oxidizing agents*
Azides, inorganic	Acids Heavy metals and their salts Oxidizing agents*
Cyanides, inorganic	Acids Strong bases
Nitrates, inorganic	Acids Reducing agents*
Nitrites, inorganic	Acids Oxidizing agents*
Organic compounds Organic acyl halides Organic anhydrides Organic halogen compounds Organic nitro compounds	Oxidizing agents* Bases Organic hydroxy and amino compounds Bases Organic hydroxy and amino compounds Group IA and IIA metals Aluminum Strong bases
Oxidizing agents* Chlorates Chromates Chromium trioxide Dichromates Halogens Halogenating agents Hydrogen peroxide Nitric acid Nitrates Perchlorates Peroxides Permanganates Persulfates	Reducing agents* Ammonia, anhydrous and aqueous Carbon Metals Metal hydrides Nitrites Organic compounds Phosphorus Silicon Sulfur
Reducing agents*	Oxidizing agents* Arsenates Arsenites Phosphorus Selenites Selenates Tellurium salts and oxides
Sulfides, inorganic	Acids

*The examples of oxidizing and reducing agents are illustrative of common laboratory chemicals; they are not intended to be exhaustive.

From *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*, Committee on Prudent Practices for Handling, Storage, and Disposal of Chemicals in Laboratories, et al., National Academy Press, Washington, D.C., 1995.

TABLE 6.3 INCOMPATIBLE MATERIALS CHART

Chemical	Is Incompatible With
Acetic Acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetic anhydride	Hydroxyl-containing compounds such as ethylene glycol, perchloric acid
Acetone	Concentrated nitric and sulfuric acid mixtures, hydrogen peroxide
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali and alkaline earth metals, such as sodium, potassium, lithium, magnesium, calcium, powdered aluminum	Carbon dioxide, carbon tetrachloride, other chlorinated hydrocarbons (also prohibit the use of water, foam, and dry chemical extinguishers on fires)
Ammonia (anhydrous)	Mercury (in manometers, for example), chlorine, calcium hypochlorite, iodine, bromine, hydrogen fluoride
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organics, combustible
Aniline	Nitric acid, hydrogen peroxide
Arsenates and arsenites	Any reducing agents
Azides	Acids, heavy metals and their salts, oxidizing agents
Bromine	Ammonia, acetylene, butadiene, butane, other petroleum gases, sodium carbide, turpentine, benzene, finely divided metals
Calcium oxide	Water
Carbon (activated)	Calcium hypochlorite, other oxidants
Carbon tetrachloride	Sodium
Chlorates	Ammonium salts, acids, metal powders, sulfur, finely divided organics, combustibles
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, benzene, finely divided metals, turpentine
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Chromic acid and chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, turpentine, alcohol, other flammable liquids
Koper	Acetylene, hydrogen peroxide
Cumene hydroperoxide	Acids (organic or inorganic)
Cyanides	Acids
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Fluorine	Isolate from everything
Hydrides	Water
Hydrocarbons (benzene, butane, propane, gasoline, turpentine, etc.)	Fluorine, chlorine, bromine, chromic acid, peroxides
Hydrocyanic acid	Nitric acid, alkalis
Hydrofluoric acid (anhydrous); Hydrogen fluoride	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, any flammable liquid, combustible materials, aniline, nitromethane
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous)
Mercury	Acetylene, fulminic acid (produced in nitric acid-ethanol mixtures), ammonia
Nitrates	Acids, reducing agents
Nitric acid (concentrated)	Acetic acid, acetone, alcohol, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, nitratable substances
Nitrites	Acids, oxidizing agents
Nitroparaffins	Inorganic bases, amines
Oxalic acid	Silver, mercury, and their salts
Oxygen	Oils, grease, hydrogen, flammable materials (liquids, solids, or gases)
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils (all organics)
Peroxides, organic	Acids (organic or mineral); avoid friction, store cold
Phosphorus (white)	Air, oxygen, alkalis, reducing agents
Phosphorus pentoxide	Alcohol, strong bases, water
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate (see also chlorates)	Acids
Potassium perchlorate (see also perchloric acid)	Acids
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver and silver salts	Acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid (produced in nitric acid-ethanol mixtures)
Sodium (see also alkali metals)	Carbon tetrachloride, carbon dioxide, water
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium peroxide	Any oxidizable substance, such as ethanol, methanol, glacial acetic acid, acetic anhydride,

	benzaldehyde, carbon disulfide, glycerol, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulfides	Acids
Sulfuric acid	Chlorates, perchlorates, permanganates
Tellurides	Reducing agents

Adapted from *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*, National Research Council, 1995, with additions from SHyS.

6.6 Safety for Specific Chemical Operations

6.6.1 Unattended/Overnight Operations. If experiments run while a researcher is not present, an Overnight Experiment Notice containing information about the experiment and the name of a contact person for emergencies shall be posted on the laboratory door. Forms are available from SHyS.

The "Emergency Information for Laboratories" posting on the outside of the laboratory shall have current emergency contact information.

Reactions that are left unattended for long periods of time or overnight are prime sources of fires, floods, and explosions. Do not let equipment such as power stirrers, hot plates, heating mantles, and water condensers run overnight without fail-safe provisions such as flow monitors that will shut down equipment in case of water supply failure, temperature monitors interlocked into the system, or fail-safe hose connectors.

At its discretion, el Comite de Seguridad may specify and require labels or signs for operations involving chemical agents. Signs and warning labels are specified in Section 5.0. Remember that at night, emergency personnel are entirely dependent on accurate instructions and information available at the laboratory.

6.6.2 Extractions and Distillations.

6.6.2.1 Extractions Extractions can present a hazard because of the potential buildup of pressure from a volatile solvent and an immiscible aqueous phase. Glass separatory funnels used in laboratory operations are particularly susceptible to problems because their stoppers or stopcocks can be forced out, resulting in a spill of the contained liquid. It is even possible for pressure to burst the vessel.

To use a separatory funnel correctly, do not attempt to extract a solution until it is cooler than the boiling point of the extractant. When a volatile solvent is used, the unstoppered separatory funnel should first be swirled to allow some solvent to vaporize and expel some air. Close the funnel and invert it with the stopper held in place and immediately open the stopcock to release more air plus vapor. Do this with the hand extended around the barrel to keep the stopcock plug securely seated.

Point the barrel of the separatory funnel away from yourself and others and vent it to the hood. Do not vent the funnel near a flame or other ignition source. Close the stopcock, shake with a swirl, and immediately open the stopcock with the funnel in the inverted position to vent the vapors again. If it is necessary to use a separatory funnel larger than one liter for an extraction with a volatile solvent, the force on the stopper may be too great, causing the stopper to be expelled. Consider performing the extraction in several smaller batches.

6.6.2.2 Distallations Potential dangers arise from pressure buildup, commonly used flammable materials, and the use of heat to vaporize the chemicals involved. Careful design and construction of the distillation system is required to accomplish effective separation and avoid leaks that can lead to fires or contamination of the work area. For example, wrap distillation collection flasks with cloth tape or wire for support and reinforcement.

It is necessary to ensure smooth boiling during the separation process and avoid bumping, which can blow apart the distillation apparatus. Stirring the distillation mixture is the best method to avoid bumping. Boiling stones are only effective for

distillations at atmospheric pressure. Use fresh boiling stones when a liquid is boiled without stirring. Do not add boiling stones or any other solid material to a liquid that is near its boiling point, because this may cause it to boil over spontaneously.

An electric mantle heater, a ceramic cavity heater, steam coils, or a nonflammable liquid bath are best to provide even heating. Silicone oil or another suitable high-boiling-temperature oil can be used on a hot plate. Hot water or steam may also be used in some cases. An extra thermometer inserted at the center bottom of the distilling flask will warn of dangerously high temperatures that could indicate exothermic decomposition. Do not distill or evaporate organic compounds to dryness unless they are known to be free of peroxides.

Because superheating and bumping occur frequently during distillation using reduced pressure, it is important that the distillation assembly is secure and the heat distributed more evenly than is possible with a flame. Evacuate the assembly gradually to minimize the possibility of bumping. Stirring, or using an air or nitrogen bleed tube, provides good vaporization without overheating and decomposition.

Put a standing shield in place for protection in the event of an implosion. After finishing a reduced-pressure distillation, cool the system, then slowly bleed in air so as not to induce an explosion in a hot system. Pure nitrogen is preferred to air and can be used even before cooling the system.

In a steam distillation, minimize the accumulation of condensate in the distillation flask. The heat of steam condensation is very high, and overfilling the flask is less likely if condensation from the entering steam line is trapped and the flask heated or insulated to prevent excessive condensation.

Alternative. There are commercially available distillation units that can replace traditional solvent stills which require sodium metal as a drying agent, a very hazardous process prone to fires. Solicite subsidios específicos para for specific types of safety equipment, including the new still technology that does not rely on reactive metals. Consider purchasing this alternative system to reduce the risk associated with the older method.

6.6.3 Temperature Control.

Since the rates of most reactions accelerate as the temperature increases, highly exothermic reactions can become violent without adequate cooling. Viscous liquids transfer heat poorly and require special precautions. Apparatus shall be assembled so that either heating or cooling can be applied or withdrawn readily.

6.6.3.1 Oil and Sand Baths Improper use of a hot oil or sand bath may create serious hazards such as an overturned bath, spatter from water falling into the bath, smoke caused by decomposition of the oil or organic materials in the oil, and fire from overheating the oil. Baths shall not be left unattended without a high-temperature shutoff. The oil shall be properly labeled, including information on its safe working temperature.

6.6.3.2 Cooling Baths Ice with salt may be used when ice water is not cool enough for use as a bath. Dry ice may be used with an organic liquid. A cooling liquid ideal for use with dry ice should have nontoxic vapors, low viscosity, no flammability, and low volatility. Although no substance is likely to meet all these criteria, some of the better liquids are:

- Ethylene glycol or propylene glycol in a 3:2 ratio with water and thinned with isopropyl alcohol.

- Isopropyl alcohol (less flammable than other common solvents such as acetone or butanone).
- Some glycol ethers.

Either add the dry ice to the liquid or the liquid to the dry ice in small increments. Wait for the foaming to stop before proceeding with the addition. The rate of addition can be increased gradually as the liquid cools. Do not handle dry ice with bare hands; if the skin is even slightly moist, severe burns can result. Use dry leather gloves or suitable cryo-gloves. Wear goggles when chipping ice.

Cryogenic coolants shall be handled in properly vented containers. Very-low-temperature coolants may condense oxygen and cause an explosion with combustible materials. Use gloves and a face shield; immerse the cooling object slowly to avoid too-vigorous boiling and overflowing the coolant. Dewar flasks should be made of borosilicate glass and wrapped with cloth-backed friction or duct tape or put in a metal enclosure to contain flying pieces in the event of implosion.

Dewar flasks should be equipped with safety necks. The flasks should be inspected periodically (at least once a day) to ensure that no air or ice plugs have collected in the neck opening.

Avoid pouring cold liquid onto the edge of a glass Dewar flask when filling because the flask may break and implode. For the same reason, do not pour liquid nitrogen out of a glass Dewar flask. Instead, use mild air pressure or a siphon. Metal or plastic Dewar-type flasks are preferable and eliminate this problem. Never use a household Thermos bottle in place of a Dewar flask.

6.6.4 Reduced Pressure Operations.

Protect vacuum dessicators by covering them with cloth-backed friction or duct tape or shielding them for protection in case of implosion. Vacuum lines shall be trapped and shielding used whenever apparatus is under reduced pressure. Only chemicals being dehydrated should be stored in a dessicator. Before opening a dessicator that is under reduced pressure, make sure that atmospheric pressure has been restored.

Water aspirators for reduced pressure are used mainly for filtration purposes, and only equipment that is approved for this purpose should be used. Never apply reduced pressure to a flat-bottomed flask unless it is a heavy-walled filter flask designed for that purpose. Place a trap and a check valve between the aspirator and the apparatus so that water cannot be sucked back into the system if the water pressure falls unexpectedly during filtering. This also applies to rotary evaporation equipment that use water aspirators for reduced pressure.

If vacuum pumps are used, place a cold trap between the apparatus and the vacuum pump so that volatiles from a reaction or distillation do not get into the pump oil or out into the atmosphere. **Exhausts from pumps shall be vented to a hood or ventilation system.** Pumps with belt drives must be equipped with belt guards to prevent hands, hair, or loose clothing from being caught in the belt pulley.

6.6.4.1 Dessicators If a glass vacuum dessicator is used, it should be made of Pyrex or similar glass, completely enclosed in a shield or wrapped with friction tape in a grid pattern that leaves the contents visible and at the same time guards against flying glass should the vessel implode. Plastic (e.g., polycarbonate) dessicators reduce the risk of implosion and may be preferable, but should also be shielded while evacuated. Solid desiccants are preferred. An evacuated dessicator should never be carried or moved. Care should be taken in opening the valve to avoid a shock wave into the dessicator.

6.6.4.2 Rotary Evaporators Glass components of the rotary evaporator should be made of Pyrex or similar glass, completely enclosed in a shield or wrapped in cloth tape or mesh to guard against flying glass should the components implode.

Increases in rotation speed and application of a vacuum to the flask whose solvent is to be evaporated should be gradual.

6.6.5 Cold Traps.

Cold traps used in reduced-pressure systems should be placed in vermiculite-filled metal cans. If this option is not possible, the cold traps should be wrapped with cloth-backed friction or duct tape. In the event of an implosion, the tape will reduce the amount of flying glass.

Users of cold traps should be aware of the boiling points of the components and the possible products of materials in the reduced-pressure system. For instance, argon, a common inert gas, may condense into traps cooled with liquid nitrogen. When the cooling bath is removed, the argon rapidly vaporizes, and the rate of pressure buildup may be too great for the gas to be vented or pumped down. A serious explosion could occur.

6.6.6 Transporting Chemicals In-House.

The precautions that should be followed to protect colleagues, nonlaboratory personnel, and facilities when you transport chemicals in FCEN buildings are listed below.

Use secondary containers. The container-within-a-container concept will protect the primary containers from shock during any sudden change of movement. Secondary containment is especially important when chemicals are moved in public areas, such as hallways or elevators, where the effects of a spill would be more severe.

Always use a sturdy cart, and make sure the cart has a low center of gravity. Carts with large wheels are best for negotiating irregularities in floors and at elevator doors.

Freight elevators shall be used for moving chemicals and biological materials. Passenger elevators shall not be used for this purpose.

Do not transport incompatible chemicals together on the same cart.

All chemical containers being transported shall have labels identifying the contents. See labeling requirements in Section 6.5.1.

Transport large containers of corrosives in a chemically-resistant bucket or other container designed for this purpose.

Anticipate sudden backing up or changes in direction from others. If you stumble or fall while carrying glassware or chemicals, try to project them away from yourself and others.

6.7 Hazards of Chemical Groups

6.7.1 Corrosives: Acids and Bases. See Table 6.4 for inorganic acid neutralization procedures. Corrosive acids and bases attack the skin and can cause permanent damage to the eyes. Therefore, exercise great care in attempting neutralization.

All the **hydrogen halide acids** are serious respiratory irritants. Hydrofluoric (HF) acid poses a special danger; both its gas and solutions are toxic, and it is rapidly absorbed through the skin, penetrating deeply into the body tissues. Contact with dilute solutions of hydrofluoric acid may cause no pain for several hours but result in serious burns. In all cases, immediate and thorough flushing with water for 5 minutes, followed by calcium gluconate antidote gel application and prompt attention by a physician are necessary.

Oxyacids such as sulfuric and nitric acid have widely differing properties. Sulfuric acid is a very strong dehydrating agent. When preparing solutions, always add the acid to water and remember that the heat of solution may produce a large increase in temperature. Nitric acid is a strong oxidizing agent that acts rapidly and turns exposed skin yellow to brown as a denaturing reaction occurs. Paper

that has been used to wipe up nitric acid spills can ignite spontaneously when dry and should not be thrown into a wastebasket until first rinsed with water and neutralized.

Chromic acid is generally prepared as a cleaning solution; SHyS recommends the use of replacement cleaners without chromium, which is carcinogenic. All chromic acid waste shall be collected and disposed of through SHyS. For information regarding chromic acid substitutes, contact SHyS.

Perchloric acid is a powerful oxidizing agent that may react explosively with organic compounds and other reducing agents. If heated, it shall be used only in a perchloric-acid, water-wash-down fume hood of noncombustible construction. Perchloric acid should be handled with extreme care and kept from organic matter to prevent a serious explosion. Beakers of fuming perchloric acid shall be handled with tongs rather than rubber gloves. Perchloric acid hoods shall be washed down after every perchloric acid digestion.

Perchloric acid containers shall be stored in glass outer containers and shall not be stored on wood shelving, as drips or leaks may render the wood shock-sensitive. Keep perchloric acid bottles on glass or ceramic trays that are large enough to hold all the acid if the bottle breaks. Storage of perchloric acid containers should not exceed one year. Digest organic matter with nitric acid before addition of perchloric acid. Never heat perchloric acid with sulfuric acid because dehydration may produce anhydrous perchloric acid, which is explosive.

Perchlorate esters have the same shattering effect as nitroglycerine. Transition metal perchlorates are capable of exploding. Perchlorates shall not be used without prior consultation with SHyS.

The most common bases found in laboratories include the alkali metal hydroxides and aqueous solutions of ammonia. Sodium and potassium hydroxides are extremely destructive to both skin and eye tissues. When concentrated solutions are prepared, the heat of solution can raise the temperature to dangerous levels. Because ammonia solution vapors are such strong irritants, they should be used only in a chemical fume hood.

6.7.2 Flammable and Combustible Liquids. Definitions. According to most fire codes and regulations, including those for laboratories, a flammable liquid is a liquid with a flash point below 100°F and a vapor pressure not exceeding 40 psi (absolute) at 100° F; it is called a Class I liquid. A liquid with a flash point at or above 100° F is classified as a combustible liquid and may be referred to as a Class II or Class III liquid (see Table 6.5).

Some agencies define flammable liquids as those with a flash point of 140° F or lower and combustible liquids as those with a flash point greater than 140° F but less than 200° F. DOT and EPA definitions apply primarily to chemicals in transit and hazardous waste.

Flash point is the minimum temperature at which the liquid gives off vapors in sufficient concentration to form an ignitable mixture with air. The classes of liquids are further divided into subclasses, depending on the flash points and boiling points of the liquids. The classifications are important because regulations governing storage and use of a liquid are largely based on the liquid's flash point.

TABLE 6.4 PROCEDURE FOR INORGANIC ACID NEUTRALIZATION
(Does not apply to chromic acid)

Applicable Acids:	Hydrochloric, nitric, sulfuric, perchloric
Equipment:	Chemical fume hood, vertical sash pulled down as far as possible, locate horizontal sash pane in front of you as a barrier Goggles Gloves Lab coat, either acid resistant or with impermeable apron pH paper, wide range
Caution:	Wear protective clothing and work in a hood

Beware of heat and fumes generated by neutralizing acid
Add acid to water
Keep containers cool while neutralizing, using ice in the water or in baths
Dilute concentrated acids before neutralization
Keep concentrated nitric and perchloric acids, which are strong oxidizers, away from reducing agents, including organic substances, to avoid possibly violent reactions

1. Prepare a large amount of an ice-water-and-base solution of one of the following:

   Sodium carbonate (soda ash)
   Calcium hydroxide (slaked lime)
   Sodium hydroxide, 5 to 10% (best for nitric and perchloric acids); one-molar solution is about 4% (4 grams per 100 ml)

2. Slowly stir acid (which has been diluted to about 5%) into the base solution until the pH reaches about 5 to 10.
3. Slowly pour the neutralized solution down the drain with large amounts of water.

Note: The pH of solutions poured down the drain shall be between 5 and 10 to avoid violating local, state, or federal regulations.

Flammable liquids shall be handled only in areas with no ignition sources and shall not be heated with open flames. If flammable liquids in metal containers or equipment are transferred, the equipment and containers shall be bonded to avoid static-generated sparks.

Storage. Flammable liquids shall not be stored in ordinary refrigerators or cold rooms. If it is necessary to refrigerate flammable materials, "explosion-proof," "explosion-safe" or flammable-storage refrigerators shall be used. Combustible liquids are less of a fire hazard, although a rise in temperature increases their evaporation rate and the potential for ignition. If the quantity of flammable liquids in storage exceeds 10 gallons (including liquid waste), flammable-liquid storage cabinets shall be used.

Allowable Quantities. The maximum allowable size of containers and portable tanks for flammable and combustible liquids is shown in Table 6.6. Although the table indicates that the maximum allowable size of glass containers for Class IA and Class IB are one pint and one quart respectively, the liquids may be stored in glass containers of not more than one-gallon capacity if the required liquid purity (such as ACS analytical reagent grade or higher) would be affected by storage in metal containers or if the liquid would cause excessive corrosion of the metal container.

Bonding and Grounding. When a flammable liquid is poured into or withdrawn from a metal drum, the drum and the secondary container shall be electrically bonded to each other and to the ground to avoid the possible buildup of a static charge. Only small quantities should be transferred to a glass container. If the liquid is transferred from a metal container to glass, the metal container should be grounded. Drums of flammable liquids are not permitted in laboratories unless the quantity is necessary for daily use and is approved by SHyS.

6.7.3 Compressed Gases.
Securing Cylinders. An added hazard of toxic, oxidizing, and other hazardous gases as well as inert gases in cylinders is the potential for accidental pressure release; a cylinder with the valve broken off can turn into a rocket. It is important to keep cylinders secured to the bench or wall and to keep the caps on when they are not in use. It is required that cylinders be chained to the wall or secured by bench straps, floor stands, or chains. See Table 6.7 for maximum size and quantity limitations for compressed-gas or liquified-gas cylinders in laboratories.

Storage. Only cylinders that are in use shall be kept in the laboratory. All others, including empties, shall be sent to the compressed-gas cylinder storage area for the particular facility. When the cylinder is not in use, close the main cylinder valve tightly. Promptly remove the regulator from an empty cylinder, replace the protective cap, and label the cylinder by using an "empty" tag or writing on the

side of the cylinder with chalk. Never bleed cylinders completely empty; leave a slight pressure to keep contaminants out.

Transport. When transporting a cylinder, use a wheeled cylinder cart with the capped cylinder strapped to the cart.

Connections. Threads on cylinder-valve outlet connections have been standardized by the Compressed Gas Association and are not the same on all cylinders. This prevents accidental mixing of incompatible gases from an interchange of connections. Never lubricate, modify, force, or tamper with cylinder valves. Especially do not put oil or grease on the high-pressure side of a cylinder containing oxygen, chlorine, or another oxidizing agent. An autoignition or explosion could result.

Environmental. Do not expose cylinders to temperatures higher than 50° C. Some rupture devices on cylinders release at about 65° C.

Toxic Gases. For the purposes of this section, the definitions of toxic gas and highly toxic gas in the Compressed Gas Association Standard CGA P-1.1991, "Safe Handling of Compressed Gases in Containers," can be applied. A toxic gas is one with a median lethal concentration (LC50) of more than 200 and less than 2,000 parts per million by volume of gas or vapor when administered by inhalation for an hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each. A highly toxic gas is characterized by a median LC50 of 200 ppm or less under the same conditions.

Toxic gases shall be treated by absorption, wet or dry scrubbing, combustion, or condensation via refrigeration, before being vented to chemical fume hoods or other local exhaust arrangements. Pressure-relief devices on cylinders shall be vented to a safe place. Flow-restricting orifices are required on cylinders of toxic gases. Toxic-gas cylinders shall be stored in continuously mechanically ventilated enclosures, with no more than three cylinders per enclosure. Any new laboratory construction shall require gas cabinets for storage of highly toxic gases. Some toxic gases may be supplied in mixtures. Purchase of diluted toxic gas, if feasible, will serve to reduce risk.

If these alternatives are not possible, alarm systems shall be employed to monitor the toxic gas in use. Respirators or self-contained breathing apparatus (SCBA) may be available in the event of a leak. Consult the emergency plan for the given lab area to determine the action expected during a leak situation. SHyS shall be contacted for information on selection, fit testing, and training if respirators or SCBA have been provided. No one may use respirators on the job without prior medical approval, fit testing, and training.

6.7.3.1 Acetylene The following special rules apply to work with cylinders of acetylene in the laboratory:

- Acetylene cylinders are partially filled with acetone and should always be kept upright. If a cylinder has been handled in a non-upright position, do not use it until it has sat upright for at least 30 minutes.
- When connecting an acetylene cylinder, be sure to use a flash arrestor at the outlet of the cylinder and the correct kind of tubing to transfer the gas. Some tubing materials, such as copper and lead solder, form explosive acetylides.
- Never exceed the pressure limit indicated by the warning red line of an acetylene pressure gauge.

TABLE 6.5 FLAMMABLE LIQUID CLASSIFICATION

Class	Flash Point (℉)	Boiling Point (℉)
IA	Below 73	Below 100
IB	Below 73	At or above 100

IC	At or above 73, below 100	N/A
II	At or above 100, below 140	N/A
IIIA	At or above 140, below 200	N/A
IIIB	At or above 200	N/A

TABLE 6.6 MAXIMUM ALLOWABLE SIZE OF FLAMMABLE AND COMBUSTIBLE LIQUID CONTAINERS IN LABORATORIES

	Flammable Liquids			Combustible Liquids	
Container	Class IA	Class IB	Class IC	Class II	Class IIIA
Glass	1 pint[a]	1 quart[a]	1 gallon	1 gallon	5 gallons
Metal (other than DOT drums) or approved plastic	1 gallon	5 gallons[b]	5 gallons[b]	5 gallons[b]	5 gallons
Safety cans	2 gallons	5 gallons[b]	5 gallons[b]	5 gallons[b]	5 gallons
Metal drum (DOT Spec.)	Not allowed	5 gallons[b]	5 gallons[b]	60 gallons[b]	60 gallons
Polyethylene	1 gallon	5 gallons[b]	5 gallons[b]	60 gallons[b]	60 gallons

[a]Glass containers of not more than one-gallon capacity are acceptable if the required purity would be adversely affected by storage in metal or if excessive corrosion would result from storage in metal.
[b]In instructional laboratory work areas, no container for Class I or II liquids shall exceed a capacity of one-gallon, other than safety cans which may be of two-gallon capacity.

Reference: *NFPA 45, Fire Protection for Laboratories Using Chemicals*, National Fire Protection Association, 1996.

6.7.3.2 Lecture Bottles In addition to standard precautions, the following special rules apply to work with lecture bottles in the laboratory:

- Lecture bottles shall be stored where the temperature does not exceed 50° C, because unlike larger cylinders, they do not have pressure-relief devices to prevent rupturing. Also unlike larger cylinders, lecture bottles all have identical valve threads, irrespective of the gas contained within.
- If labels and valve tags do not agree or if there is any question as to the contents of a lecture bottle, return the unused bottle to the supplier or contact SHyS. Whenever possible, purchase lecture bottles from suppliers who will accept the return of empty or partially empty bottles.
- When transporting lecture bottles, use a cart and block the bottles to prevent rolling and falling.

6.7.4 Cryogenic Liquids and Liquified Gases. The hazards of cryogenic liquids include fire or explosion, pressure buildup, embrittlement of structural materials, asphyxiation, and destruction of living tissue on contact. Liquid helium and liquid nitrogen may displace air and create an atmosphere without sufficient oxygen. Fire or explosion may occur when the liquid form of flammable gases, such as hydrogen, is used without proper management of the gaseous phase. Liquid oxygen may produce an enriched oxygen atmosphere, which increases the flammability of ordinary combustible materials. Enriched oxygen levels may also cause some nonflammable materials, such as carbon steel, to burn readily.

Contact with cryogenic liquids generally causes tissue freezing and frostbite. Even brief contacts may be intense and painful. Prolonged contact may result in blood clots. Appropriate protective clothing, gloves, and eye protection-preferably a face shield-shall be worn when cryogenic liquids are handled.

Do not use cloth gloves, as the cryogenic liquids can saturate them and cause more extensive cold damage to the skin.

TABLE 6.7 MAXIMUM SIZE AND QUANTITY LIMITATIONS FOR COMPRESSED OR LIQUIFIED GAS CYLINDERS IN LABORATORIES

	Flammable Gases and Oxygen	Liquified Flammable Gases	Gases with High Health Hazard Rating
Maximum cylinder size (approximate dimensions in inches)	10 × 50	9 × 30	4 × 15
Maximum number of cylinders per 500 square feet or less of floor space in nonsprinklered areas	3	2	3[a]
In sprinklered areas	6[b]	3	3[a]

[a]Cylinders of all toxic gases shall be kept in a continuously mechanically ventilated hood or other continuously mechanically vented enclosure, with no more than 3 cylinders per enclosure.
[b]In instructional laboratory work areas, the total number of cylinders shall be reduced to 3 maximum-sized cylinders. Ten approximately 2" × 12" cylinders (lecture bottles) are allowed. In other than instructional laboratories, 25 lecture bottles are permitted.

Reference: *NFPA 45, Protection for Laboratories Using Chemicals*, National Fire Protection Association, 1996.

6.7.5 Highly Reactive Chemicals.

6.7.5.1 Organic Peroxides Organic peroxides are among the most hazardous chemicals normally handled in laboratories. As a group, they are flammable, low-power explosives and powerful oxidizers that are sensitive to shock, heat, sparks, friction, impact, and light. Many of them are much more shock-sensitive than typical explosives such as TNT.

Purchase and use of peroxides shall be kept to a minimum. Unused peroxides shall not be returned to the container. Glass containers with screw caps or glass stoppers shall not be used. Polyethylene bottles with screw caps are acceptable. Liquid peroxides or solutions shall be stored so that the peroxide will not freeze or precipitate, because these forms are extremely sensitive to heat or shock. Consistent with this precaution, they shall be kept as cold as practical to avoid decomposition.

The sensitivity of organic peroxides to heat and shock may be reduced by diluting the peroxides with inert solvents (such as aliphatic hydrocarbons or mineral oil). However, not all solvents are appropriate to mix with peroxides. Toluene, in particular, is known to induce the decomposition of diacyl peroxides. Do not use acetone or other oxidizable materials for dilution of organic peroxides.

Ceramic, Teflon, or wood spatulas shall be used. Metal spatulas may catalyze explosive decomposition of the peroxide. Friction, grinding, and other forms of impact shall be avoided.

6.7.5.2 Peroxide-Forming Chemicals Certain chemicals are known to form peroxides on exposure to air or light. Peroxide concentrations may accumulate over long periods of time. The distillation of solvents contaminated with peroxides may lead to violent explosions as the peroxides become concentrated during the process. A peroxide present as a contaminating reagent in a solvent can change the course of a planned reaction.

Keep all stored chemicals, especially flammable liquids, away from heat and direct sunlight. Peroxide-forming chemicals call for special consideration at all times and

particularly in storage. They should be stored in dark bottles; ultraviolet light and elevated temperature accelerate peroxide formation.

Peroxide-forming solvents shall be dated on receipt in the laboratory and on opening. Once the containers are opened, the solvents shall be regularly checked for the presence of peroxides with either wet chemicals or test strips. The checks should be conducted prior to heating the solvent and after each month of storage. Peroxides may be removed by passing the solvent through an alumina column. The alumina shall not be allowed to dry out and shall be given to SHyS promptly for disposal.

Some peroxide-forming chemicals are listed in Table 6.8. Most typical are ethyl ether, dioxane, isopropanol, and tetrahydrofuran. **They shall not be stored more than six months** and shall not be put into storage without special posting indicating their presence and removal date.

Several acceptable colorimetric tests for peroxides in ethers are available. Contact SHyS for information. If sufficient peroxide is present to form a precipitate, the container and its contents shall be handled with extreme care. Call SHyS to have it removed. Generally, if you think you should test for the presence of peroxides, then you probably have kept the material too long and should dispose of it immediately.

A test for peroxides should only be attempted if it is clear that no danger will result from moving or opening the container. Solids in the liquid or around the cap can indicate dangerous peroxide buildup.

If old containers of peroxide-forming chemicals are found, do not move them without consulting SHyS. This is especially true if they contain precipitate. If they are to be moved, handle them only by the bottom of the container and never by the cap or lid, as friction may cause a violent explosion.

In general, do not attempt to dilute the concentration of peroxides in peroxide-forming solvents by adding additional solvent. Increasing the total volume may dilute the peroxide concentration but creates a larger quantity of waste for disposal. The higher volume of waste may require stabilization because of the presence of the peroxides.

6.7.5.3 Polynitro Compounds Many polynitroaromatic compounds are shock-sensitive, as are some aliphatic compounds containing more than one nitro group. Many of these compounds are sold and stored with 10 to 20 percent water, which desensitizes their reaction to shock, although they are still flammable solids.

Storage. Polynitro compounds shall be stored separately from most chemicals and labeled so they will be easily identified as reactive. They shall not be placed in long-term storage without special posting indicating their presence and removal date. Long-term storage without checking for proper water content may allow the compounds to dehydrate sufficiently to make them highly reactive.

Surplus and waste polynitro compounds shall be given to SHyS promptly for proper disposal or recycling and not left on a shelf to be forgotten.

If old containers of polynitro compounds are found, including picric acid or dinitrophenyl hydrazine, do not move them without consulting SHyS. If they are moved, handle them only by the bottom of the container and never by the cap or lid, as friction may cause a violent explosion.

Picric Acid. Dry picric acid is highly explosive and should be brought into the laboratory only when specifically required. Users should have a thorough understanding of its hazards. Although not explosive when wetted, picric acid solutions may evaporate to leave the hazardous solid. Picric acid should be stored

away from combustible materials and should not be kept for extended periods. Old containers of picric acid shall be handled only by SHyS.

Methyl nitronitrosoguanidine. Methyl nitronitrosoguanidine is a carcinogenic agent that is also shock-sensitive. It shall be stored in a separate area, preferably locked. Waste paper, plastic, and glass contaminated with this material shall be given to SHyS for proper disposal.

6.7.5.4 Catalysts Catalysts such as raney nickel or palladium on carbon shall be filtered from catalytic hydrogenation reaction mixtures with care. The catalyst has usually become saturated with hydrogen and will produce flames spontaneously on exposure to air. The filter cake should not be allowed to become dry. The funnel containing the still-moist catalyst filter cake should be put into a water bath immediately after completion of the filtration. Use a purge gas (nitrogen or argon) for hydrogenation procedures so that the catalyst can be filtered and handled under an inert atmosphere.

6.7.5.5 Calorimeters (commonly known as Parr Bombs) Calorimeters/Parr bombs shall be handled behind shields. The operator shall wear goggles or preferably a face shield.

6.7.5.6 Sodium Azide Sodium azide is a toxic, highly reactive, heat-sensitive, and potentially shock-sensitive material. Because it reacts with metals, Teflon or other nonmetal spatulas should be used with the material. It shall be stored in a locked cabinet and used with appropriate personal protective gear.

Sodium azide should only be purchased in small quantities, ideally the minimum amount needed in the laboratory. Consult SHyS for a list of vendors who supply 10-gram containers of sodium azide. Storage of solid sodium azide is strongly discouraged.

Solid sodium azide, in quantities above 25 g, shall be dissolved when it arrives in the lab. Solutions of sodium azide do not pose the danger of shock-sensitivity associated with the solid form; however, the hydrazoic acid generated when the azide is dissolved is extremely toxic. Therefore, the solution shall always be prepared inside a chemical fume hood.

6.7.5.7 Organometallics Organometallics are organic compounds comprised of a metal or nonmetal attached directly to carbon (RM). Examples are Grignard compounds and metallic alkyls such as alkyl lithiums, triethylaluminum, and trimethylindium. Many organometallics are highly toxic or flammable. Many are also water-reactive and spontaneously combustible in air. Trialkyltins are the most toxic as a group. Most are highly reactive chemically. Special firefighting equipment (e.g., dry chemical powder fire extinguisher) may be needed where organometallics are handled.

6.7.5.8 Hydrides Hydrides are inorganic compounds composed of hydrogen and another element, often a metal. Examples include arsine (AsH_3), phosphine (PH_3), diborane (B_2H_6), germane (GeH_4), stibine (SbH_3), and silane (SiH_4). The listed hydrides are highly toxic and flammable. They react violently with water and oxidizing agents and pose a dangerous fire risk. Phosphine, diborane, and silane are spontaneously flammable in air.

Certain hydride gases, notably arsine and phosphine, are commonly used as dopants in semiconductor research applications. Arsine is one of the most toxic gases known. It is a potent hemolytic agent (symptoms: red discoloration of the urine and sclera). Phosphine is extremely toxic to organs of high oxygen flow and demand. Thorough emergency planning for accidental releases shall be in place when such gases are to be used in the laboratory. Provision of air-supply respiratory protection may be called for as well as continuous system monitoring for releases.

Exhaust streams of hydride gases shall be treated (e.g., scrubbing or thermal decomposition) before release. Inform SHyS of the treatment procedures to be applied.

6.8 Chemical Waste Management

Proper handling of reaction byproducts, surplus and waste chemicals, and contaminated materials is an important part of laboratory safety procedures. Each laboratory worker is responsible for ensuring that wastes are handled in a manner that minimizes personal exposure and the potential for environmental contamination.

The first steps in managing chemical wastes are selecting the least hazardous chemicals for the task and ordering chemicals only in quantities really needed. Chemicals should not be kept in laboratories if they will not be needed, especially if they are peroxide-forming chemicals such as ethyl ether or dioxane, polynitro compounds such as picric acid or dinitrophenyl hydrazine, or chemicals that are air- or water-reactive.

TABLE 6.8 LIST OF PEROXIDIZABLE COMPOUNDS

Acetal
Acetaldehyde
Acrylamide
Acrylic Acid
Acrylonitrile
Allyl ethyl ether
Allyl phenyl ether
Allyl vinyl ether
1-Allyloxy-2,3-epoxypropane
Benzyl-1-naphthyl ether
Benzyl butyl ether
Benzyl ethyl ether
Bis(2-ethoxyethyl) ether
Bis(2-methoxyethyl) ether
1,3-Butadiene
1,3-Butadiyne
2-Butanol
Buten-3-yne
Butyl ethyl ether
Butyl formate
Butyl vinyl ether
2-Chloro-1,3-butadiene
1-Chloro-2,2-diethoxyethane
2-Chloroacrynitrile
2-Chloroethyl vinyl ether
Chloroethylene
Chloroprene
Chlorotrifluoroethylene
Cinnamaldehyde
Crotonaldehyde
Cyclohexene
Cyclooctene
Cyclopropyl methyl ether
Decahydronaphthalene
Decalin
Di(2-propynyl)ether
Diacetylene
Diallyl ether
Dibenzyl ether
p-Dibenzyloxybenzene
1,2-Dibenzyoxyethane
Dibutyl ether
Diethyl ether
Diethyl fumarate
Diethylene glycol dimethyl ether
Diethylketene
Digylme
2,3-Dihydrofuran
2,3-Dihydropyran
Diisopropyl ether*
1,1-Dimethoxyethane
1,2-Dimethoxyethane
1,1-Dimethoxypropane
2,2-Dimethoxypropane
3,3-Dimethoxypropene
2,2-Dimethyl-1,3-dioxolane
2,6-Dimethyl-1,4-dioxane
1,3-Dioxane
1,4-Dioxane
1,3-Dioxep-5-ene
1,3-Dioxol-4-en-2-one
Dipropoxymethane
Dipropyl ether
Divinyl acetylene*
Divinyl ether
1,2-Epoxy-3-isopropoxy propane
1-Ethoxy-2-propyne
2-Ethoxyethanol
2-Ethyl butanal
Ethyl isopropyl ether
Ethyl propenyl ether
Ethyl vinyl ether
2-Ethylacrylaldehyde oxime
Ethylene glycol dimethyl ether
2-Ethylhexanal
2-Ethylhexyl vinyl ether
2-Furaldehyde
Furan
Glyme compounds
4,5-Hexadien-2-yn-1-ol
2,4-Hexadienal
2,5-Hexadiyn-1-ol
2-Hexenal
Isopropyl vinyl ether
2-Isopropylacrylaldehyde oxime
Isovaleraldehyde
Limonene
1,5-p-Menthadiene
Methoxy-1,3,5,7-cyclo octatetraene
2-Methoxyethanol
2-Methoxyethyl vinyl ether
Methyl acetylene
Methyl methacrylate
4-Methyl-1,3-dioxane
2-(1-Methylheptyl)-4,6 dinitrophenyl crotonate
2,3-Methyl-2-methylene butanal
4-Methyl-2-pentanone
2-Methyltetrahydrofuran
Methyl vinyl ether
2-Penten-4-yn-3-ol
a-Pentylcinnamaldehyde
Potassium* (forms yellow potassium peroxide on the surface)
Potassium amide
2-Propanol
Propionaldehyde
2-Propyne-1-thiol
Sodium 5,8,11,14,-eicosatetraenoate
Sodium amide*
Sodium ethoxyacetylide
Styrene
1,1,2,3-Tetrachloro-1,3,-butadiene
Tetrafluoroethylene
Tetrahydrofuran
Tetrahydronaphthalene
Tetrahydropyran
Tetralin
Tridecanal
1,3,3-Trimethoxypropene
3,3,5-Trimethyl-2-cyclo-hexene-1-one (isophorone)
Vinyl acetate
Vinyl acetylene
Vinyl chloride
Vinyl ethers
Vinyl pyridine
4-Vinylcyclohexene

1,1-Dichloroethylene	Indole-2-carboxyaldehyde	Vinylidene chloride
Dicyclopentadiene	Isobutyl vinyl ether	
1,1-Diethoxyethane	Isobutyraldehyde	
1,2-Diethoxyethane	Isopropoxypropionitrile	
Diethoxymethane	Isopropyl alcohol	
3,3-Diethoxypropene	Isopropyl ether*	
	Isopropyl propyl ether	

*Forms peroxides rapidly upon storage.

From *Handbook of Reactive Chemicals*, L. Bretherick, 1990, and *J. Chem Education*, Jackson et al., vol. 47, No. 3 (1970).

Bench covers, gloves, disposable coats, pipette tips, broken thermometers, and other disposable laboratory ware potentially contaminated with toxic chemicals, including metals or carcinogens, shall be disposed of through SHyS.

The FCEN complies with National and Local regulations for disposal of hazardous chemical wastes and with National and Local Transportation regulations for shipment to disposal sites. It is a federal and state offense to dispose of chemicals improperly. SHyS is responsible for disposal of chemicals and should be contacted to arrange for the removal of chemical wastes.

6.8.1 Pickups. Chemical wastes are removed by SHyS. To request a pickup, complete a Surplus Chemical Collection Form. Chemicals shall not be brought directly to SHyS. Chemical waste containers shall always be labeled with the complete chemical name. Abbreviations, trade names, or chemical formulas shall not be permitted. When materials have been added, the amount and concentration of constituents must be listed on the container or on a log next to the container.

6.8.2 Sanitary Sewer Disposal. It is a violation of both safety and environmental regulations to pour chemicals down the drain unless they are treated or neutralized and local regulation allows them in the sanitary sewer system. Nothing except water or dilute aqueous solutions of low-toxicity material shall be disposed of in the sink.

Laboratory quantities of inorganic acids and bases, except chromic acid, may be neutralized but shall be at a pH between 5 and 10 to comply with Aguas Argentinas requirements before being flushed down the drain with excess water; a procedure is provided in Table 6.4. Laboratory quantities of oxidizers may also be reduced and flushed down the drain. Contact SHyS for procedures.

6.8.3 Treatment. The FCEN administration requires investigators to make every effort to minimize the amount and toxicity of waste removed from FCEN facilities. When feasible, the last step of an experiment should include treatment methods to reduce the hazards or toxicity of by-products. All methods of treatment require advance approval by SHyS. Generally, only neutralization of inorganic acids and bases is acceptable. In certain cases, specific treatment is required by the Comite de Seguridad. Where treatment is dictated, the method must still be approved.

SHyS maintains references for the deactivation of various drugs and can also provide recommendations for treatment of carcinogenic N-nitrosamides such as N-methyl-N-nitrosourea (MNU), N-ethyl-N-nitrosourea (ENU), N-nitroso-N-methylurethane (MNUT), N-nitroso-N-ethylurethane (ENUT), and N-methyl-N'-nitro-N-nitrosoguanidine (MNNG). Approved methods additionally exist for various N-nitrosamines; for example, N-nitrosodimethylamine, N-nitrosodiethylamine, N-nitrosodipropylamine, N-nitrosobutylamine, etc.

In the event of a spill of ethidium bromide, SHyS offers a handout describing approved methods of treatment for the spilled material, whether concentrated or dilute. Please refer to *Deactivation of Ethidium Bromide*, available from SHyS or on the web at ethid2.htm. Ethidium bromide- and acrylamide-contaminated gels are accepted for disposal by SHyS and shall be listed on the Surplus Chemical Collection Form. Gels should be packaged in one- or five-gallon polyethylene containers distributed by SHyS and properly labeled.

6.8.4 Storage. Storage of waste chemicals shall include separation of incompatible materials, as in "Chemical Storage," Section 6.5. Separate organic and inorganic chemicals. When incompatible materials are mixed as part of a research procedure, contact SHyS about proper waste disposal.

Keep caps loose to allow vapors to escape, and keep wastes in well-ventilated areas. Waste containers shall be capped at all times and uncapped only for addition of more waste.

Include flammable waste volumes when you calculate the amount of flammable liquid present in a laboratory. All stored waste containers must be properly labeled.

6.8.5 Containers. Chemically contaminated laboratory waste is collected in **yellow bags** to prevent its being inadvertently placed in the trash. Yellow bags, which are used for chemical waste **only**, are available from SHyS. Wastes shall be bagged, sealed, and placed in a second yellow bag prior to pickup. Custodians shall not handle yellow bags. Each yellow bag shall have a label or tag identifying its contents. Contaminated sharps such as broken glass or needles shall not be placed in yellow bags.

One-gallon and one-quart wide-mouth plastic bottles are available from SHyS for hazardous wastes. All containers shall be sealed and properly labeled prior to pickup. The container should be compatible with the chemical waste.

6.8.6 Collection of Sharps. Chemically contaminated sharps such as broken glass, syringes, pipettes, and razors shall be collected in sturdy, rigid, puncture-resistant containers for proper disposal. Plastic bags are not suitable for the collection of sharps as they provide those handling the bags with no protection from needlesticks or cuts.

Keep in mind that the sharps containers will be handled by a number of individuals before final disposal. It is the responsibility of the sharps users to ensure that the packaging of the waste does not pose a hazard for providers of disposal service. For information concerning suppliers of suitable sharps containers, consult SHyS.

6.8.7 Mixed Waste. Mixed waste is any waste that contains radioactive material and also one or more hazardous chemical or biological components. Potential mixed-waste generation must be addressed in the **planning** stage of any experiment that will create mixed waste. Generators shall contact SHyS **prior** to generating a mixed waste. Special requirements govern the disposal of such waste. Disposal of some mixed waste is prohibited by law. Generation of mixed waste in a FCEN laboratory could jeopardize the FCEN's compliance with federal regulations.

6.8.8 Waste Minimization. The Environmental Protection Agency's policy for hazardous waste management places the highest priority on waste minimization. Under current environmental laws, the FCEN must certify that it has a waste minimization program in place. In addition, the FCEN must annually report to the government on efforts it has made to reduce hazardous wastes.

Waste minimization as defined by the EPA means a reduction in both the volume and physical hazard or toxicity of the material. The benefits of waste minimization include reduced disposal costs, decreased liability, improved working conditions, and less impact on the environment at the time of disposal.

The FCEN's waste minimization policy requires investigators to make every effort to minimize the volume or the toxicity of their waste. Substitutions can be made to eliminate or reduce the amount of hazardous components. Experimental by-products can be treated to produce less hazardous or toxic materials. Experimental procedures can also be altered to reduce wastes. Finally, improved laboratory management can result in waste minimization.

It is the responsibility of every investigator who generates waste to incorporate the principles of waste minimization into experimental design. SHyS offers lists of specific methods (see SHyS web site) for reducing wastes and can help evaluate procedures for potential waste minimization benefits.

7.0 BIOLOGICAL AGENTS

7.1 General

Many laboratory practices and requirements are common to laboratories using chemical and biological agents. The laboratory procedures described in Section 5.0, "General Laboratory Safety," and Section 6.0, "Chemical Hazards," also apply to laboratories using biological agents, and that information will not be repeated in this part. Most of the information in this section is taken from the book *Biosafety in Microbiological and Biomedical Laboratories* (U.S. Health and Human Services Publication No. CDC93-8395, Public Health Service, Centers for Disease Control and Prevention, and National Institutes of Health, 1999). A copy of the book is available for reference in SHyS.

Biological agent hazards in the laboratory are relatively well defined, especially in the case of conventional disease-producing agents. Major exceptions to this general observation are oncogenic agents and "slow virus" infections.

Broadly speaking, two major risk situations can be identified. In the first, known agents are used and are integral to scientific research or teaching; in the second, potentially harmful biological agents are endogenous to humans or laboratory animals or to animal tissues or fluids. Examples of these are zoonotic infections harbored in the research animal population, viral contaminants in human tissues and cell cultures, and lymphocytic or choriomeningitis-infected animal tumor lines.

Other issues that do not relate specifically to personal safety but should be considered include work with agents that infect lower animals and plants, especially if an accident could seriously jeopardize the agricultural sector of the economy. The possibility of cross-contamination by infectious agents in laboratory animals and media preparation areas can also be a significant problem, especially in common resource facilities.

See Table 7.4 for a list of agents that have summary statements available from SHyS.

7.2 Responsibilities

7.2.1 General. The responsibilities of the department head, investigador responsable, and others working with biological hazards include all those described in Section 2.0 of this document. Additional responsibilities specific to the handling of biological agents include selecting safety practices based on awareness of the particular hazard and training all personnel accordingly.

7.2.2 Plan de Protección. Investigators shall submit a *Plan de Protección* to SHyS and/or the Comite de Seguridad for research involving biological agents that require containment at Biosafety Level 2 or above. Investigators shall comply with the requirements for each level of containment based on the biological agents used in research projects. SHyS can assist in determining the biosafety level of an agent. The classification of the biosafety level is subject to the approval of the CS. An investigator shall also submit a *Plan de Protección* for research involving human materials and recombinant DNA.

7.3 Containment Methods

The term containment is used to describe safe methods for managing infectious agents in the laboratory environment. The purpose of containment is to reduce exposure of laboratory workers and others to potentially hazardous agents and to prevent their escape into the outside environment. The three elements of containment are laboratory practice and technique, safety equipment, and facility design.

7.3.1 Laboratory Practice. The most important element of containment is strict adherence to standard microbiological practices and techniques. Persons working with infectious agents or infected materials shall be aware of potential hazards and shall be trained and proficient in the practices and techniques required for safely handling such material. When standard laboratory practices are not sufficient to control the hazard associated with a particular agent or laboratory procedure, additional measures may be needed involving safety equipment and facility design.

7.3.2 Safety Equipment (Primary Barriers). Safety equipment includes biological safety cabinets, enclosed containers, and other engineering controls designed to prevent or minimize exposures to hazardous biological materials. The use of vaccines may in some cases provide an increased level of personal protection.

7.3.2.1 Biological Safety Cabinets (BSCs) The biological safety cabinet is the principal device used to provide containment of infectious splashes or aerosols. There are three types of biological safety cabinets: Class I, Class II, and Class III.

Class I is an open-fronted, negative-pressure, vented cabinet with HEPA-filtered exhaust. It may be equipped with a front closure and gloves for use as a glove box. The inward face velocity is a minimum of 75 linear feet per minute. Suitable for work with low- or moderate-risk biological agents, it provides protection for personnel and the environment but not for the product.

Class II cabinets are open-fronted laminar-flow cabinets with a minimum inward face velocity of 75 linear feet per minute. Class II design resembles that of a fume hood but with HEPA-filtered, recirculated mass airflow within the workspace. Exhaust air is also filtered. Class II cabinets provide protection for personnel, product, and the environment. They are designed for work with low- or moderate-risk biological agents.

Class III cabinets provide the highest level of protection. Class III is a totally enclosed glove-box cabinet of gas-tight construction. The cabinet is maintained under negative air pressure of at least 0.5 inches of water gauge. Supply air is drawn into the cabinet through HEPA filters, and the exhaust air is filtered by two HEPA filters in series before it is discharged to the outside. Generally, the ventilation system is separate from the facility's ventilation system. Class III cabinets are suitable for high-risk biological agents.

Biological safety cabinets used to protect workers from hazardous biological agents shall be tested and certified after installation and before use, any time they are moved, and at least annually. The department head shall provide annual certification and maintain certification records for the department. The biological safety cabinet shall be decontaminated prior to certification or performance tests. See "Decontamination of Biological Safety Cabinets" at biosafe/parafrm2.htm. Call SHyS for information on the standard and a list of companies qualified to certify biological safety cabinets.

For more detailed information about BSCs, refer to the 1995 CDC/NIH publication "Primary Containment for Biohazards: Selection, Installation and Use of Biological Safety Cabinets." It can be found at http://www.cdc.gov/od/ohs/biosfty/bsc/bsc.htm.

7.3.2.2 Other Safety Equipment
Other safety equipment includes enclosed containers. An example of an enclosed container is the safety centrifuge cap, designed to prevent release of aerosols during centrifugation.

Safety equipment also includes personal protective clothing and equipment such as gloves, coats, gowns, shoe covers, boots, respirators, face masks or shields, and safety glasses or goggles. This clothing and equipment is generally used in combination with biological safety cabinets and other devices that contain the agents, animals, or materials in use.

In situations in which it is impractical to work in biological safety cabinets, personal protective devices may form the primary barrier between personnel and the infectious materials. Examples of such situations include certain animal studies, animal necropsy, and activities relating to maintenance, service, or support of the laboratory facility.

7.3.3 Facility Design (Secondary Barriers). Secondary barriers protect the environment within the facility but outside the laboratory—and the community outside the facility—from exposure to infectious materials. The design of the facility provides the secondary barrier. The three facility designs are the basic laboratory, the containment laboratory, and the maximum containment laboratory.

The Basic Laboratory provides general space where work is done with viable agents that are not associated with disease in healthy adults; it includes Biosafety Levels 1 and 2 facilities. This laboratory is also appropriate for work with infectious agents or potentially infectious materials when the hazard levels are low and laboratory personnel can be adequately protected by standard laboratory practice. While work is commonly conducted on the open bench, certain operations are confined to biological safety cabinets. Conventional laboratory designs are adequate.

The Containment Laboratory has special engineering features that enable laboratory workers to handle hazardous materials without endangering themselves, the community, or the environment. The containment laboratory is described as a Biosafety Level 3 facility. The features that distinguish this laboratory from the basic laboratory are the provisions for access control and a specialized ventilation system. In all cases, a controlled access zone separates the laboratory from areas open to the public.

The Maximum Containment Laboratory has special engineering and containment features that allow laboratory workers to safely conduct activities involving infectious agents that are extremely hazardous to humans or capable of causing serious epidemic disease. The maximum containment laboratory is described as a Biosafety Level 4 facility; it is not applicable to activities at the FCEN.

7.4 Biosafety Levels

The following guidelines have been adopted as required procedure at the FCEN. They are drawn from the book *Biosafety in Microbiological and Biomedical Laboratories*.

7.4.1 Biosafety Level 1. Biosafety Level 1 (BSL-1) is suitable for work involving agents of no known or minimal potential hazard to laboratory personnel and the environment. The laboratory may be integral to general traffic patterns in the building. Work may be conducted on open bench tops. Special containment equipment is neither required nor generally used. Laboratory personnel shall have specific training in procedures conducted in the laboratory.

7.4.1.1 Standard Microbiological Practices for BSL-1

1. At the discretion of the investigador responsable, access to the laboratory shall be limited or restricted while experiments are in progress.
2. A biohazard sign shall be posted at the entrance to the laboratory whenever infectious agents are present. The sign must include the name of the agent(s) in use and the name and phone number of the investigador responsable.
3. Work surfaces shall be decontaminated once a day and after any spill of viable material.
4. All contaminated liquid or solid wastes shall be decontaminated before disposal. Contaminated materials that are to be decontaminated at a site outside the laboratory shall be placed in a durable, leakproof, closed container before being removed from the laboratory.
5. The laboratory shall have an established policy for the safe handling of sharps.
6. Mechanical pipetting devices shall be used; mouth pipetting is prohibited.
7. Eating, drinking, smoking, and applying cosmetics are not permitted in the work area. Food may be stored in cabinets and refrigerators designated and used for this purpose only. Food storage cabinets and refrigerators shall be located outside the work area.
8. Laboratory personnel shall wash their hands after they handle viable materials and animals and before leaving the laboratory.
9. All procedures shall be performed carefully to minimize the creation of aerosols.
10. An insect and rodent control program is in effect. SHyS is responsible for the control of pests and should be contacted if insects or rodents not involved in research, or their wastes, are observed in the laboratory.

7.4.1.2 Safety Equipment for BSL-1

1. Special containment equipment is generally not required for manipulation of agents assigned to Biosafety Level 1.
2. It is recommended that laboratory coats, gowns, or uniforms be worn to prevent contamination or soiling of street clothes.
3. Gloves should be worn if skin is broken or afflicted by a rash.

7.4.1.3 Laboratory Facilities for BSL-1

1. The laboratory shall be designed so that it can be easily cleaned.
2. Bench tops shall be impervious to water and resistant to acids, alkalis, organic solvents, and moderate heat.
3. Laboratory furniture shall be sturdy. Spaces between benches, cabinets, and equipment shall be accessible for cleaning.
4. Each laboratory shall contain a sink for handwashing.
5. If the laboratory has windows that open, they shall be fitted with fly screens.

7.4.2 Biosafety Level 2. Biosafety Level 2 is similar to Level 1 and is suitable for work involving agents of moderate potential hazard to personnel and the environment. It differs in that (1) laboratory personnel are specifically trained to handle pathogenic agents and are directed by scientists who are experienced in working with these agents, (2) access to the laboratory is limited when work is being conducted, (3) extreme precautions are taken with contaminated sharp items, and (4) certain procedures that may result in the creation of infectious aerosols or splashes are conducted in biological safety cabinets or other physical containment equipment.

The following standard and special practices, safety equipment, and facilities apply to agents assigned to Biosafety Level 2.

7.4.2.1 Standard Microbiological Practices for BSL-2

1. At the discretion of the laboratory director, access to the laboratory is limited or restricted while experiments are in progress.
2. Laboratory personnel are to wash their hands after they handle viable materials and animals, after removing gloves, and before leaving the laboratory.
3. Eating, drinking, smoking, handling contact lenses, and applying cosmetics are not permitted in the work areas. Food is stored outside the work area in cabinets or refrigerators designated and used for this purpose only.
4. The laboratory shall have an established policy for the safe handling of sharps.
5. Mouth pipetting is prohibited; mechanical pipetting devices are used.
6. All procedures are performed carefully to minimize the creation of splashes or aerosols.
7. Work surfaces are decontaminated at least once a day and after any spill of viable material.
8. All cultures, stocks, and other regulated wastes are decontaminated by an approved decontamination method, such as autoclaving before disposal. Materials to be decontaminated outside the immediate laboratory are to be placed in a durable, leakproof container that is closed for transport from the laboratory.
9. An insect and rodent control program is in effect. SHyS is responsible for the control of pests and should be contacted if insects or rodents not involved in research, or their wastes, are observed in the laboratory.

7.4.2.2 Special Practices for BSL-2

1. Access to the laboratory is limited or restricted by the investigador responsable when work with infectious agents is in progress. In general,

persons at increased risk of acquiring infection or for whom infection may be unusually hazardous are not allowed in the laboratory or animal rooms. Persons who are immunocompromised or immunosuppressed may be at unusual risk of acquiring infections.

2. The investigador responsable establishes policies and procedures whereby only persons who have been advised of the potential hazard and meet specific requirements (e.g., immunization) enter the laboratory or animal rooms.
3. When an infectious agent requires special provisions (e.g., immunization) for entering a laboratory where it is in use, a hazard warning sign incorporating the universal biohazard symbol is posted on the access door to the laboratory work area. The hazard warning sign identifies the infectious agent, lists the name and telephone number of the principal investigator or other responsible person, and indicates the special requirements for entering the laboratory.
4. Laboratory personnel receive appropriate immunizations for the agents handled or potentially present in the laboratory.
5. When appropriate, baseline serum samples for laboratory and other at-risk personnel are collected and stored. Additional specimens may be collected periodically.
6. A biosafety manual shall be developed for the laboratory. Laboratory personnel are advised of special hazards and are required to read and follow instructions on practices and procedures.
7. Laboratory personnel receive appropriate training on the potential hazards associated with the work involved, the necessary precautions to prevent exposures, and the exposure evaluation procedures. Personnel receive annual retraining and receive additional training when procedures or policies change.
8. A high degree of precaution must always be taken with any contaminated sharp items, including needles and syringes, slides, pipettes, capillary tubes, and scalpels. Needles and syringes should be used in the laboratory only when there is no alternative, such as when parenteral injection, phlebotomy, or aspiration of fluids from laboratory animals and diaphragm bottles are conducted. Plasticware should be substituted for glassware whenever possible.
    1. Only needle-locking syringes or disposable syringe-needle units (i.e., the needle is integral to the syringe) are used for injection or aspiration of infectious materials. Used disposable needles must not be bent, sheared, broken, recapped, removed from disposable syringes, or otherwise manipulated by hand before disposal; rather they must be carefully placed in conveniently located puncture-resistant containers used for sharps disposal. Nondisposable sharps must be placed in a hard-walled container for transport to a processing area for decontamination, preferably by autoclaving.
    2. Syringes that resheathe the needle, needleless systems, and other safe devices should be used when appropriate.
    3. Broken glassware must not be handled directly by hand but must be removed by mechanical means such as a brush and dustpan, tongs, or forceps. Containers of contaminated needles, sharp equipment, and broken glass are decontaminated before disposal.
9. Cultures, tissues, and specimens of body fluids are placed in a container that prevents leakage during collection, handling, processing, storage, transport, or shipping.
10. Laboratory equipment and work surfaces should be decontaminated with an appropriate disinfectant on a routine basis as well as after work with infectious material is finished and, especially, after overt spills, splashes, or other contamination by infectious materials. Contaminated equipment must be decontaminated before it is sent for repair or maintenance or packaged for transport.

11. Spills or accidents that result in overt exposures to infectious materials are immediately reported to the laboratory director. Medical evaluation, surveillance, and treatment are provided by ART.
12. Animals not involved in the work being performed are not permitted in the lab.

7.4.2.3 Safety Equipment for BSL-2

1. Properly maintained biological safety cabinets, preferably Class II, or other appropriate personal protective equipment or physical containment devices are used whenever:
    1. Procedures with a potential for creating infectious aerosols or splashes are conducted. These may include centrifuging, grinding, blending, vigorous shaking or mixing, sonic disruption, opening containers of infectious materials in which internal pressure may differ from ambient pressure, inoculating animals intranasally, and harvesting infected tissues from animals or eggs.
    2. High concentrations or large volumes of infectious agents are used. Such materials may be centrifuged in the open laboratory if sealed rotor heads or centrifuge safety cups are used and if these rotors or safety cups are opened only in a biological safety cabinet.
2. Face protection (goggles, mask, face shield, or other splatter guards) is used for anticipated splashes or sprays of infectious or other hazardous materials to the face when the microorganisms must be manipulated outside the biological safety cabinet.
3. Protective laboratory coats, gowns, smocks, or uniforms designated for lab use are worn in the laboratory. This protective clothing is removed and left in the laboratory before lab personnel leave for nonlaboratory areas (e.g., cafeteria, library, or offices). All protective clothing is either disposed of in the laboratory or sent to the laundry service (only after being decontaminated). It is never taken home.
4. Lab personnel wear gloves when handling infected animals and when hands may come in contact with infectious materials or contaminated surfaces or equipment. Wearing two pairs of gloves may be appropriate; if a spill or splatter occurs, the hand will be protected after the contaminated glove is removed. Gloves are disposed of when contaminated, removed when work with infectious materials is completed, and not worn outside the laboratory. Disposable gloves are not washed or reused.

7.4.2.4 Laboratory Facilities (Secondary Barriers) for BSL-2

1. Provide lockable doors for facilities that house restricted agents (see Table 7.1).
2. Each laboratory contains a sink for handwashing.
3. The laboratory is designed so that it can be easily cleaned. Rugs are not appropriate in laboratories.
4. Bench tops are impervious to water and resistant to acids, alkalis, organic solvents, and moderate heat.
5. Laboratory furniture is sturdy, and spaces between benches, cabinets, and equipment are accessible for cleaning.
6. If the laboratory has windows that open, they are fitted with fly screens.
7. An eyewash facility is readily available.
8. Biological safety cabinets shall be installed in such a manner that fluctuations of the room supply and exhaust air do not cause them to operate outside their parameters for containment. Biological safety cabinets shall be located away from doors, from windows that can be opened, from heavily traveled laboratory areas, and from other potentially

disruptive equipment so as to maintain the biological safety cabinets' air flow parameters for containment.

9. Illumination shall be adequate for all activities, avoiding reflections and glare that could impede vision.

7.4.3 Biosafety Level 3. All work to be conducted with agents assigned to Biosafety Level 3 must be approved in advance by the Comite de Seguridad. If you desire to work with BSL-3 agents, contact SHyS in advance.

BSL-3 work must be conducted in accordance with the facility safeguards, standard microbiological practices, special practices, and safety equipment described in *Biosafety in Microbiological and Biomedical Laboratories*. See Tables 7.7 and 7.8 for lists of biohazardous agents that must be handled at BSL-3.

Biosafety Level 3 is applicable to clinical, diagnostic, teaching, research, or production facilities in which work is done with indigenous or exotic agents that may cause serious or potentially lethal disease as a result of exposure by inhalation. Laboratory personnel have specific training in handling pathogenic and potentially lethal agents and are supervised by scientists experienced in working with these agents.

All procedures involving the manipulation of infectious materials are conducted within biological safety cabinets or other physical containment devices, or by personnel wearing appropriate personal protective clothing and equipment. The laboratory has special engineering and design features such as access zones, sealed penetrations, and directional airflow.

Many laboratories may not have all the facility safeguards recommended for Biosafety Level 3. In these circumstances, acceptable safety may be achieved for routine or repetitive operations (e.g., diagnostic procedures involving the propagation of an agent for identification, typing, and susceptibility testing) in Biosafety Level 2 facilities. However, the recommended standard microbiological practices, special practices, and safety equipment for Biosafety Level 3 must be rigorously followed.

7.4.4 Biosafety Level 4. FCEN use of biological agents requiring Biosafety Level 4 containment practices is not anticipated. Should an investigator wish to conduct research with these agents, a specially developed *Plan de Protección* shall be submitted to the Comite de Seguirdad for review and approval prior to initiation of research. Approval is also required by the Decano prior to initiation of research.

7.5 Biological Spills

A biological spill shall be followed by prompt action to contain and clean up the spill. When a spill occurs, warn everyone in the area and call for assistance as needed. The degree of risk involved in the spill depends on the volume of material spilled, the potential concentration of organisms in the material spilled, the hazard of the organisms involved, the route of infection of the organisms, and the diseases caused by the organisms.

Spills of biological agents can contaminate areas and lead to infection of laboratory workers. Prevention of exposure is the primary goal in spill containment and cleanup, exactly as in chemical spills. In evaluating the risks of spill response, generation of aerosols or droplets is a major consideration.

If an accident generates droplets or aerosols in the laboratory room atmosphere, especially if the agent involved requires containment at Biosafety Level 2 or higher, **the room shall be evacuated immediately**.

Doors shall be closed and clothing decontaminated. Call SHyS to supervise the cleanup. In general, a 30-minute wait is sufficient for the droplets to settle and aerosols to be reduced by air changes. Longer waiting periods may be imposed depending on the situation. Laboratory personnel and/or SHyS must exercise judgment as to the need for outside emergency help in evacuation.

If a spill of a biological agent requiring containment at Biosafety Level 2 or higher occurs in a public area, evacuation of the area shall be immediate. The principal investigator shall be responsible for designating the extent of evacuation until SHyS or emergency personnel arrive. Prevention of exposure to hazardous aerosols is of primary importance.

Anyone cleaning a spill shall wear personal protective equipment (for example, laboratory coat, shoe covers, gloves, and possible respiratory protection) to prevent exposure to organisms. An air-purifying negative-pressure respirator with P-100 filter cartridges is generally adequate protection against inhalation of most biological agents. However, there may be exceptions. Contact SHyS for advice in choosing the correct respiratory protection and for information regarding the requirements that must be met to wear a respirator.

An appropriate chemical disinfectant should be chosen that is effective against the organisms involved in the spill (see Tables 7.3A and 7.3B).

7.5.1 Sterilization, Disinfection, and Decontamination. The Environmental Protection Agency recognizes the following categories of chemical germicides (a germicide is an agent that kills pathogenic organisms). The information in this section is drawn from *Protection of Laboratory Workers from Instrument Biohazards and Infectious Disease Transmitted by Blood, Body Fluids, and Tissue*, Approved Guideline, NCCLS Document M29-A, Vol. 17, No.20 (National Committee for Clinical Laboratory Standards, December, 1997).

Sterilizer or **Sterilant**: An agent intended to destroy all microorganisms and their spores on inanimate surfaces.

Disinfectant: An agent intended to destroy or irreversibly inactivate specific viruses, bacteria, or pathogenic fungi, but not necessarily their spores, on inanimate surfaces. Most disinfectants are not effective sterilizers.

Hospital Disinfectant: An agent shown to be effective against specific organisms such as *Staphylococcus aureus*, *Salmonella choleraesuis*, and *Pseudomonas aeruginosa*. It may also be effective against other organisms and some viruses. The labels of all commercially available hospital disinfectants contain a claim (which must be documented) of effectiveness for specific agents.

Antiseptic: A chemical germicide formulated for use on skin or tissue. Antiseptics should not be used as disinfectants.

Decontamination: A procedure that eliminates or reduces microbial contamination to a safe level with respect to the transmission of infection. Sterilization and disinfection procedures are often used for decontamination.

The OSHA Bloodborne Pathogens Standard requires that all equipment and environmental and working surfaces shall be cleaned and decontaminated after contact with blood or other potentially infectious materials. The standard also requires decontamination of contaminated work surfaces after completion of procedures, immediately or as soon as feasible after any overt contamination of surfaces or any spill of potentially infectious material, and at the end of the work shift if the work surface has become contaminated. All reusable equipment shall be decontaminated immediately or as soon as feasible upon visible contamination.

It should be emphasized that, for any infectious material, adequate precleaning of surfaces is important for any disinfection or sterilization procedure. Ten minutes of exposure to a disinfectant may not be adequate to disinfect objects that have narrow channels or other areas that can harbor microorganisms. **Alcohols**, for example, are effective for killing hepatitis B virus (HBV) but are not recommended for this purpose because of their rapid evaporation and the consequent difficulty of maintaining proper contact times.

Chlorine compounds are probably the most widely used disinfectants in the laboratory. You can easily prepare an inexpensive, broad-spectrum disinfectant by diluting common household bleach.

Bleach is a 5.25% sodium hypochlorite solution—this is equal to approximately 50,000 ppm of free available chlorine. This level of chlorine can be harmful to skin and eyes. Lower concentrations are effective in disinfection and are less hazardous for the worker. The concentration to be used is based on your assessment of the severity of the contamination or spill of infectious materials.

- For small spills of infectious agents or for contamination on hard, smooth surfaces, a 1:100 dilution of commercial bleach is adequate. This is equivalent to 500 ppm of free chlorine.

- In the case of large or concentrated spills of infectious agents, a higher level of chlorine is needed to be effective in destroying the microorganisms. Use a 1:10 dilution (5,000 ppm of free chlorine) and flood the contaminated area with the solution. Alternatively, you can mix the disinfectant with the spilled material. This higher concentration is more suitable for porous surfaces that may harbor organisms in tiny cracks or pits.

Make the solution fresh each day. Be aware that chlorine compounds may corrode metals, especially aluminum. While a 10% household bleach solution is a commonly used decontaminant concentration, it is probably stronger than necessary for ordinary uses. It can be extremely irritating to personnel. Therefore, the use of higher concentrations of bleach in chemical fume hoods, and the autoclaving of materials that have been treated with bleach, should be reserved for significant contamination.

Note that bleach will react with water to form hypochlorous acid (HOCl), which will decompose to chlorine (Cl_2) and hydrogen chloride (HCl). Special care should be taken when autoclaving hypochlorite solutions because the procedure can generate chlorine gas, which will corrode steel. To avoid evolution of chlorine, the hypochlorite solution should be neutralized with sodium thiosulfate prior to autoclaving.

Formaldehyde is an OSHA-regulated chemical that is a suspect carcinogen, so its use as a disinfectant is not recommended.

Iodophors that are registered with the EPA may be effective hard-surface decontaminants when used per manufacturer's instructions, but iodophors formulated as antiseptics are not suitable for use as disinfectants.

Peracetic (peroxyacetic) acid and hydrogen peroxide mixtures minimize the negative effects of corrosiveness sometimes seen with chlorine compounds and high concentrations of peracetic acid alone. A limited number of trade-name products containing ‹0.1% peracetic acid and ‹1.0% hydrogen peroxide and registered with the EPA as sterilants/disinfectants are available. The benefit of these products is their rapid action and broad-spectrum of germicidal activity, in addition to the reduced corrosiveness.

In Section 5.0, the use of any chemicals with the prefix "per" is discouraged for cleaning glassware due to the reactivity of oxidizing materials. Peracetic acid is generally a strong irritant. The low percentage in these products reduces this danger. Nonetheless, these products are intended only for highly concentrated spills of biological materials.

Quaternary ammonium compounds are low-level disinfectants and are not recommended for spills of human blood, blood products, or other potentially infectious materials.

7.5.2 Decontamination of Spills. The following procedure is recommended for decontaminating spills of agents used at BSL-2.

1. Wear gloves and a laboratory coat or gown. Heavyweight, puncture-resistant utility gloves, such as those used for housecleaning and dishwashing, are recommended.
2. Do not handle sharps with the hands. Clean up broken glass or other sharp objects with sheets of cardboard or other rigid, disposable material. If a broom and dustpan are used, they must be decontaminated later.
3. Avoid generating aerosols by sweeping.
4. Absorb the spill. Most disinfectants are less effective in the presence of high concentrations of protein, so absorb the bulk of the liquid before applying disinfectants. Use disposable absorbent material such as paper towels. After absorption of the liquid, dispose of all contaminated materials as waste.
5. Clean the spill site of all visible spilled material using an aqueous detergent solution (e.g., any household detergent). Absorb the bulk of the liquid to prevent dilution of the disinfectant.
6. Disinfect the spill site using an appropriate disinfectant, such as a household bleach solution. Flood the spill site or wipe it down with disposable towels soaked in the disinfectant.
7. Absorb the disinfectant or allow it to dry.

8. Rinse the spill site with water.
9. Dispose of all contaminated materials properly. Place them in a biohazard bag or other leakproof, labeled biohazard container for sterilization.

7.5.3 Biological Spill in the Open Laboratory. For a spill in the open laboratory outside a biological safety cabinet, the spill response depends on the size of the spill and hazard of the material. A minimally hazardous material spilled without generating appreciable aerosols can be cleaned with a paper towel soaked in a chemical disinfectant.

A spill of a larger volume of hazardous material with aerosol generation requires evacuating the room, waiting for aerosol reduction, donning personal protective gear (including appropriate respiratory protection), selecting a disinfectant effective against the organisms involved, and cleaning as described above. Following cleanup, response personnel shall wash or shower with a disinfectant soap.

7.5.4 Biological Spill Within a Biological Safety Cabinet. A spill that is confined within a biological safety cabinet generally presents little or no hazard to personnel in the area. However, chemical disinfection procedures are to be initiated at once while the cabinet continues to operate. The disinfectant shall be one that is active against the organisms of potential hazard. Flammable liquids, such as ethanol or isopropanol, shall not be used, even if effective, because of the fire hazard of generating dangerous vapor concentrations within the cabinet that could be ignited by an electrical spark or other source.

Spray or wipe the walls, work surfaces, and equipment with the chosen disinfectant. Allow the disinfectant to remain on the surface for the appropriate contact time (refer to Table 7.3A and 7.3B for recommended contact times).

Minimize the generation of aerosols and use sufficient disinfectant to ensure that drain pans and catch basins below the work surface contain disinfectant. The front exhaust shall also be wiped and the disinfectant drained into a container.

7.5.5 Biological Spill in a Centrifuge or Other Equipment. A biological spill in a centrifuge has the potential for producing large volumes of aerosols. On becoming aware that a spill may have occurred within a centrifuge or other piece of equipment, turn off the equipment, warn others in the area, notify the investigador responsable, allow aerosols to settle, and decontaminate following the principles described above.

7.5.6 Biological Spill on a Person. If a biological material is spilled on a person, emergency response is based on the hazard of the biological agent spilled, the amount of material spilled, and whether significant aerosols were generated. If aerosol formation is believed to have been associated with the spill, a contaminated person shall leave the contaminated area immediately. If possible, (s)he should go to another laboratory area so that hallways and other public areas do not become contaminated.

Contaminated clothing is removed and placed in red or orange biohazard bags for disinfecting. Contaminated skin shall be flushed with water and thoroughly washed with a disinfectant soap. Showering may be appropriate, depending on the extent of the spill.

7.6 Human Blood, Blood Products, and Other Potentially Infectious Materials

FCEN is required to comply with the National Laws. The requirements of the standard are covered in the *Bloodborne Pathogens Program*. This document is available from SHyS or on the Web at biosafe/index.htm.

You should refer to the *Bloodborne Pathogens Program* if your work requires occupational exposure to any of the following human materials:

- Blood (human blood, human blood components, and products made from human blood)
- These human body fluids:
  semen
  vaginal secretions

cerebrospinal fluid
synovial fluid
pleural fluid
pericardial fluid
peritoneal fluid
amniotic fluid
saliva (in dental procedures)
any body fluid that is visibly contaminated with blood
all body fluids in situations where it is difficult or impossible to differentiate between body fluids

- Any unfixed tissue or organ (other than intact skin) from a human, living or dead.
- HIV-containing cell, tissue, or organ cultures; HIV- or HBV-containing culture medium or other solutions; and blood, organs, or other tissues from experimental animals infected with HIV or HBV.

Occupational exposure means reasonably anticipated skin, eye, mucous membrane, or parenteral contact with blood or other potentially infectious materials that may result from the performance of an employee's duties.

7.7 Recombinant DNA Research

Recombinant DNA research shall comply with the National Laws. El Sub-Comite de Seguridad en ADN Recombinante is responsible for implementing the guidelines and overseeing recombinant DNA research.

El investigadors responsable intending to use recombinant DNA molecules shall follow the directions in the FCEN's *Recombinant DNA Safety Program*, available from SHyS or on the Web at biosafe/index.htm. All recombinant DNA research falls into one of six classes.

If an experiment falls into section III-A, III-B, or III-C and one of the other sections as well, the rules pertaining to section III-A, III-B, or III-C shall be followed. If an experiment falls into section III-F alone, or into section III-F and into section III-D or III-E as well, the experiment is considered exempt from regulations.

In general, the containment practices to be used for recombinant DNA research shall follow those described for Biosafety Levels 1, 2, and 3 in the CDC-NIH *Biosafety in Microbiological and Biomedical Laboratories*. However, the NIH Recombinant DNA guidelines take precedence.

7.8 Animal Studies

Animal studies involving the use of hazardous biological agents represent special problems in containment. Policies and operational practices governing the use of animal containment facilities are under the direction of the Animal Care and Use Committee and the Bioterio. In general, practices for Animal Biosafety Levels 1, 2, and 3 presented in the CDC-NIH manual, *Biosafety in Microbiological and Biomedical Laboratories*, are followed.

Experiments involving the use of infectious biological agents in animals are generally conducted in containment facilities. Research in laboratory facilities shall be reviewed and approved, prior to the initiation of work, by the CS in conjunction with the Animal Care and Use Committee and the Bioterio.

7.9 Handling of Sheep Cells

The FCEN has adopted special policies for the handling of sheep cells due to the potential risk associated with Q fever.

All potentially infectious sheep cells shall be handled at BSL-2, similar to requirements for human cell cultures (as written in the *Safety Plan*).

Lab workers shall assume that all sheep cells are infectious unless there is acceptable serologic confirmation that they are not. Where vendors offer verification of testing of cells before shipment, the following criterion must be met: a biological safety professional or other qualified scientist with background and experience to review potential contamination and risk shall comment, in writing, on the test methods and molecular technology applied to a cell line sample to identify or screen for infectivity.

BSL-3 practices shall be applied in handling cells from sheep birth products (e.g., amniotic fluid, placenta).

7.10 Importation or Transport Permits

Está regulado por la leguislación vigente:

- the importation of all **animal-origin materials** (animal products and byproducts) that could present a disease risk to US livestock
- the import and transport of infectious organisms and vectors of disease agents
- biological materials that contain or have been in contact with certain organisms and animal materials (including cell cultures).

Generally, a veterinary permit is needed for materials derived from animals or exposed to animal-source materials. Materials which require a permit include animal tissues, blood, cells or cell lines of livestock or poultry origin, RNA/DNA extracts, hormones, enzymes, monoclonal antibodies for IN VIVO use in non-human species, certain polyclonal antibodies, antisera, bulk shipments of test kit reagents, and microorganisms including bacteria, viruses, protozoa, and fungi. Exceptions to this requirement are human and nonhuman primate tissues, serum, and blood.

There are certain materials (listed below) allowed to be imported without a permit; however, inspectors will nonetheless review these materials at the port of entry. SHyS maintains a copy of the national "Guidelines for Importation" on file for a discussion of the necessary shipping documents that must accompany the materials. These particular guidelines cover:

- Human and nonhuman primate material
  Includes: tissues, blood, extracts, proteins, DNA, human vaccines in final dosage form
- Feline and canine material
  Includes: blood, tissues, serum, feces, extracts, fluids, canine semen for research purposes
  Does Not Include: cell cultures, tissue cultures, cell culture products, canine semen for reproductive purposes
- Live laboratory mammals and their material—for research purposes
  Includes: transgenic/knock-out mice and rats, hamsters, gerbils, guinea pigs, rabbits, and their blood, tissue, DNA, extracts, antibodies, feces, sera, and antisera
  Does Not Include: primates, dogs, cats, livestock*, poultry, hedgehogs, tenrecs, monoclonal antibodies, hybridomas, cell lines, and material for commercial purposes
- Amphibians, fish, reptiles, shellfish and aquatic species
  Includes: blood, tissues, serum, feces, extracts, fluids, venom, urine from these species
  Does Not Include: antivenom
- Chemically synthesized materials
  Includes: biochemicals, materials not containing or derived from animal products
- Microbially produced materials
  Includes: enzymes, plasmids, proteins, antibiotics, hormones, extracts, phages, DNA
- Recombinant microbes and their products
  Includes: microbes (bacteria, viruses, yeasts/fungi), proteins, hormones, extracts, plasmids, DNA, RNA
  Does Not Include: materials produced by cell culture techniques
- Nonpathogenic microorganisms (and their extracts)
  Includes: environmental or water organisms, such as algae
- Cell cultures/lines, recombinant cell cultures/lines, and their products (for IN VITRO use)
  Includes: monoclonal antibodies, cell culture supernatants, ascitic fluid, cell extracts, hybridomas, cell cultures/lines which are not derived from livestock* or avian species
  Does Not Include: cell lines of livestock* or avian species origin and their products, microbial cultures and their products
- Test kits
  Includes: pre-packaged kits and kit components (reagents, calibraters, controls) packaged for final use
  Does Not Include: kits used to diagnose infectious diseases of animals (excluding humans)

*Livestock includes any bovine, ovine, caprine, porcine, and equine animal.

7.11 Transfer of Select Agents

The transfer of some select agents is regulated (listed in Table 7.1) that are capable of causing substantial harm to human health.

Current regulations specify the packaging, labeling, and transport of select agents in interstate commerce. Facilities that transfer or receive select agents shall register with SHyS and be approved as being equipped and capable of handling the covered agent at the appropriate Biosafety Level (BSL). The regulations further dictate destruction procedures for select agents once use is terminated.

To be permitted to transfer and receive select agents, your lab will need to register with SHyS for the specific agent intended to be used. Before considering transfer or receipt of select agents for your research work, contact your department head or SHyS. There are various exemptions (see Table 7.1 and 7.2) which may apply to your particular use of a given select agent. Thus, facility registration may not be necessary. If it is, SHyS shall coordinate the registration process.

SHyS surveys departments on an annual basis to determine the potential use of select agents, both exempt and nonexempt. Department heads are required to report the status of use of select agents in individual laboratories. Please supply your department head with the correct information when requested.

7.12 Infectious Waste Management

Infectious waste materials shall be treated properly to eliminate the potential hazard that these wastes pose to human health and the environment. Treatment commonly involves steam sterilization.

7.12.1 Separation and Packaging of Infectious Waste. Infectious wastes shall be separated from general, noninfectious waste materials and from wastes containing radioactive, carcinogenic, or toxic materials. Some wastes may contain multiple hazards. These shall be handled such that priority is given to the greatest hazard present. A procedure for handling mixed biological/radioactive waste has been prepared by SHyS and is available on request. It is also available in the SHyS publication *Radiation Safety Handbook*.

Disposable infectious materials shall be placed in red or orange plastic bags. The bags shall be seamless, tear-resistant, and autoclavable. Single bags shall have a minimum thickness of 3.0 mils and double bags, 1.5 to 2.0 mils. Bags shall be closed by folding or tying when full, at the end of the day, or before transporting.

To minimize formation of aerosols, infectious wastes shall not be compacted prior to decontamination.

7.12.2 Storage and Transport of Infectious Waste. Infectious wastes that are removed from a laboratory or stored temporarily shall be closed and double-bagged or placed inside a covered, unbreakable outer container.

7.12.3 Infectious Waste Treatment. Infectious wastes are generally rendered noninfectious by autoclaving. After sterilization, previously infectious wastes are disposed of as noninfectious. They may be placed in noninfectious trash collection containers and sent to a sanitary landfill. Treated wastes in red or orange bags shall be overpacked into opaque plastic bags of another color (not yellow) for noninfectious disposal. The custodial staff has been instructed not to touch or remove red, orange, or yellow bags. Sterilized liquid wastes may be discarded to the sewer.

As described under procedures for Biosafety Levels 2 and 3 and in the *Bloodborne Pathogens Program*, syringes and needles shall be handled with extreme caution to avoid autoinoculation and the generation of aerosols. Needles shall not be bent, sheared, replaced in the sheath or guard, or removed from the syringe following use. The needle and syringe shall be promptly placed in a puncture-resistant container and decontaminated, preferably by autoclaving. Needles may be rendered unusable following sterilization. Grinding, compaction, or clipping in a destruction device are acceptable techniques for destroying sterile needles.

All human blood, blood products, nonfixed human tissues, and other potentially infectious materials are considered infectious and shall be disinfected or steam sterilized. Sterilized blood-related waste materials are discarded as nonhazardous.

Infectious wastes, including cultures and stocks of etiologic agents, shall be made noninfectious by steam sterilization. Sterilized wastes are disposed of as nonhazardous.

Pathological wastes are generally steam sterilized, although after sterilization, pathological wastes shall be porperly dispossed.

Animal carcasses, bedding, and wastes are generally dispossed by the Bioterio.

7.12.3.1 Steam Sterilization

Most infectious wastes are sterilized, based on the type of waste, load volume, packaging material, and load configuration. It is recommended that the efficacy of the autoclave be monitored using *Bacillus stearothermophilis*. The frequency of monitoring depends on the hazard of the organism being used and the frequency of waste sterilization.

Infectious wastes that also contain volatile chemicals should be autoclaved only if a chemical (hydrophobic) filter is on line. SHyS shall be contacted before steam sterilizing wastes containing carcinogens or radionuclides.

7.12.3.2 Incineration

Incineration is not allowed at the FCEN. SHyS may be contacted for additional information.

7.12.3.3 Chemical Disinfection

Chemical treatment is usually a disinfection rather than sterilization. Thus it is usually intended as a temporary measure to control infectious wastes until sterilization can treat the hazard. Disinfection may be used as final treatment on a case-by-case basis following a petition by the principal investigator and approval by the Comite de Seguridad.

Section 7.5.1 and Tables 7.3A and 7.3B summarize information on practical disinfectants.

Table 7.1 Select infectious agents

Viruses	**Toxins**
Crimean-Congo haemorrhagic fever virus	Abrin
Eastern Equine Encephalitis virus	Aflatoxins
Ebola viruses	Botulinum toxins
Equine Morbillivirus	Clostridium perfringens epsilon toxin
Lassa fever virus	Conotoxins
Marburg virus	Diacetoxyscirpenol
Rift Valley fever virus	Ricin
South American Haemorrhagic fever viruses (Junin, Machupo, Sabia, Flexal, Guanarito)	Saxitoxin
	Shigatoxin
Tick-borne encephalitis complex viruses	Staphylococcal enterotoxins
Variola major virus (Smallpox virus)	Tetrodotoxin
Venezuelan Equine Encephalitis virus	T-2 toxin
Viruses causing hantavirus pulmonary syndrome	*Exemptions:* Toxins for medical use, inactivated for use as vaccines, or toxin preparations for biomedical research use at an LD_{50} for vertebrates of more than 100 nanograms per kilogram body weight are exempt. National standard toxins required for biological potency testing as described in 9 CFR Part 113 are exempt.
Yellow fever virus	
Exemptions: Vaccine strains of viral agents (Junin Virus strain candid #1, Rift Valley fever virus strain MP-12, Venezuelan Equine encephalitis virus strain TC-83, Yellow fever virus strain 17-D) are exempt.	
Bacteria	**Recombinant**

	organisms/molecules
Bacillus anthracis	Genetically modified microorganisms or genetic elements from organsims on Appendix A, shown to produce or encode for a factor associated with a disease.
Brucella abortus, B. melitensis, B. suis	
Burkholderia (Pseudomonas) mallei	
Burkholderia (Pseudomonas) pseudomallei	
Clostridium botulinum	Genetically modified microorganisms or genetic elements that contain nucleic acid sequences coding for any of the toxins listed in this Appendix, or their toxic subunits.
Francisella tularensis	
Yersinia pestis	
Exemptions: vaccine strains as described in Title 9 CFR, Part 78.1 are exempt.	
Rickettsiae	**Other restrictions**
Coxiella burnetii	The deliberate transfer of a drug resistance trait to microorganisms listed in this Appendix that are not known to acquire the trait naturally is prohibited by NIH "Guidelines for Research Involving Recombinant DNA Molecules," if such acquisition could compromise the use of the drug to control these disease agents in humans or veterinary medicine.
Rickettsia prowazekii	
Rickettsia rickettsii	
Fungi	
Coccidioides immitis	

From Centers for Disease Control and Prevention (CDC) Web site www.cdc.gov/od/ohs/lrsat/42cfr72.htm#AppendixA

Table 7.2 Exemptions for Certain Select Agents

Select agents otherwise covered by this part are exempt from its provisions if:

1. The agent is part of a clinical specimen intended for diagnostic, reference, or verification purposes. Isolates of covered agents from clinical specimens shall be disposed of in accordance with biosafety standards after diagnostic, reference, or verification procedures have been completed;
2. The agent is a toxin having an LD_{50} for vertebrates of more than 100 nanograms per kilogram of body weight which is used for legitimate medical purposes or biomedical research or is one of the listed toxins which has been inactivated for use as a vaccine or otherwise detoxified for use in a biomedical research procedure.

Table 7.3A Summary of Practical Disinfectants

Disinfectant	**Dilution**	**Contact time (minutes)**		**Irritant type**		
		Lipovirus	Broad-Spectrum	Skin	Eye	Respiratory
Quaternary ammonium cpds. (L)	0.1-2.0%	10	Not effective	Yes	Yes	No
Phenolic cpds. (L)	1.0-5.0%	10	Not effective	Yes	Yes	No
Chlorine cpds. (L)	500ppm*	10	30	Yes	Yes	Yes
Iodophor cpds. (L)	25-1600ppm	10	30	Yes	Yes	No
Ethyl alcohol (L)	70-85%	10	Not effective	No	Yes	No

Isopropyl alcohol (L)	70-85%	10	Not effective	No	Yes	No
Formaldehyde (L)	0.2-8.0%	10	30	Yes	Yes	No
Glutaraldehyde (L)	2%	10	30	Yes	Yes	No
Ethylene oxide (G)	8-23g/ft^3	60	60	Yes	Yes	Yes
Paraformaldehyde (G)	0.3g/ft^3	60	60	Yes	Yes	Yes

L = liquid; G = gas

*Commercially available chlorine bleach is 5.25% chlorine (52,200 ppm). A dilution of 1 to 100 will yield a 525 ppm solution, which is suitable for disinfecting purposes.

Source: *Laboratory Safety Monograph*, U.S. Department of Health, Education, and Welfare, Public Health Servic, and National Institutes of Health, 1979.

Table 7.3B Decontaminants and Their Use in Infectious Waste Management

	Ethylene Oxide	Para-form-aldehyde (gas)	Quaternary Ammonium Compounds	Phenolic Compounds	Chlorine Compounds	Iodophor Compounds	Alcohol (ethyl or isopropyl)	Form-aldehyde (liquid)	Glutar-aldehyde
Use Parameters									
Concen-tration of active ingredient	400-800mg/l	0.3g/ft^3	0.1-2%	0.2-3%	0.01-5%	0.47%	70-85%	4-8%	2%
Temper-ature, ºC	35-60	>23							
Relative humidity, %	30-60	>60							
Contact time, minutes	105-240	60-180	10-30	10-30	10-30	10-30	10-30	10-30	10-600
Effective Against[a]									
Vegetative bacteria	+	+	+	+	+	+	+	+	+
Bacterial spores	+	+			×			×	+
Lipo viruses	+	+	+	+	+	+	+	+	+
Hydrophilic viruses	+	+		×	+	×	×	+	+
Tubercl bacilli	+	+		+	+	+	+	+	+
HIV	+	+	+	+	+	+	+	+	+
HBV	+	+		×	+	×	×	+	+
Applications[a]									
Contam-inated liquid discard				+				×	
Contam-inated glassware	×		+	+	+	+		×	+
Contam-inated instruments	×			+	+			×	+
Equipmen total decontam-ination	×	+							

[a] + denotes very positive response; ×, a less positive response; and a blank, a negative response or not applicable.

Adapted from *Laboratory Safety, Principles and Practices*, D. Fleming, J. Richardson, J. Tulis, D. Vesley; American Society for Microbiology, 1995: 226-227.

Table 7.4 Agent Summary Statements Available

The following agent summary statements are available from SHyS. Source: *Biosafety in Microbiological and Biomedical Laboratories*, HHS Publication No. (CDC) 93-8395, CDC/NIH, 3rd edition, May 1999.

Parasitic Agents
Blood and Tissue Protozoal Parasites of Humans
Intestinal Protozoal Parasites of Humans
Trematode Parasites of Humans
Cestode Parasites of Humans
Nematode Parasites of Humans

Fungal Agents
Blastomyces dermatitidis
Coccidioides immitis
Cryptococcus neoformans
Histoplasma capsulatum
Sporothrix schenckii
Pathogenic Members of the Genera Epidermophyton, Microsporum, and Trichophyton
Miscellaneous Molds

Bacterial Agents
Bacillus anthracis
Bordetella pertussis
Brucella (*B. abortus*, *B. canis*, *B. melitensis*, *B. suis*)
Burkholderia pseudomallei (Pseudomonas pseudomallei)
Campylobacter (*C. jejuni/C. coli*, *C. fetus* subsp. *fetus*)
Chlamydia psittaci, *C. pneumoniae*, *C. trachomatis*
Clostridium botulinum
Clostridium tetani
Corynebacterium diphtheriae
Escherichia coli (Cytotoxin-producing (VTEC/SLT) organisms)
Francisella tularensis
Helicobacter pylori
Leptospira interrogans - all serovars
Listeria monocytogenes
Legionella pneumophila; *other Legionella-like agents*
Mycobacterium leprae
Mycobacterium spp. other than *M. tuberculosis*, *M. bovis* or *M. leprae*
Mycobacterium tuberculosis, *M. bovis*
Neisseria gonorrhoeae
Neisseria meningitidis
Salmonella - all serotypes except typhi
Salmonella typhi
Shigella spp.
Treponema pallidum
Vibrionic enteritis (*Vibrio cholerae*, *V. parahaemolyticus*)
Yersinia pestis

Prions

Rickettsial Agents
Coxiella burnetii
Rickettsia prowazekii, *Rickettsia typhi* (*R. mooseri*), *Orientia (Rickettsia) tsutsugamushi and Spotted Fever Group agents of human disease; Rickettsia rickettsii*, *Rickettsia conorii*, *Rickettsia akari*, *Rickettsia australis*, *Rickettsia siberica, and Rickettsia japonicum*

Viral Agents (other than arboviruses)
Hantaviruses
Hendra and Hendra-like Viruses (includes virus formerly known as Equine Morbillivirus)
Hepatitis A Virus, Hepatitis E Virus
Hepatitis B Virus, Hepatitis C Virus (formerly known as nonA nonB Virus), Hepatitis D Virus
Herpesvirus simiae (*Cercopithecine herpesvirus* [CHV-1], B-virus)
Human Herpesviruses
Influenza
Lymphocytic Choriomeningitis Virus
Poliovirus
Poxviruses
Rabies Virus
Retroviruses, including Human and Simian Immunodeficiency Viruses (HIV and SIV)
Transmissible Spongiform Encephalopathies (*Creutzfeldt-Jakob*, *kuru and related agents*)
Vesicular Stomatitis Virus

Arboviruses and Related Zoonotic Viruses -
see the following tables:

Table 7.5 Arboviruses and Arenaviruses Assigned to Biosafety Level 2

Table 7.6 Vaccine Strains of BSL-3/4 Viruses Which May be Handled at BSL-2

Table 7.7 Arboviruses and Certain Other Viruses Assigned to BSL-3 (on the basis of insufficient experience)

Table 7.8 Arboviruses and Certain Other Viruses Assigned to BSL-3

Table 7.5 Arboviruses and Arenaviruses Assigned to Biosafety Level 2				
Acado	Chandipura	Kamese	Murutucu	Sokuluk
Acara	Changuinola	Kammavanpettai	Mykines	Soldado
Aguacate	Charleville	Kannamangalam	Navarro	Sororoca
Alfuy	Chenuda	Kao Shuan	Nepuyo	Stratford
Almpiwar	Chilibre	Karimabad	Ngaingan	Sunday Canyon
Amapari	Chobar gorge	Karshi	Nique	Tacaiuma
Ananindeua	Clo Mor	Kasba	Nkolbisson	Tacaribe
Anhanga	Colorado tick fever	Kemerovo	Nola	Taggert
Anhembi	Corriparta	Kern Canyon	Ntaya	Tahyna
Anopheles A	Cotia	Ketapang	Nugget	Tamiami
Anopheles B	Cowbone Ridge	Keterah	Nyamanini	Tanga
Apeu	Csiro Village	Keuraliba	Nyando	Tanjong Rabok
Apoi	Cuiaba-	Keystone	O'nyong-nyong	Tataguine
Aride	D'Aguilar	Kismayo	Okhotskiy	Tehran
Arkonam	Dakar Bat	Klamath	Okola	Tembe
Aroa	Dengue-1	Kokobera	Olifantsvlei	Tembusu
Aruac	Dengue-2	Kolongo	Oriboca	Tensaw
Arumowot	Dengue-3	Koongol	Ossa	Tete
Aura	Dengue-4	Kotonkan	Pacora	Tettnang
Avalon	Dera Ghazi Khan	Kowanyama	Pacui	Thimiri
Abras	East equine encephalitis*	Kunjin	Pahayokee	Thottapalayam
Abu Hammad	Edge Hill	Kununurra	Palyam	Tibrogargan
Babahoyo	Entebbe Bat	Kwatta	Parana	Timbo
Bagaza	Ep. Hem. Disease	La Crosse	Pata	Timboteua
Bahig	Erve	La Joya	Pathum Thani	Tindholmur
Bakau	Eubenangee	Lagos Bat	Patois	Toscana
Baku	Eyach	Landjia	Phnom-Penh bat	Toure
Bandia	Flanders	Langat	Pichinde	Tribec
Bangoran	Fort Morgan	Lanjan	Pixuna	Triniti
Bangui	Frijoles	Las Maloyas	Pongola	Trivittatus
Banzi	Gamboa	Latino	Ponteves	Trubanaman
Barmah Forest	Gan Gan	Le Dantec	Precarious Point	Tsuruse
Barur	Gomoka	Lebombo	Pretoria	Turlock
Batai	Gossas	Lednice	Prospect Hill	Tyuleniy
Batama	Grand Arbaud	Lipovnik	Puchong	Uganda S
Bauline	Great Island	Lokern	Punta Salinas	Umatilla
Bebaru	Guajara	Lone Star	Punta Toro	Umbre
Belmont	Guama	Lukuni	Qalyub	Una
Benevides	Guaratuba	M'poko	Quaranfil	Upolu
Benfica	Guaroa	Madrid	Restan	Urucuri
Bertioga	Gumbo Limbo	Maguari	Rio Bravo	Usutu
Bimiti	Hart Park	Mahogany hammock	Rio Grande	Uukuniemi
Birao	Hazara	Main Drain	Ross River	Vellore
Bluetongue	Highlands J	Malakal	Royal Farm	Venkatapuram
Boraceia	Huacho	Manawa	Sabo	Vinces
Botambi	Hughes	Manitoba	Saboya	Virgin River
Boteke	Icoaraci	Manzanilla	Saint Floris	VS-Indiana
Bouboui	Ieri	Mapputta	Sakhalin	VS-New Jersey
Bujaru	Ilesha	Maprik	Salehabad	Wad Medani
Bunyamwera	Ilheus	Marco	San Angelo	Wallal
Bunyip Creek	Ingwavuma	Marituba	Sandfly fever (Naples)	Wanowrie
Burg El Arab	Inkoo	Marrakai	Sandfly fever (Sicilian)	Warrego
Bushbush	Ippy	Matariya	Sandjimba	West equine encephalitis*
Bussuquara	Irituia	Matruh	Sango	Whataroa
Buttonwillow	Isfahan	Matucare	Sathuperi	Witwatersrand
Bwamba	Itaporanga	Melao	Sawgrass	Wongal
Cacao	Itaqui	Mermet	Sebokele	Wongorr
Cache Valley	Jamestown Canyon	Minatitlan	Seletar	Wyeomyia
Caimito	Japanaut	Minnal	Sembalam	Yaquina Head
California encephalitis	Johnson Atoll	Mirim	Serra do Navio	Yata
Calovo	Joinjakaka	Mitchell River	Shamonda	Yogue
Candiru	Juan Diaz	Modoc	Shark River	Zaliv Terpeniya
Cape Wrath	Jugra	Moju	Shuni	Zegla
Capim	Jurona	Mono Lake	Silverwater	Zika
Caraparu	Jutiapa	Mont. myotis leuk.	Simbu	Zingilamo
Carey Island	Kadam	Moriche	Simian hem. fever	Zirqa

Catu	Kaeng Khoi	Mosqueiro	Sindbis	
Chaco	Kaikalur	Mossuril	Sixgun City	
Chagres	Kaisodi	Mount Elgon bat	Snowshoe hare	

*A vaccine is available and is recommended for all persons working with this agent.

Table 7.6 Vaccine Strains of BSL-3/4 Viruses Which May Be Handled at BSL-2

Virus	Vaccine Strain
Chikungunya	131/25
Junin	Candid#1
Rift Valley fever	20MP-12
Venezuelan equine encephalomyelitis	TC-83
Yellow fever	17-D

Table 7.7 Arboviruses and Certain Other Viruses Assigned to BSL-3 (On the Basis of Insufficient Experience)

Adelaide River	Estero Real	Meaban	Razdan
Agua Preta	Fomede	Mojui Dos Compos	Resistencia
Alenquer	Forecariah	Monte Dourado	Rochambeau
Almeirim	Fort Sherman	Munguba	Salanga
Altamira	Gabek Forest	Naranjal	San Juan
Andasibe	Gadgets Gully	Nariva	Santa Rosa
Antequera	Garba	Nasoule	Santarem
Araguari	Gordil	Ndelle	Saraca
Aransas Bay	Gray Lodge	New Minto	Saumarez Reef
Arbia	Gurupi	Ngari	Sedlec
Arboledas	Iaco	Ngoupe	Sena Madureira
Babanki	Ibaraki	Nodamura	Sepik
Batken	Ife	Northway	Shokwe
Belem	Iguape	Odrenisrou	Slovakia
Berrimah	Inhangapi	Omo	Somone
Bimbo	Inini	Oriximina	Sripur
Bobaya	Issyk-Kul	Ouango	Tai
Bobia	Itaituba	Oubangui	Tamdy
Bozo	Itimirim	Oubi	Telok Forest
Buenaventura	Itupiranga	Ourem	Termeil
Cabassou*	Jacareacanga	Palestina	Thiafora
Cacipacore	Jamanxi	Palma	Tilligerry
Calchaqui	Jari	Para	Tinaroo
Cananeia	Kedougou	Paramushir	Tlacotalpan
Caninde	Khasan	Paroo River	Tonate*
Chim	Kindia	Perinet	Utinga
Coastal Plains	Kyzylagach	Petevo	Xiburema
Connecticut	Lake Clarendon	Picola	Yacaaba
Corfou	Llano Seco	Playas	Yaounde
Dabakala	Macaua	Pueblo Viejo	Yoka
Douglas	Mapuera	Purus	Yug Bogdanovac
Enseada	Mboke	Radi	

*Subcommittee on Arbovirus Laboratory Safety (SALS) recommends that work with this agent should be conducted only in Biosafety Level 3 facilities which provide for HEPA filtration of all exhaust air prior to discharge from the laboratory.

*TC-83 vaccine is available and is recommended for all persons working with this agent.

Table 7.8 Arboviruses and Certain Other Viruses Assigned to BSL-3	
Aino	Murray Valley enc.
Akabane[c]	Nairobi sheep disease[a,i]
Banna[a,f]	Ndumu
Bhanja	Negishi
Central Eur. TBE [b,d] (Absettarov, Hanzalova, Hypr, and Kumlinge)	Oropouche[c]
	Orungo
Chikungunya[c,d]	Peaton
Cocal	Piry[i]
Dhori	Powassan
Dobrava-Belgrade	Puumala
Dugbe	Rift Valley fever[a,c,d,h,i]
Everglades[c,d]	Rocio[c]
Flexal	Sagiyama
Germiston[c]	Sal Vieja
Getah	San Perlita
Hantaan[h]	Semliki Forest
Israel Turkey mening.	Seoul
Japanese enc.[h]	Sin Nombre
Junin[c,d,h]	Spondweni
Kairi	St. Louis enc.
Kimberley	Thogoto
Koutango	Turuna
Kumlinge (Cent. Eur. TBE)	Venezuelan equine encephalitis[c,d,h,i]
Louping III[a,c,h]	Vesicular stomatitus (Alagoas)[h,i]
Mayaro	Wesselsbron[a,c,i]
Middelburg	West Nile
Mobala	Yellow fever[c,d]
Mopeia[e]	Zinga[g]
Mucambo[c,d]	

a. The importation, possession, or use of this agent is restricted by USDA regulation or administrative policy.
b. Central European Tick Borne Encephalitis virus (CETBE) is not a registered name in *The International Catalogue of Arboviruses-1985*. Until the registration issue has been resolved taxonomically, CETBE refers to the following group of very closely related, if not essentially identical, tick-borne flaviviruses isolated from Czechoslovakia, Finland and Russia: Absettarov, Hanzalova, Hypr, and Kumlinge. These four viruses are antigenically homogeneous and are distinguishable from Russian Spring-Summer encephalitis (RSSE) virus. While there is a vaccine available which confers immunity to the CETBE group of genetically (>98%) homogeneous viruses, the efficacy of this vaccine against RSSE virus infections has not been established. Thus, SALS has reclassified the CETBE group of viruses as Biosafety Level 3 when personnel are immunized with CETBE vaccine. RSSE remains classified as a Biosafety Level 4 virus.
c. Subcommittee on Arbovirus Laboratory Safety (SALS) recommends that work with this agent should be conducted only in Biosafety Level 3 facilities that provide for HEPA filtration of all exhaust air prior to discharge from the laboratory.
d. A vaccine is available and is recommended for all persons working with this agent.
e. This virus is presently being registered in the *Catalogue of Arboviruses*.
f. Scientists from the People's Republic of China have verbally reported Banna

virus to be associated with severe human cases of encephalitis. Translations of the original publications from Chinese into English were not available for this revision.

g. Zinga virus is now recognized as being identical to Rift Valley Fever virus.

h. Export permit required from Department of Commerce.

i. An importation or domestic transfer permit for this agent can be obtained from USDA/APHIS/VS.

Appendix A: Regulated or Listed Carcinogens

Carcinogen Name	ACGIH-TLV	IARC	NIOSH	NTP	NU	OSHA
acetaldehyde	X	X	X	X		
acetamide		X				
2-acetylaminofluorene			X	X		X
acrolein*						
acrylamide	X	X	X	X		
acrylic acid, ethyl ester		X	X	X		
acrylonitrile	X	X	X	X		X
aldrin	X		X			
allyl chloride	X					
3-amino-1,2,4-triazole	X	X	X	X		
o-aminoazotoluene		X		X		
4-aminodiphenyl	X	X	X	X		X
amitrole	X	X	X	X		
ammonium perfluorooctanoate	X					
amosite	X	X	X	X		X
aniline & homologues	X		X			
o-anisidine	X	X	X			
antimony trioxide, production	X					
arsenic, elemental & inorganic compounds (except arsine), as As	X	X	X	X		X
arsenous acid, arsenic acid and salts	X	X	X	X		X
arsine			X			
asbestos, amosite	X	X	X	X		X
asbestos, chrysotile	X	X	X	X		X
asbestos, crocidolite	X	X	X	X		X
asbestos, other forms	X	X	X	X		X
asphalt (petroleum) fumes		X	X			
atrazine		X				
auramine		X				
azacitidine				X		
beech wood dust			X			
benz[a]anthracene	X	X		X		
benzal chloride		X				
benzene	X	X	X	X		X
benzidine	X	X	X	X		X

benzo[a]pyrene	X	X	X	X		
benzo[b]fluoranthene	X	X		X		
benzotrichloride	X	X		X		
benzyl chloride	X	X				
benzyl dichloride		X				
benzyl trichloride	X	X		X		
beryllium and compounds, as Be	X	X	X	X		
4-(p-bis(2-chloroethyl)aminophenyl)-butyric acid					X	
1,3-bis-2-chloroethyl-1-nitrosourea					X	
bisoxypropylamine					X	
2,5-bisphenyloxazole					X	
bitumen		X	X			
bromacil	X					
bromoethane	X					
bromoform	X					
1,3-butadiene	X	X	X	X		
tert-butyl chromate, as CrO3			X			
N-butyl-N-(3-carboxylpropyl)nitrosamine					X	
cadmium and compounds, as Cd	X	X	X	X		X
calcium chromate, as Cr	X	X	X	X		
captafol		X	X			
captan	X		X			
carbamic acid, ethyl ester		X		X		
carbon black		X	X			
carbon tetrachloride	X	X	X	X		
catechol	X					
ceramic fibers				X		
chlordane	X	X	X			
chlordecone		X	X	X		
chlorinated camphene	X	X	X	X		
1-chloro,2,3-epoxypropane	X	X	X	X		
2-chloro-1,3-butadiene			X			
3-chloro-2-methylpropene				X		
4-chloro-o-phenylenediamine		X		X		
4-chloro-o-toluidine		X				
p-chloro-o-toluidine				X		
chlorobenzene	X					
chlorodiphenyl (42% chlorine)		X	X	X		
chlorodiphenyl (54% chlorine)	X	X	X	X		
chloroethane	X					
bis(beta-chloroethyl)-sulfide		X		X		
chloroethylene	X	X	X	X		X
chloroform	X	X	X	X		
chloromethyl methyl ether	X	X	X	X		X
bis(chloromethyl) ether	X	X	X	X		X

p-chloronitrobenzene	X		X			
chloroparaffins (20%-70% chlorine)				X		
beta-chloroprene			X			
chlorozotocin				X		
chromates, alkaline, as Cr	X					
chromic acid and chromates	X		X			
chromite ore processing (chromate), as Cr	X					
chromium (VI) compounds, as Cr, water insoluble	X	X	X	X		
chromium (VI) compounds, as Cr, water soluble	X	X	X	X		
chromium trioxide, as Cr	X	X	X	X		
chromyl chloride		X	X			
chrysene	X		X			
chrysotile	X	X	X	X		X
coal tar pitch volatiles, as benzene solubles	X	X	X	X		
cobalt carbonyl, as Co		X				
cobalt hydrocarbonyl, as Co		X				
cobalt, elemental & inorganic compounds, as Co	X	X				
coke oven emissions		X	X	X		X
p-cresidine		X		X		
cristobalite		X	X	X		
crocidolite	X	X	X	X		X
crotonaldehyde	X					
cyclonite*						
cyclosporin				X		
2,4-D		X				
danthron				X		
DDT	X	X	X	X		
di(2-ethylhexyl)phthalate	X	X	X	X		
di-sec-octyl-phthalate	X	X	X	X		
diaminobenzidine					X	
4,4'-diaminodiphenyl ether		X		X		
4,4'-diaminodiphenylmethane	X	X	X	X		X
2,4-diaminosanisole		X	X			
2,4-diaminotoluene		X	X	X		
o-dianisidine-based dyes		X	X	X		
diazomethane	X					
1,2-dibromo-3-chloropropane		X	X	X		X
1,2-dibromoethane	X	X	X	X		
1,4-dichloro-2-butene	X					
dichloroacetylene	X		X			
p-dichlorobenzene	X	X	X	X		
3,3'-dichlorobenzidine	X	X	X	X		X
2-2'-dichlorodiethylsulfide		X		X		
dichlorodiphenyltrichloroethane	X	X	X	X		
1,2-dichloroethane	X	X	X	X		

1,1-dichloroethane*						
dichloroethyl ether			X			
1,1-dichloroethylene	X		X			
dichloromethane	X	X	X	X		X
2,4-dichlorophenoxyacetic acid		X				
1,2-dichloropropane			X			
1,3-dichloropropene	X	X	X	X		
dichlorvos		X				
dieldrin			X			
diesel engine emissions		X	X			
diethyl sulfate		X		X		
diethylene dioxide (dioxane)		X	X	X		
diglycidyl ether			X			
diglycidyl resorcinol ether		X		X		
dihydroxybenzene	X					
3,3'-dimethoxybenzidine		X	X	X		
dimethyl carbamoyl chloride	X	X	X	X		
dimethyl sulfate	X	X	X	X		
4-dimethylaminoazobenzene		X	X	X		X
dimethylaminobenzaldehyde					X	
dimethylaminobenzene	X					
3,3'-dimethylbenzidene	X	X	X	X		
dimethylformamide		X				
1,1-dimethylhydrazine	X	X	X	X		
1,2-dimethylhydrazine		X				
N,N-dimethylnitrosoamine	X	X	X	X		X
1,6-dinitropyrene				X		
1,8-dinitropyrene				X		
dinitrotoluene	X		X			
dioxane	X	X	X	X		
disperse blue 1				X		
epichlorohydrin	X	X	X	X		
2,3-epoxy-1-propanol	X			X		
1,2-epoxypropane	X	X	X	X		
ethidium bromide					X	
ethyl acrylate		X	X	X		
ethyl bromide	X					
ethyl chloride	X					
ethylene dibromide	X	X	X	X		
ethylene dichloride		X	X	X		
ethylene oxide	X	X	X	X		X
ethylene thiourea		X	X	X		
ethylenimine	X	X	X			X
ethylidene chloride*						
fibrous glass dust		X		X		

formaldehyde	X	X	X	X		X
furan				X		
furfural	X					
gallium arsenide			X			
gasoline	X	X	X			
glycidol	X			X		
heptachlor and heptachlor epoxide	X	X	X			
hexachlorobenzene	X	X		X		
hexachlorobutadiene	X		X			
gamma-hexachlorocyclohexane	X	X		X		
hexachloroethane	X		X	X		
hexamethyl phosphoramide	X	X	X	X		
hydrazine	X	X	X	X		
hydrogen peroxide	X					
hydroquinone	X					
isophorone	X					
kepone		X	X	X		
lead arsenate, as Pb(AsO4)2		X	X	X		X
lead chromate	X	X	X	X		
lead elemental and inorganic compounds, as Pb	X	X		X		
lead phosphate	X	X		X		
lindane	X	X		X		
man-made mineral fibers		X				
methoxychlor			X			
methyl bromide			X			
methyl chloride			X			
methyl hydrazine	X		X			
methyl iodide			X			
methyl mercury		X				
N-methyl-bis(2-chloro-ethyl) amine		X		X		
methyl-o-anisidine		X		X		
methyl-tert-butyl ether	X					
2-methylaziridine	X	X	X	X		
methylbenzylnitrosamine					X	
4,4'-methylene bis(2-chloroaniline)	X	X	X	X		
4,4'-methylene bis(N,N-dimethyl) benzenamine				X		
4,4'-methylene bis-(2-methylaniline)		X				
methylene chloride	X	X	X	X		X
4,4'-methylene dianiline	X	X	X	X		X
Michler's ketone				X		
monochlorobenzene	X					
monochlorodimethyl ether	X	X	X	X		X
mustard gas		X		X		
alpha-naphthylamine			X			X
beta-naphthylamine	X	X	X	X		X

nickel sulfide roasting, fume & dust, as Ni	X	X	X	X		
nickel, carbonyl, as Ni		X	X	X		
nickel, elemental/metal		X	X	X		
nickel, insoluble compounds, as Ni		X	X	X		
nickel, soluble compounds, as Ni		X	X	X		
5-nitroacenaphthene		X				
o-nitroanisole				X		
nitrobenzene	X					
4-nitrobiphenyl	X		X			X
p-nitrochlorobenzene	X		X			
6-nitrochrysene				X		
4-nitrodiphenyl	X		X			X
nitrogen mustard		X		X		
2-nitronaphthalene		X	X			
2-nitropropane	X	X	X	X		
1-nitropyrene				X		
4-nitropyrene				X		
nitropyrenes mono-, di-, tri-, tetra-isomers		X				
N-nitrosodi-n-butylamine		X		X		
N-nitrosodi-n-propylamine		X		X		
N-nitrosodiethanolamine		X		X		
N-nitrosodiethylamine		X		X		
N-nitrosodimethylamine	X	X	X	X		X
N-nitrosoguanidine					X	
N-nitrosomethylethylamine		X				
N-nitrosomorpholine		X		X		
N-nitrosopiperidine		X		X		
N-nitrosopyrrolidine		X		X		
4,4'-oxydianiline		X		X		
paraquat*						
parathion*						
particulate polycyclic aromatic hydrocarbon	X	X	X	X		
pentachlorophenol	X	X				
perchloroethylene	X	X	X	X		
phenyl glycidyl ether	X	X	X			
N-phenyl-2-naphthylamine	X		X			
N-phenyl-beta-naphthylamine			X			
o-phenylenediamine	X					
phenylethylene		X				
phenylhydrazine	X		X			
phorbol esters					X	
polychlorinated biphenyls (PCBs)		X		X		
polychlorobiphenyls		X	X	X		
propane sultone	X	X	X	X		
beta-propiolactone	X	X	X	X		X

propoxur	X					
propylene dichloride			X			
propylene imine	X	X	X	X		
propylene oxide	X	X	X	X		
pyrocatechol	X					
quartz		X	X	X		
RDX (cyclonite)*						
rosin core solder pyrolysis products, as formaldehyde			X			
selenium and compounds, as Se				X		
silica, fused			X			
silica-amorphous silica, fused		X	X			
silica-crystalline crystobalite		X	X	X		
silica-crystalline quartz		X	X	X		
silica-crystalline tridymite		X	X	X		
silica-crystalline tripoli		X	X	X		
strontium chromate, as Cr	X	X	X	X		
styrene, monomer		X				
sulfuric acid	X	X				
synthetic vitreous fibers, glass wool fibers	X	X		X		
synthetic vitreous fibers, refractory ceramic fibers		X		X		
synthetic vitreous fibers, rock wool fibers	X	X				
synthetic vitreous fibers, slag wool fibers	X	X				
synthetic vitreous fibers, special purpose glass fibers	X					
2,4,5-T		X				
talc (containing asbestos fibers)	X	X	X	X		X
2,3,7,8-tetrachlorodibenzo-p-dioxin		X	X	X		
1,1,2,2-tetrachloroethane			X			
1,1,1,2-tetrachloroethane*						
tetrachloroethylene	X	X	X	X		
tetrachloromethane	X	X	X	X		
tetranitromethane	X			X		
4,4'-thiodianiline		X				
thiotepa				X		
thiourea		X		X		
titanium dioxide			X			
o-tolidine	X	X	X	X		
o-tolidine-based dyes			X			
toluene-2,4-diamine		X	X	X		
toluene-2,4-diisocyanate		X	X	X		
toluene-2,6-diisocyanate		X	X			
o-toluidine	X	X	X	X		
p-toluidine	X		X			
toxaphene	X	X	X	X		
tremolite	X	X	X	X		X
tribromomethane	X					

trichloroacetic acid	X						
1,1,2-trichloroethane	X		X				
trichloroethylene			X				
trichloromethane	X	X	X	X			
2,4,5-trichlorophenoxy-acetic acid		X					
1,2,3-trichloropropane	X		X	X			
tridymite		X	X	X			
2,4,6-trinitrotoluene (TNT)*							
tripoli		X	X	X			
tungsten carbide (containing > 0.3% Ni), as Ni			X				
uranium (natural) soluble & insoluble compounds, as U	X		X				
urethane		X		X			
vinyl acetate	X	X					
vinyl benzene		X					
vinyl bromide	X	X	X				
vinyl chloride	X	X	X	X		X	
vinyl cyanide	X	X	X	X		X	
4-vinyl cyclohexene	X						
vinyl cyclohexene dioxide	X		X	X			
vinylidene chloride	X		X				
VM & P Naphtha	X						
welding fumes (NOC)			X				
wood dust (certain hard woods as beech & oak)	X		X				
wood dust, soft wood			X				
wood dust, Western red cedar			X				
xylidine (mixed isomers)	X						
zinc beryllium silicate, as Be	X	X	X	X			
zinc chromates, as Cr	X	X	X	X			

Last Updated on 1/8/02

Appendix B: Known or Suspected Reproductive Toxins

The following chemicals have shown reproductive effects in animal studies or have been investigated as mutagens, tumorigens, or reproductive effectors.

Reproductive Toxin	CAS #	ACGIH	ACOEM	CDC	DART	HSDB	IARC	LBL	NIOSH	NTP	OSHA
(d)-propoxyphene	469-62-5					X					
(l)-phenylalanine	63-91-2										
(l)-proline	147-85-3					X					
1-(2-chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU) (lomustine)	13010-47-4							X			
1,1,2,2-tertchloroethane	79-34-5								X		
1,1-dichloroethane	75-34-3			X		X					

1,1-dichloroethylene	75-35-4	X							X		
1,1-dimethylhydrazine	57-14-7	X					X		X	X	
1,2,3-trichloropropane	96-18-4	X							X	X	
1,2-dichloroethane	107-06-2	X				X	X		X	X	
1,2-dichloropropane	78-87-5								X		
1,2-dimethylhydrazine	306-37-6						X				
1,2-epoxypropane	75-56-9	X					X		X	X	
1,2-propylene oxide	75-56-9					X					
1,3-butadiene	106-99-0	X					X		X	X	
1,3-dichloropropane	142-28-9	X					X		X	X	
1,3-dichloropropene	542-75-6					X					
1,4-butanediol dimethylsulfonate	55-98-1							X			
1,6-dinitropyrene	42397-64-8									X	
1-chloro,2,3-epoxypropane	106-89-8	X					X		X	X	
1-chloropentane	543-59-9					X					
1-decene	872-05-9					X					
1-dodecene	112-41-4					X					
1-octene	111-66-0					X					
1-pentene	109-67-1					X					
1-tridecene	2437-56-1					X					
2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD)	1746-01-6										
2,3-dimethylbutane	79-29-8					X					
2,3-dimethylmaleic anhydride	766-39-2					X					
2,3-epoxy-1-propanol	106-89-8	X								X	
2,4,4-trimethyl-1-pentene	107-39-1					X					
2,4,5-trichlorophenoxyacetic acid	93-76-5						X				
2,4-bis((3-methoxypropyl)amino)-6(methylthio)-s-triazine	845-52-3					X					
2,4-diaminoanisole	615-05-4						X		X		
2,4-diaminotoluene	95-80-7						X		X	X	
2,4-dichlorophenoxyacetic acid	94-75-7						X				
2-aminoanthracene	613-13-8										
2-nitropropane	79-46-9	X					X		X	X	

3-amino-1,2,4-triazole	61-82-5	X					X		X	X	
4-aminodiphenyl	92-67-1	X					X		X	X	X
4-dimethylaminobenzene	60-11-7	X					X		X	X	
4-nitrobiphenyl	92-93-3	X							X		X
4-vinyl toluene	622-97-7					X					
5-methoxypsoralen	484-20-8					X					
5-nitroacenaphthene	602-87-9						X				
6-nitrochrysene	7496-02-8									X	
Acetaldehyde	75-07-0	X					X		X	X	
Acetamide	60-35-5						X				
Acetic acid	64-19-7					X					
Acetohexamide	968-81-0										
Acetohydroxamic acid	546-88-3							X			
Acetone	67-64-1										
Acrolein	107-02-8										
Acrylamide	79-06-1	X				X	X		X	X	
Acrylic acid	79-10-7										
Acrylonitrile	107-13-1			X							
Actinomycin C	8052-16-2										
Actinomycin D	50-76-0										
Adriamycin	25316-40-9										
Aflatoxin B1	1162-65-8					X					
Aflatoxin B2	7220-81-7					X					
Aflatoxin G1	1165-39-5					X					
Aflatoxin G2	7241-98-7					X					
Aflatoxins	1402-68-2					X					
Alanine nitrogen mustard	148-82-3										
Aldicarb	116-06-3					X					
Aldosterone	52-39-1										
All-trans retinoic acid	302-79-4							X			
Allyl alcohol	107-18-6										
Allyl chloride	107-05-1										
Allylamine	107-11-9					X					
Alpha-amanitin	23109-05-9					X					
Alpha-methyl styrene	98-83-9					X					

Alprazolam	28981-97-7							X			
Alum, potassium	10043-67-1					X					
Aluminum ammonium sulfate	7784-25-0					X					
Aluminum fluoride	7784-18-1					X					
Aluminum hydroxide	21645-51-2					X					
Aluminum nitrate	13473-90-0					X					
Aluminum oxide	1344-28-1					X					
Aluminum sodium sulfate	10102-71-3					X					
Aluminum sulfate	10043-01-3					X					
Amanin	21150-21-0					X					
Ametryn	834-12-8					X					
Amikacin sulfate	39831-55-5							X			
Aminoacetonitrile	540-61-4										
Aminoazobenzene	60-09-3										
Aminoglutethimide	125-84-8							X			
Aminopterin	54626							X			
Aminopyrine	58-15-1										
Amitrole	61-82-5	X					X		X	X	
Ammonia	7664-41-7					X					
Ammonium chloride	12125-02-9					X					
Ammonium metavanadate	7803-55-6					X					
Ammophyllin	317-34-0										
Amoxicillin	26787-78-0					X					
Ampicillin	69-53-4					X					
Androstenedione	63-05-8										
Androsterone	53-41-8										
Angiotensin converting enzyme (ACE) inhibitors	Various										
Aniline & homologues	62-53-3	X		X					X		
Anisindione	117-37-3										
Antimony trioxide, production	1309-64-4	X									

Apomorphine	58-00-4										
Aprotinin	9087-70-1										
Arsenic	7440-38-2			X							
Arsenic, elemental and inorganic compounds except arsine	Various	X					X		X	X	X
Arsenous acid	1327-53-3	X					X		X	X	X
Ascorbic acid	50-81-7					X					
Aspartame	22839-47-0					X					
Aspartic acid	56-84-8										
Aspirin	50-78-2	(NOTE: It is especially important not to use Aspirin during the last three months of pregnancy, unless specifically directed to do so by a doctor. It may cause problems with the unborn child or complications during delivery.)									
Atrazine	1912-24-9					X	X				
Atropine	51-55-8					X					
Auramine	2465-27-2						X				
Azacitidine	320-67-2									X	
Barbituates	Various										
Benomyl	17804-35-2							X			
Benzal chloride	98-87-3						X				
Benzene	71-43-2	X		X		X	X		X	X	X
Benzidine	92-87-5	X					X		X	X	X
Benzo(a)pyrene	50-32-8			X							
Benzodiazepines	Various										
Benzotrichloride	98-07-7	X					X			X	
Benzphetamine hydrochloride	5411-22-3							X			
Benzyl chloride	100-44-7	X					X				
Benzyl dichloride	98-87-3						X				
Benzyl trichloride	98-07-7	X					X			X	
Beryllium and compounds	7440-41-7	X		X			X		X	X	
Beryllium sulfate	13510-49-1					X					
Beta-amanitin	13567-07-2					X					
Bis(2-methoxyethyl) phthalate	117-82-8					X					
Bis(tributyltin) oxide	56-35-9					X					

Bisacodyl	603-50-9					X					
Bischloroethyl nitrosourea (BCNU) (carmustine)	1540-93-8							X			
Bismuth subsalicylate	14882-18-9					X					
Boric acid	10043-35-3			X							
Brodifacoum	56073-10-0					X					
Bromoform	75-25-2	X									
Bromoxynil	1689-84-5							X			
Butabarbital sodium	143-81-7										
Butylated hydroxyanisole	25013-16-5					X					
Butyric acid	305-03-3										
Cadmium and its compunds	Various	X		X	X		X		X	X	X
Calcium hypochlorite	7778-54-3					X					
Cantharidine	56-25-7					X					
Captan	133-06-2	X							X		
Carbamic acid, ethyl ester	51-79-6										
Carbenicillin	4697-36-3					X					
Carbon disulfide	75-15-0					X		X			
Carbon monoxide	630-08-0			X	X						
Carbon tetrachloride	56-23-5	X					X		X	X	
Carboplatin	41575-94-4							X			
Castor oil	8001-79-4					X					
Catechol	126-80-9	X									
Cefazolin	25953-19-9					X					
Cephalexin	15686-71-2					X					
Charcoal	16291-96-6					X					
Chenodiol	474-225-9							X			
Chlorambucil	305-03-3										
Chlorazine	580-48-3										
Chlordane	57-74-9	X					X		X		
Chlordecone (kepone)	143-50-0			X		X	X	X			
Chlordiazepoxide	58-25-3										

Chlordiazepoxide hydrochloride	438-41-5										
Chlorinated camphene	8001-35-2	X					X		X	X	
Chlorobenzene	108-90-7	X									
Chlorobromomethane	74-97-5					X					
Chlorocyclizine hydrochloride	1620-21-9							X			
Chlorodiphenyl (42% chlorine)	53469-21-9						X		X	X	
Chlorodiphenyl (54% chlorine)	11097-69-1	X					X		X	X	
Chloroethane	75-00-3	X									
Chloroethylene	75-01-4	X					X		X	X	X
Chloroform	67-66-3	X		X	X		X		X	X	
Chloromethyl methyl ether	542-88-1	X					X		X	X	X
Chloroprene	9010-98-4			X	X						
Chloroquine	54-05-7										
Chlorotrifluoroethylene	79-38-9					X					
Cholic acid	81-25-4					X					
Chromic acid and chromates	1333-82-0	X					X				
Chromium (VI) compounds as Cr, water insoluble	1333-82-0	X					X		X	X	
Chromium (VI) compounds as Cr, water soluble	1333-82-0	X					X		X	X	
Chromium trioxide, as Cr	1333-82-0	X					X		X	X	
Chrysene	218-01-9						X		X		
Cimetidine	51481-61-9					X					
Citrinin	518-75-2					X					
Clomiphene citrate	50-41-9							X			
Clorazepate dipotassium	57109-90-7										
Cloxacillin	61-72-3					X					
Cocaine	50-36-2										
Coke oven emissions	7440-44-0						X		X	X	X
Colchicine	64-86-8					X					
Conjugated estrogens	N/A							X			
Cumene (isopropylbenzene)	98-82-8										

Cyanazine	21725-46-2							X			
Cycasin	14901-08-7					X					
Cyclochlorotine	12663-46-6					X					
Cycloheptane	291-64-5					X					
Cyclohexane	110-82-7					X					
Cyclohexene	110-83-8					X					
Cycloheximine	66-81-9							X			
Cyclopamine	4449-51-8										
Cyclopentane	287-92-3							X			
Cyclophosphamide (anhydrous)	50-18-0							X			
Cyclophosphamide (hydrated)	6055-19-2										
Cyhexatin	13121-70-5							X			
Cyprazine	22936-86-3					X					
Cyproheptadine	129-03-3					X					
Cytarabine	147-94-4							X			
Cytochalasin B	14930-96-2					X					
Cytochalasin E	36011-19-5					X					
Dacarbazine	4342-03-4					X					
Danazol	17230-88-5							X			
Daunorubicin	20830-81-3					X					
Daunorubicin hydrochloride	23541-50-6							X			
DDT	50-29-3	X					X		X	X	
Decalin (decahydronaphthalene)	91-17-8										
Decane	124-18-5					X					
Decylbenzene	104-72-3					X					
Demeclocycline hydrochloride (internal use)	64-73-3										
Deoxycholic acid	83-44-3					X					
Desemetryn	1014-69-3					X					
Dexamethasone	50-02-2					X					

Dexpanthenol	81-13-0					X					
Di(2-ethylhexyl) phthalate	117-81-7	X					X		X	X	
Diacetyl	431-03-8										
Diazepam	439-14-5										
Dibromochloropropane (DBCP)	96-12-8			X	X						
Dibutyltin diacetate	1067-33-0					X					
Dibutyltin dilaurate	77-58-7					X					
Dichlorobenzene	Various			X							
Dichloromethane	75-09-2	X		X			X		X	X	X
Dichlorvos	62-73-7						X				
Dicumarol	66-76-2										
Dicyclopentadiene	77-73-6					X					
Dieldrin	60-57-1								X		
Diethyl ether (ether)	60-29-9										
Diethyl sulfate	64-67-5						X			X	
Diethylene dioxide (dioxane)	123-91-1						X		X	X	
Diethylene glycol dimethyl ether (diglyme)	111-96-6										
Diethylstilbestrol (DES)	56-53-1							X			
Dihydroxybenzene	123-31-9	X									
Diisopropyl fluorophosphate	55-91-4					X					
Dimethyl sulfate	77-78-1	X					X		X	X	
Dimethyl sulfoxide (DMSO)	67-68-5										
Dimethylformamide	68-12-2						X				
Dimethyltin bis(isooctyl mercaptoacetate)	26636-01-1					X					
Di-n-butyltin dichloride	683-18-1										
Dinitrotoluene	121-14-2	X							X		
Dinocap	39300-45-3							X			
Dinoseb	88-85-7							X			
Dioxane	123-91-1	X		X			X		X	X	
Diphenylamine	122-39-4										
Diphenylhydantoin (phenytoin)	54-41-0							X			
Di-sec-octyl-phthalate	11781-7	X					X		X	X	
Doxycycline (internal use)	564-25-0							X			
Doxycycline calcium (internal use)	94088-85-4							X			

Doxycycline hyclate (internal use)	24390-14-5										
Doxycycline monohydrate (internal use)	17086-28-1										
Dyrene	101-05-3					X					
E-amino-n-caproic acid	60-32-2										
Egomaketone	59204-74-9					X					
Ethylene glycol monomethyl ether	109-86-4										
Enflurane	13838-16-9										
Epichlorohydrin	106-89-8	X		X	X		X		X	X	
Ergot alkaloid	12126-57-7										
Ergotamine tartrate	379-79-3							X			
Estradiol	8001-29-4										
Ethanol	64-17-5					X					
Ethidium bromide	1239-45-8										
Ethoxyacetic acid	627-03-2										
Ethyl acrylate	140-88-5					X					
Ethyl alcohol in alcoholic beverages	N/A										
Ethyl bromide	74-96-4	X									
Ethyl chloride	75-00-3					X					
Ethyl formate	109-94-4					X					
Ethyl mercaptan	75-08-1										
Ethylene dibromide	106-93-4	X		X	X		X		X	X	
Ethylene dichloride	107-06-2			X			X		X	X	
Ethylene glycol	107-21-1					X					
Ethylene glycol dimethyl ether (glyme)	110-71-4										
Ethylene glycol monoethyl ether	110-80-5					X		X			
Ethylene glycol monomethyl ether acetate	110-49-6							X			
Ethylene glycol monomethyl ether acrylate	3121-61-7										
Ethylene glycol monoethyl ether acetate	111-15-9										
Ethylene oxide	71-21-8	X		X	X		X		X	X	X
Ethylene thiourea	96-45-7						X		X	X	
Ethylidene chloride	75-34-3										

Etoposide	33419-42-0							X			
Etretinate	54350-48-0							X			
Fenbutatin oxide	13356-08-6					X					
Fenvalerate	51630-58-1					X					
Fluorocarbons	76-14-2			X							
Fluorouracil	51-21-8							X			
Fluoxymestrone	76-43-7							X			
Fluphenazine	69-23-8					X					
Flurazepam hydrochloride	1172-18-5										
Flutamide	13311-84-7							X			
Formaldehyde	50-00-0	X		X	X	X	X		X	X	X
Formamide	75-12-7			X							
Furan	110-00-9										
Furfural	98-01-1	X				X					
Fusarenon x	23255-69-8										
Fusaric acid	539-69-6					X					
Galactose	59-23-4										
Gallium arsenide	1303-00-0								X		
Gamma-amanitin	13567-11-8										
Gamma-hexachlorocyclohexane	58-89-9	X					X			X	
Gentian extract	72968-42-4					X					
Germanium dioxide	1310-53-8					X					
Glutaric acid	110-94-1					X					
Glycidol	556-52-5	X								X	
Grayanotoxin I	4720-09-6					X					
Gum benzoin	9000-05-9					X					
Gyromitrin	16568-02-8					X					
Halazepam	23092-17-3							X			
Halothane	151-67-7										
Heptachlor	76-44-8				X	X					

Heptane	142-82-5					X					
Heroin	561-27-3										
Heroin hydrochloride	1502-95-0										
Hexachlorobenzene	118-74-1	X					X	X		X	
Hexachlorobutadiene	87-68-3	X							X		
Hexamethyl phosphoramide	680-31-9	X					X		X	X	
Hydroquinone	123-31-9	X									
Ifosfamide	3778-73-2							X			
Imazalil	35554-44-0					X					
Indomethacin	53-86-1					X					
Iodine-131	10043-66-0							X			
Iodoacetic acid	64-69-7										
Ipomeanol	32954-58-8					X					
Isoamyl acetate	123-92-2										
Isobutylene	115-11-7					X					
Isopentane	78-78-4					X					
Isopropanol	67-63-0					X					
Isotretinoin	4759-48-2							X			
Isovaleraldehyde	590-86-3					X					
Juniper oil	8012-91-7					X					
Juniper tar oil	8013-10-3					X					
Kaolin	1332-58-7					X					
Kepone	143-50-0						X		X	X	
Kerosene	8008-20-6					X					
Lasiocarpine	303-34-4					X					
Lead	7439-92-1	X		X	X		X	X		X	
Lead chromate	7758-97-6	X					X		X	X	
Lead compounds	Various			X	X			X			
Lindane	58-89-9	X					X			X	
Lithium carbonate	554-13-2							X			
Lithium citrate	919-16-4							X			
L-lysine	56-87-1					X					

Lorazepam	846-49-1										
Lovastatin	75330-75-5										
L-serine	56-45-1					X					
L-tyrosine	60-18-4					X					
Manganese and its compounds	Various			X							
Mannitol nitrogen mustard	576-68-1										
Medroxyprogesterone acetate	71-58-9							X			
Megestrol acetate	595-33-5							X			
Melphalan	148-82-3							X			
Menotropins	9002-68-0							X			
Meprobamate	57-53-4										
Mercaptopurine	6112-76-1							X			
Mercury and its compounds	Various			X	X			X			
Methacycline	914-00-1					X					
Methacycline hydrochloride	3963-95-9							X			
Methanol	67-56-1					X					
Methicillin	61-32-5					X					
Methimazole	60-56-0					X					
Methoprotryne	841-06-5										
Methotrexate	59-05-2										
Methotrexate sodium	15475-56-6							X			
Methoxychlor	72-43-5								X		
Methyl bromide	74-83-9								X		
Methyl chloride	74-87-3								X		
Methyl chloroform	71-55-6			X							
Methyl disulfide	624-92-0					X					
Methyl ethyl ketone (MEK)	78-93-3			X							
Methyl iodide	74-88-4								X		
Methyl isobutyl ketone	108-10-1										
Methyl mercury (dimethyl mercury)	593-74-8				X		X	X			
Methyl n-butyl ketone	591-78-6			X							
Methylacetylene	59355-75-8										
Methylal	109-87-5					X					

Methylamine	74-89-5					X					
Methylcyclohexane	108-87-2										
Methylcyclopentane	96-37-7					X					
Methylene blue	61-73-4					X					
Methylhydrazine	60-34-4					X					
Methyl-o-anisidine	120-71-8						X			X	
Methyltestosterone	58-18-4							X			
Michler’s ketone	90-94-8									X	
Midazolam hydrochloride	59467-96-8							X			
Minocycline hydrochloride (internal use)	13614-98-7										
Misoprostol	59122-46-2							X			
Mitoxantrone hydrochloride	70476-82-3							X			
Monomethyltin tris(isooctyl mercaptoacetate)	54849-38-6					X					
Mono-n-butyltin trichloride	1118-46-3					X					
Muscarine chloride	2303-35-7					X					
Muscimol	2763-96-4					X					
N,N-dimethylformamide (DMF)	68-12-2										
N,N-dimethylnitrosamine	62-75-9	X					X		X	X	X
Nafarelin acetate	86220-42-0							X			
Naphthalene	91-20-3					X					
N-chlorosuccinimide	128-09-6					X					
Neomycin sulfate (internal use)	1405-10-3										
Neopentane	463-82-1					X					
Netilmicin sulfate	56391-57-2							X			
Nickel	7440-02-0										
Niclosamide	50-65-7					X					
Nicotine	54-11-5					X					
Nitric oxide	10102-43-9					X					
Nitrobenzene	98-95-3	X									
Nitrogen dioxide	10102-44-0			X							

Nitrogen half mustard	107-99-3										
Nitrogen mustard (mechlorethamine)	51-75-2							X			
Nitrogen mustard hydrochloride (mechlorethamine hydrochloride)	55-86-7							X			
Nitrogen mustard N-oxide hydrochloride	302-70-5										
Nitrogen mustard oxide	126-85-2										
Nitrous oxide	10024-97-2				X						
Nivalenol	23282-20-4					X					
N-methyl-bis(2-chloroethyl) amine	55-86-7						X			X	
N-methyl-n-formylhydrazine	758-17-8					X					
N-nitrosodiethanolamine	1116-54-7						X			X	
N-nitrosodiethylamine	55-18-5						X			X	
N-nitrosodimethylamine	62-75-9	X					X		X	X	X
N-nitrosodi-n-butylamine	924-16-3						X			X	
N-nitrosomorpholine	59-89-2					X					
N-nitroso-n-methylurea	684-93-5					X					
Nonene	27215-95-8					X					
Norethisterone (norethindrone)	68-22-4							X			
Norethisterone (norethindrone)/ethinyl estradiol	68-22-4/57-63-6							X			
Norethisterone (norethindrone)/mestranol	68-22-4/72-33-3							X			
Norethisterone acetate (norethindrone acetate)	51-98-9										
Norgestrel	6533-00-2							X			
Nor-nitrogen mustard	334-22-5										
N-propanol	71-23-8					X					
o-Aminoazotoluene	97-56-3										
Ochratoxin A	303-47-9					X					
Ochratoxin C	4865-85-4										
Octanoic acid	3825-26-1										
o-dichlorobenzene	95-50-1					X					

o-toluidine	95-53-4	X					X		X	X	
Oxalic acid	144-62-7					X					
Oxazepam	604-75-1										
Oxytetracycline (internal use)	79-57-2							X			
Oxytetracycline hydrochloride (internal use)	2058-46-0										
Ozone				X		X					
Palmotoxin B0	39450-10-7										
Palmotoxin G0	39450-11-8					X					
Paraformaldehyde	30525-89-4										
Paramethadione	115-67-3							X			
Paraquat	1910-42-5										
Parathion	56-38-2										
Patulin	149-29-1					X					
p-cresidine	120-71-8						X			X	
p-dichlorobenzene	106-46-7										
Pectin	9000-69-5					X					
Penicillamine	52-67-5							X			
Penicillic acid	90-65-3					X					
Penicillin G	61-33-6					X					
Penicillin V	132-98-9					X					
Pentachlorophenol	87-86-5	X					X				
Pepper oil	8006-82-4					X					
Perchloroethylene	127-18-4	X					X		X	X	
Perphenazine	58-39-9										
Phalloidin	17466-45-4										
Phalloin	28227-92-1					X					
Phenacemide	63-98-9							X			
Phenethicillin potassium	132-93-4					X					
Phenol	108-95-2				X						
Phenprocoumon	435-97-2										
Phenyl glycidyl ether	122-60-1	X					X		X		
Phenylene	100-42-5						X				
Phenylhydrazine	100-63-0	X							X		
Phosmet	732-11-6					X					

Phthalimide	85-41-6					X					
Pipobroman	54-91-1							X			
Platinum and its compounds	Various			X							
Plicamycin	18378-89-7							X			
P-nitrochlorobenzene	100-00-5	X							X		
Polybrominated biphenyls (PBB)	59536-65-1			X	X						
Polychlorinated biphenyls (PCB)	1336-36-3			X	X	X		X			
Polychlorinated biphenyls (Aroclors)	Various			X	X	X		X			
Polyvinylpyrrolidone	9003-39-8					X					
Potassium iodide	7681-11-0										
p-Phenylenediamine	2067-58-5										
Procarbazine hydrochloride	366-70-1							X			
Prometon	1610-18-0					X					
Propazine	139-40-2					X					
Propylene dichloride	78-87-5								X		
Propylene imine	75-55-8	X					X		X	X	
Propylene oxide	75-56-9	X					X		X	X	
Propylthiouracil	51-52-5							X			
Pyrocatechol	120-80-9	X									
Quartz	14808-60-7						X		X	X	
Retinol/retinyl esters	68-26-8	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.)									
Retrorsine	480-54-6					X					
Ribavirin	36791045										
Ricin	9009-86-3										
Rifabutin	72559-06-9					X					
Rubratoxin A	22467-31-8					X					
Rubratoxin B	21794-01-4					X					
Saxitoxin dihydrochloride	35554-08-6					X					

Secobarbital sodium	309-43-3										
Selenium and its compounds	7782-49-2various			X							
Silver (I) nitrate	7761-88-8										
Simazine	122-34-9					X					
Sodium ascorbate	134-03-2					X					
Sodium phenobarbital	57-30-7										
Streptomycin sulfate	3810-74-0							X			
Streptozotocin	18883-66-4					X					
Strychnine	57-24-9					X					
Styrene	100-42-5			X	X		X				
Sulfamethoxazole	723-46-6					X					
T-2 toxin	21259-20-1					X					
Tamoxifen citrate	54965-24-1							X			
Tellurium and its compounds	236-81-3/ various			X							
Temazepam	846-50-4										
Terbutryne	886-50-0					X					
Testosterone cypionate	58-20-8										
Testosterone enanthate	315-37-7										
Tetrachloroethylene	127-18-14			X							
Tetrachloroethylene	127-18-4	X					X		X	X	
Tetrachloromethane	56-23-5	X					X		X	X	
Tetracycline (internal use)	60-54-8										
Tetracycline hydrochoride (internal use)	64-75-5										
Tetracycline compounds (internal use)	Various										
Tetraethyl tin	597-64-8					X					
Tetrahydrofuran (THF)	109-99-9										
Tetralin (tetrahydronaphthalene)	119-64-2										
Tetra-n-butyltin	1461-25-2					X					
Tetrodotoxin	4368-28-9					X					
Thalidomide	50-35-1							X			
Thallium and its compounds	N/A			X							
Thioguanine	154-42-7							X			

Thiourea	62-56-6						X			X	
Tobacco smoke (primary)	N/A										
Tobramycin sulfate	49842-07-1							X			
Toluene	108-88-3			X				X			
Toluene-2,4-diisocyanate	584-84-9			X			X		X	X	
Toxaphene	8001-35-2	X					X		X	X	
Triazolam	28911-01-5							X			
Trichloroacetic acid	76-03-9	X									
Trichloroethylene	79-01-6			X	X				X		
Trichloromethane	67-66-3	X					X		X	X	
Tricyclohexyltin hydroxide	13121-70-5										
Triethylenetetramine	4961-40-4										
Trifluprom azine	146-54-3					X					
Trilostane	13647-35-3							X			
Trimethanione	127-48-0							X			
Trimethyltin chloride	1066-45-1					X					
Tri-n-butyltin hydride	688-73-3					X					
Triphenyltin acetate	900-95-8					X					
Triphenyltin chloride	693-58-7					X					
Triphenyltin hydroxide	76-87-9					X					
Uracil mustard	66-75-1										
Uranium	Various										
Urethane	51-79-6						X			X	
Urofollitropin	26995-91-5							X			
Valerian root	8057-49-6					X					
Valproate (valproic acid)	99-66-1							X			
Vanadic acid, ammonium salt	11115-67-6					X					
Vinblastine sulfate	143-67-9							X			
Vincristine sulfate	2068-78-2							X			
Vinyl acetate	108-05-4	X					X				
Vinyl benzene	100-42-5						X				
Vinyl chloride	75-01-4	X					X		X	X	X
Vinyl cyanide	N/A	X					X		X	X	X
Vinylcyclohexene dioxide	106-87-6	X							X	X	

Vinyl ether	109-93-3										
Vinyl toluene	25013-15-4					X					
Vinylidene chloride	75-35-4	X		X							
VM & P Naphtha	8032-32-4	X									
Warfarin	81-81-2					X		X			
Xylene	Various			X							
Zearalenone	17924-92-4					X					
Zidovudine	30516-87-1					X					
Zinc chromate	13530-65-9	X					X		X	X	

Last Updated on 1/8/02

This list does not cover all chemicals currently in existence or under investigation. Material Safety Data Sheets were used to classify those chemicals that do not have an “X” in a column. Please check the Material Safety Data Sheet to determine if the chemical is considered a reproductive toxin.