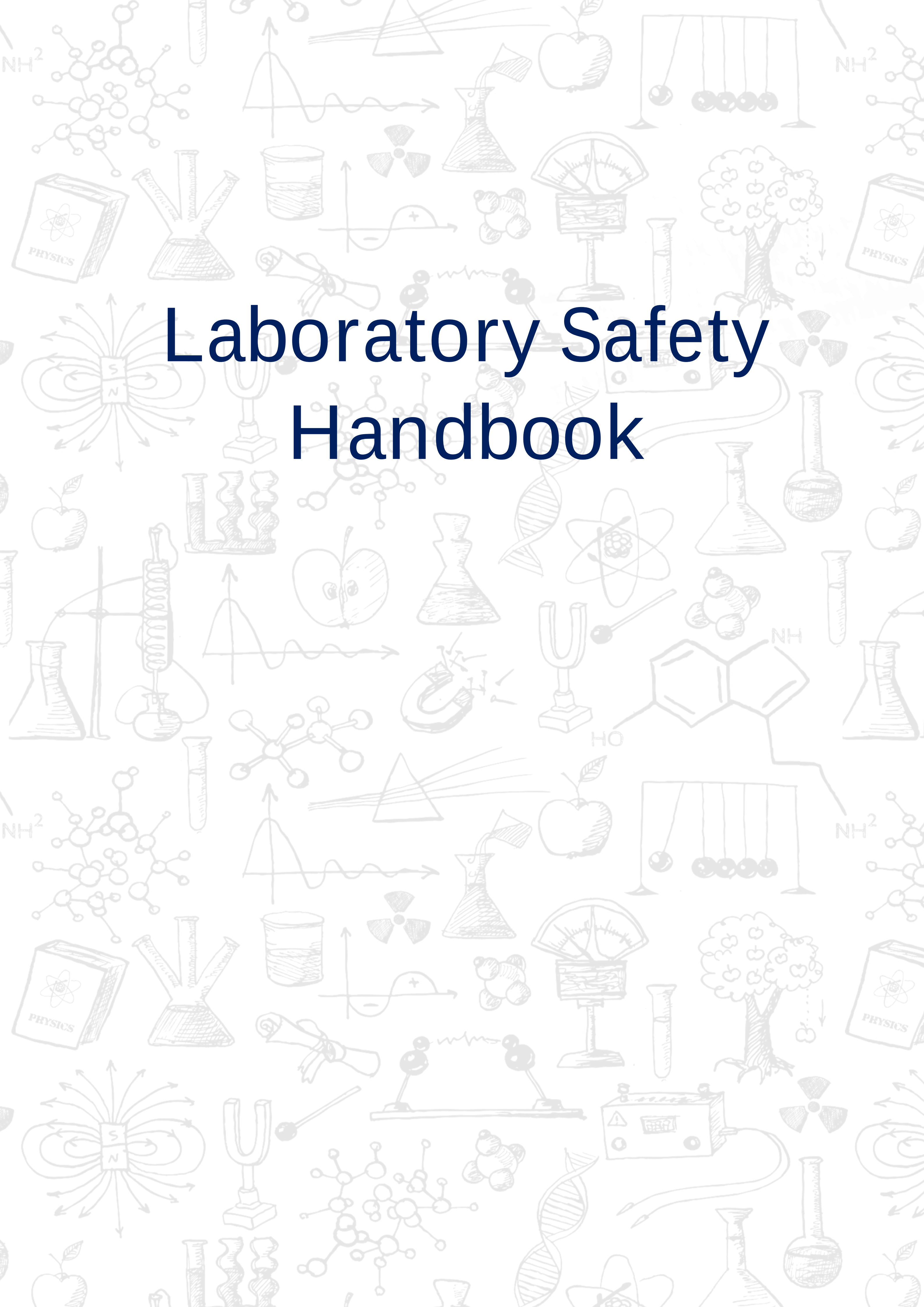
Laboratory Safety Handbook



Prepared by

FENS LABORATORY SAFETY TEAM

Graduate Students
Anastasia Zakharyuta
Canhan Şen
Merve Senem Avaz
Tuğçe Akkaş

Laboratory Specialists (LS)
Sibel Pürçüklü
Tuğba Baytekin Birkan
Turgay Gönül

Laboratory Safety Specialist (LSS)
Bilge Günaydın

Faculty Member
Fevzi Çakmak Cebeci

Manager
Adnan İnce

Cover and Content Design - Saime Yakupoğlu
General Design - Hakan Tatlı

First Edition

ISBN: 978-605-9178-59-4

Yıldız Matbaa
Bağdat Caddesi, Feyzullah Mahallesi, Tecer Sokak, No:2/A Maltepe - İstanbul
(90) 216 3053013

Certificate No: 21927

References and sources for information from the relevant websites and documentation of different universities, NGOs and government agencies used in the preparation of this handbook are provided at the end of each section.

Preface

Welcome to the Faculty of Engineering and Natural Sciences (FENS) at Sabancı University (SU), a place where Laboratory Health and Safety is one of the highest priorities. Our primary objective is to provide a safe working environment for students, faculty, staff and visitors. It is very important for all laboratory users to follow the policies and guidelines provided with this “SU FENS Laboratory Safety Handbook” to ensure their own safety and the safety of the people they work with.

Our Dean *Yusuf Z. Menceloğlu* started an initiative to attract more attention to laboratory safety in 2011 and planned an extensive study to create a better work environment and provide necessary guidelines and policies to the users. Thereafter, we developed a project and started to implement it. This project was aimed to contribute to SU Occupational Health and Safety Council’s activities across the campus.

In the first phase of the study, we established a laboratory safety team which also included a professional laboratory safety specialist. We evaluated the laboratory safety using a systematic problem solving model and created a critical roadmap. Then, we performed an assessment including risk analysis, chemical inventory, safety data sheet, determination and preparation of the safety trainings.

Safety in all the laboratories is not “someone else’s responsibility”. In essence, it is the responsibility of all of us who enter our laboratories. In the following phase, we designed a laboratory notebook, brochures, safety signs, safety information cards, etc. and developed laboratory safety trainings and associated documentation to increase the awareness on laboratory safety. This faculty specific laboratory safety handbook has been prepared as a result of these extensive efforts.

This handbook provides policies and guidelines for safe laboratory work practices, and it applies to all laboratories at SU. Safe handling, storage, use and disposal of the chemical waste in the laboratory require policies for the safety of users and the environment. The handbook is intended to provide fundamental safety information regarding the use of chemicals, biomaterials, radioactive materials, lasers, electrical equipment, and so forth.

We would like to acknowledge all faculty members and laboratory specialists who contributed to the preparation of this handbook. We also would like to thank Jonathan Smith for his corrections and suggestions for improving the text.

Remember “Laboratory Safety begins with YOU!”

FENS Laboratory Safety Team

Comments and suggestions for improving the handbook are welcome and encouraged. Please send comments to labsafety@sabanciuniv.edu

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ALI - Annual by intake limits
ANSI - American National Standards Institute
BSC - Biosafety cabinets
BSL - Biological safety levels
CAS - Chemical abstracts service number
CDC - Centers for disease control and prevention
EMT - Emergency medical technician
ESD - Electrostatic discharge
FR - Flame resistant
GFCI - Ground fault circuit interrupters
HEPA - High-efficiency particulate air
HVAC - Heating venting and cooling
IARC - International Agency for Research on Cancer
LAH - Lithium aluminum hydride
LEL - Lower explosive limit
LHS - The laboratory health and safety program
LS - Laboratory specialist
LSS - Laboratory safety specialist
MEL - Microelectronics laboratory cleanroom
NIOSH - The National Institute for Occupational Safety and Health
OSHA - Occupational Safety & Health Administration
PEC - Potentially explosive chemicals
PFC - Peroxide forming chemicals
PHS - Particularly hazardous substances
PI - Principal investigator
PPE - Personal protective equipment
PSA - Prostate specific antigens
PVA - Polyvinyl alcohol
PVC - Polyvinyl chloride
RO - Reverse osmosis
RPM - Radiation producing machines
SCBA - Self-contained breathing apparatus
SDS - Safety data sheet
SOP - Standard operating procedures
SU - Sabancı University
TAEK - Turkish Atomic Energy Agency
TLC - Thin-layer chromatography
UEL - Upper explosive limit
VAV - Variable air volume
YAG - Yttrium aluminium garnet

1. INTRODUCTION

This handbook covers laboratory health and safety measures that Sabancı University (SU) Faculty of Engineering and Natural Sciences (FENS) applies. All students, laboratory associates and faculty members should read this document and be aware of safety procedures and restrictions mentioned in this handbook. In addition, a detailed laboratory safety session will also be given by lab safety specialist of FENS prior to laboratory access. Students must adhere to written and verbal safety instructions throughout the academic term. Also, it is obligatory for students to attend lab specific trainings.

It should be mentioned here that, along with all the safety measures and precautions, a person's safety depends mostly on herself/himself. Efforts have been made to address situations that may create a hazard in the lab but the information and instructions provided cannot be considered all-inclusive.

1.1. STRUCTURE OF THE HEALTH AND SAFETY PROGRAM AT FENS

The laboratory health and safety (LHS) program of FENS is run by a committee which is assigned by the Dean's Office. The duties of the LHS committee include the following:

- To identify the potential risks, dangers and hazards in the working area
- To make provision against accidents
- To provide consultancy about occupational health and safety

The backbone of this documentation involves several subjects such as trainings, guidelines on laboratory safety, emergency and waste management procedures. Therefore the LHS program at FENS should be considered to consist not only of this documentation, but also these related applications. However, the regulations and recommended actions in this document include only the general and specific safety guidelines for the lab studies at FENS.

When using the laboratory equipment and chemicals, an objective analysis of the hazards should be done and a reasonable control of the hazards through the experimental protocol control should be made by means of suitable work practices, ventilation, use of protective clothing etc.

To assess the hazards posed by particular chemicals, the safety datasheet (SDS) of the chemicals should be reviewed and proper conditions of use and necessary precautions should be determined.

1.2. AVAILABILITY OF THE LABORATORY SAFETY HANDBOOK

The official version of this laboratory safety handbook is maintanined on the lab safety website at:

http://labsafety.sabanciuniv.edu

A printed copy is available in each laboratory, and to faculty and administrative staff upon request.

2. SAFETY TRAINING

Sabancı University Faculty of Engineering and Natural Sciences has a policy for the training of the newcomers.

Administrative staff shares the list of new students/employee who will work in the laboratories with laboratory specialist (LS) and laboratory safety specialist (LSS) and informs newcomer to visit LSS. LSS performs the training need analysis with the newcomer, meaning that they decide on the trainings the newcomer will take.

New students/employees get training and have exam depending on an online training calendar which will show all the training and exam dates beforehand. When the exam results are announced, unsuccessful examiners will retake the training session. Successful ones will have the access to the laboratories and he/she will have an orientation in their laboratories with the Responsible Faculty Member / LS / LSS.

A short definition of provided trainings is given below.

2.1. GENERAL LAB SAFETY

A person who works in a laboratory must receive training to become informed about potential hazards in the laboratory. Laboratory users must attend a general session given by LSS and receive additional, more specific training from the Responsible Faculty Member / LS / LSS.

This training session covers the environmental health and safety standards and documents, hazards in the laboratories, personal protective equipment, waste disposal, safety signs and emergency situations.

This training is mandatory for all newcomers; students (graduate & undergraduate), academic staff (postdoctoral researcher & faculty member), project staff, interns and visitors.

To enroll in a class, please contact LSS.

2.2. EMERGENCY MANAGEMENT

This training is mandatory for all newcomers; students (graduate & undergraduate), academic staff (postdoctoral researcher & faculty member), project staff, interns, and visitors; and covers the emergency response plan, emergency response team, and emergency exit layout.

2.3. WASTE MANAGEMENT

Research waste management programs ensure safe and compliant management (storage and disposal) of wastes generated as a result of experimental research at Sabancı University.

This training is mandatory for students (graduate & undergraduate), academic staff (postdoctoral researcher & faculty member), project staff, interns and visitors; and covers identification, handling and disposal procedures for hazardous and non-hazardous waste in the laboratory.

2.4. CHEMICAL SAFETY

Students (graduate & undergraduate), project staff and interns should attend the chemical safety training which will be held each semester.

Chemical safety training covers the topics of storing chemicals safely, obtaining and managing personal protective equipment (PPE), knowing what training is needed, knowing the hazards of a chemical and disposing of chemicals.

2.5. BIOSAFETY

Students (graduate & undergraduate), project staff and interns should attend the biosafety training which will be held each semester.

The training covers biosafety risk levels, biological risks in the laboratory, safety precautions, biological waste disposal and PPE.

2.6. RADIATION SAFETY

Radiation safety training is held every semester and covers facilitating the safe use of radioactivity and radiation-producing machines.

Newcomer students and staff should get approval to work with radiation devices, learn to use dosimetry (radiation badge) and view their results, order radioactive materials, and dispose of radioactive waste. Emergencies involving radioactive materials and working with radiation during pregnancy are also the topics of the training.

2.7. LASER SAFETY

Laser safety training is held every semester and covers general laser safety principles, classification of lasers and laser systems, hazards, control measures, personal protective equipment.

It covers the classification of lasers, wavelength range and their pathological effects on the human body and additionally emergency situations.

2.8. COMPRESSED GAS SAFETY

This training is held every semester and is mandatory for students (graduate & undergraduate), academic staff (postdoctoral researcher), project staff and interns, visitors; and covers the safe use of compressed gases.

Compressed gases must be handled and used only by trained employees and students. Chemical hazards through a hazard communication program, labels, and other forms of warnings are included in the concept of the compressed gas safety training. Gas manufacturer's safety data sheets (SDSs) should always be consulted for specific information.

2.9. FUME HOOD SAFETY

Fume hood safety training is held each semester.

The training covers information on how to safely operate the fume hoods and instructions for controlling inhalation exposures with ventilation. These instructions are located on the SDS and/or label.

2.10. PERSONAL PROTECTIVE EQUIPMENT

PPE training is set each semester and it covers information about face and eye protection, lab coats and aprons, gloves, foot protection, respiratory protection and how to obtain all the essential PPE. It is mandatory for students (graduate & undergraduate), academic staff (postdoctoral researcher), project staff, interns and visitors.

2.11. CHEMWATCH

ChemWatch Gold FFX is the online software that provides Safety data sheet (SDS) information of all the chemicals, listing and classifying the chemicals that are owned by the faculty.

This training is held every semester for all the newcomer students and employee and this training is mandatory.

2.12. ELECTRICAL SAFETY

Hot plates, stirrers, vacuum pumps, electrophoresis apparatus, lasers, heating mantles, ultrasonicators, power supplies, and microwave ovens, named electrically powered eqipments are essential elements of many laboratories. Carriers of even more risk, these devices have high voltage or high power requirements.

Students (graduate & undergraduate), academic staff (postdoctoral researcher), project staff and interns should attend the electrical safety training which will be held each semester.

2.13. MACHINE SHOP SAFETY

When you are operating a machine or a mechanical apparatus, a defensive attitude should be adopted and the working person should be aware of the source of danger or the likely outcome of each sequence of operation.

Students (graduate & undergraduate), academic staff (postdoctoral researcher), project staff and interns should attend the machine shop safety training which will be held each semester.

2.14. MECHATRONICS LAB SAFETY

Students (graduate & undergraduate), academic staff (postdoctoral researcher), project staff and interns should attend the mechatronics lab safety training which will be held each semester.

It is important to prevent accidents or mishaps when operating mechanical equipment. There are general rules and guidelines for the people working in mechanical devices to follow in the laboratory.

2.15. CLEANROOM SAFETY

Before gaining access to the laboratories, all the users must be officially qualified in order to facilitate safe and efficient operation of the cleanroom.

Students (graduate & undergraduate), academic staff (postdoctoral researcher), project staff and interns should attend the cleanroom safety training which will be held each semester.

2.16. LABORATORY SPECIFIC TRAINING

In addition to trainings offered, all students and laboratory staff are required to have laboratory specific training on the hazards they may encounter while working. This training is usually conducted by principal investigators.

References

- Princeton University Environmental Health & Safety (2015, March). Retrieved from https://ehs.princeton.edu/
- University of California, Berkeley Environmental Health & Safety (2015, March). Retrieved from http://www.ehs.berkeley.edu/training
- Massachusetts Institute of Technology Environment Health & Safety (2015, March). Retrieved from https://ehs.mit.edu/site/training
- Oregon OSHA Compressed Gas Safety Fact Sheet (2015, March). Retrieved from http://orosha.org/pdf/pubs/fact_sheets/fs09.pdf
- McGill University Environmental Health and Safety, First Aid Training and Information (2015, March). Retrieved from https://www.mcgill.ca/ehs/training/firstaid
- University of Reading Health and Safety, Radiation Safety – Open Sources (2015, March). Retrieved from https://www.reading.ac.uk/internal/health-and-safety/hs-training/TrainingCourseDetails/training-Radiation_Safety_-_Open_Sources.aspx
- Indiana University, Environmental Health and Safety – Bloomington, Training (2015, March). Retrieved from http://ehs.iu.edu/topics/occupational-safety/cranes-lifts-hoists.shtml

3. PERSONAL PROTECTIVE EQUIPMENT (PPE)

3.1. INTRODUCTION

Personal protective equipment is intended to protect lab users from serious workplace injuries or illnesses coming about because of contact with chemical, radiological, physical, electrical, mechanical, or other workplace risks. Along with face shields, safety glasses, helmets, and safety shoes, PPE incorporates an assortment of gadgets and pieces of clothing, for example goggles, coveralls (lab coats, aprons), gloves, vests, earplugs, and respirators.

Performing any operations or experiments, appropriate PPE to wear should be decided and various variables must be mulled over, for example;

- The nature of the hazard and the task
- Compatibility with other PPE
- The chemicals being used, including concentration and quantity
- The hazards posed by the chemicals
- The routes of exposure for the chemicals
- The material the PPE is constructed of
- The permeation and degradation rates specific chemicals will have on the material
- The duration the PPE will be in contact with the chemicals

Careful consideration should be given to the comfort and fit of PPE to ensure that it will be used by the lab users.

Besides, PPE should

- be provided free of charge to users
- be maintained in an efficient working order and in good repair
- be stored in an assigned and suitable area
- be provided in conjunction with appropriate instruction and training for the user

Please see Table 3.1 for the PPE selection guide by task.

3.2. HAZARD ASSESSMENT

With a specific end goal to evaluate the requirement for PPE the accompanying steps ought to be taken:

3.2.1. Survey

In the area being referred to identify sources of dangers, conduct a walk-through survey.

Categories for consideration:

- Impact
- Penetration
- Compression (roll-over)
- Chemical
- Heat
- Harmful dust
- Light (optical) radiation
- Drowning
- Falling

Table 3.1 PPE selection guide by task

	If your task/activity involves:	Use the following PPE:
Chemicals	Solids of low or moderate toxicity	▪ Disposable gloves
	Minimal amounts of liquids (less than 0.1 L) with acute or chronic toxicity	▪ Safety glasses or goggles ▪ Appropriate chemical-resistant gloves ▪ Clothing covering to knees
	More than minimal amounts of liquids with acute or chronic toxicity (pure chemicals, mixtures or solutions)	▪ Safety glasses or goggles ▪ Appropriate chemical-resistant gloves ▪ Lab coat ▪ Acid-resistant apron if more than 4 liters of highly corrosive chemicals used ▪ Consider flame-resistant lab coat if more than 4 liters of flammable liquids used
	Cryogenic liquids	▪ Safety glasses or goggles ▪ Face shield required if handling cryovials stored in liquid phase ▪ Insulated cryogenic gloves ▪ Lab coat recommended
	Potentially explosive compounds	▪ Safety goggles ▪ Face shield ▪ Heavyweight gloves ▪ Fire-resistant lab coat
	Pyrophoric (air-reactive) solids or liquids	▪ Safety glasses or goggles ▪ Face shield recommended ▪ Fire-resistant gloves ▪ Appropriate chemical-resistant gloves ▪ Fire-resistant lab coat
	Particularly hazardous substances including carcinogens, reproductive toxins, and reagents of high acute toxicity	▪ Safety glasses or goggles ▪ Appropriate chemical-resistant gloves ▪ Lab coat ▪ Respirators as needed
Biological Materials	BL1 microorganisms or viruses	▪ Disposable gloves
	BL2 microorganisms, viruses, viral vectors, human materials or old world primate materials	▪ Disposable gloves ▪ Lab coat
	Procedures outside of the biosafety cabinet without splatter guard when splashes or sprays are anticipated	▪ Safety glasses or goggles ▪ Disposable gloves ▪ Lab coat
Radiation	Unsealed radioactive materials or waste	▪ Safety glasses if there is a splash potential ▪ Nitrile or other appropriate gloves ▪ Lab coat
	Class 3B or 4 laser	▪ Appropriate eye protection
	and if UV laser	▪ Gloves ▪ Lab coat
	Laser(s) modified by optics	▪ Appropriate eye protection
	Open ultraviolet light source ▪ and if face enters UV beam ▪ and if hand enters UV beam ▪ and if body enters UV beam	▪ Safety glasses or goggles with UV protection ▪ UV face shield ▪ Gloves ▪ Lab coat
	Infrared-emitting equipment	▪ Appropriately-shaded goggles ▪ Lab coat
Other Hazards	Handling hot surfaces and objects such as autoclaved materials and heated glassware	▪ Heat-resistant gloves ▪ Lab coat
	Glassware under pressure or vacuum	▪ Safety glasses or goggles ▪ Face shield recommended ▪ Lab coat
	Cutting and connecting glass tubing	▪ Safety glasses or goggles ▪ Cut-resistant gloves
	Sonicator or other loud equipment	▪ Ear plugs

Adopted from Harvard University, Environmental Health & Safety Department.

3.2.2. Sources

During the walk-through survey LSS, the Responsible Faculty Member and the university health and safety specialist should observe:

- Sources of motion; for instance, machinery or procedures where any development of instruments, machine components or particles could exist, or development of work force that could bring about impact with stationary articles
- Sources of high temperatures that could result in burns, eye injury or ignition of protective equipment
- Types of chemical exposures
- Sources of harmful dust
- Sources of light radiation, for instance, welding, brazing, cutting, heat treating, furnaces, and high intensity lights
- Sources of falling objects or potential for dropping objects
- Sources of sharp objects which might pierce or cut the hands
- Sources of rolling or pinching objects which could crush the feet
- Layout of work place and location of co-workers
- Any electrical hazards
- Review injury/accident data to help identify problem areas

Arrange information. Completing the walk-through survey, it is important to sort out the information and other data acquired. That material gives the premise to peril evaluation that empowers the lab user to choose the proper PPE.

Examine information. Having assembled and composed information with respect to a specific occupation, lab specialist need to assess the potential for wounds. Each of the distinguished hazards ought to be looked into and delegated to its sort, the level of danger, and the reality of any potential injury. Where it is predictable that a representative could be presented to a few perils at the same time, the outcomes of such exposure should be considered.

3.3. EYE AND FACE PROTECTION

On the table below (Table 3.2), eye and face protection equipments can be seen.

Table 3.2 Eye and face protection

Safety glasses	Splash goggles	Laser goggles	Face shields
Safety glasses provide eye protection from moderate impact and particles associated with grinding, sawing, scaling, broken glass, and minor chemical splashes, etc.	Splash goggles provide adequate eye protection from many hazards, including potential chemical splash hazards, use of concentrated corrosive material, and bulk chemical transfer.	The lens of the eyewear is a filter/absorber designed to reduce light transmittance of a specific wavelength. The lens can filter out a specific wavelength while maintaining adequate light transmission for other wavelengths.	Face shields provide additional protection to the eyes and face when used in combination with safety glasses or splash goggles. Face shields consist of an adjustable headgear and face shield of tinted or clear lenses or a mesh wire screen.
			

(Images courtesy of Egebant)
Adopted from Cornell University Environmental Health & Safety Department.

3.3.1. Eye Protection

The use of contact lenses is not recommended while working with chemicals that cause eye irritation.

Eye protection should be worn at all times while working with hazardous chemicals/biological materials or any physical hazards in the laboratory. Visitors should be provided with temporary protective goggles or, at least, protective glasses if they are allowed in any area in which the occupational use of eye protection is required.

Using contact lenses:

In the event of a chemical accident to the eyes, there could be some protection but, on the other hand, the presence of the lens would be an impediment to prompt and thorough flushing of the eyes. The lens would have to be removed which might result in damage to the eye in itself. If, however, the wearer of contact lens conscientiously wears a good-quality pair of goggles at all times when there is a possibility of an incident occuring, there is probably little risk in wearing contact lens. Even in the latter case, where extremely corrosive vapors are likely to be involved, there is a possibility of capillary action causing these vapors to be drawn under the contact lens, and the wearer should exercise caution if there is any suspicion that this could happen.

3.3.1.1. Safety glasses

Safety glasses provide eye protection from moderate effect and particles connected with grinding, sawing, scaling, broken glass, and minor chemical splashes, and so forth. Side defenders are required when there is a risk from flying items. In prescription form for those people requiring corrective lenses, safety glasses are accessible. In the case of safety glasses don't give sufficient insurance to procedures that include substantial synthetic utilize, such as, blending, pouring, or blending, splash goggles should be utilized.

3.3.1.2. Splash goggles

Including potential chemical splash hazards, utilization of concentrated corrosive material, and bulk chemical transfer splash goggles give satisfactory eye protection from numerous dangers. Goggles are available with clear or tinted lenses, fog proofing, and vented or non-vented frames. Be aware that goggles intended for carpentry (can be recognized by the various small holes throughout the face piece) are not fitting for working with chemicals. In the event of a splash, chemicals could enter into these small holes, and result in a chemical exposure to the face. Ensure the goggles you pick are evaluated for use with chemicals.

3.3.1.3. Laser goggles

The lens of the eyewear is a filter/absorber designed to reduce light transmittance of a specific wavelength. The lens can filter out (or absorb) a specific wavelength while maintaining adequate light transmission for other wavelengths.

A single pair of safety glasses is not available for protection from all LASER outputs. The type of eye protection required is dependent on the spectral frequency or specific wavelength of the laser source. See the Laser Safety section for more information.

3.3.2. Face Protection

3.3.2.1. Face shields

When utilized in combination with safety glasses or splash goggles, face shields provide additional protection to the eyes and face. Face shields comprise of a flexible headgear and face shield of tinted or clear lenses or a mesh wire screen. When the whole face needs assurance, they ought to be utilized as a part of operations and worn to shield the eyes and face from flying particles, metal sparks, and chemical/biological splashes. Face shields with a mesh wire screen are not appropriate for use with chemicals. Face shields must not be used alone and are not a substitute for appropriate eyewear and they should always be worn in conjunction with an essential type of eye protection, for example, safety glasses or splash goggles.

3.4. HEAD PROTECTION

Accidents that cause head injuries are difficult to anticipate or control. If hazards exist that could cause head injury, employees should try to eliminate the hazards, but they should also wear head protection.

Safety hats protect the head from impact, penetration, and electrical shock. Head protection is necessary if you work where there is a risk of injury from moving, falling, or flying objects or if you work near high-voltage equipment.

Figure 3.1 Head cover
(Courtesy of Egebant)

Hard hats (Figure 3.1) should be water resistant, flame resistant, and adjustable. Follow these guidelines for head safety:

- Check the shell and suspension of your headwear for damage before each use.
- Look for cracks, dents, gouges, chalky appearance, and torn or broken suspension threads.
- Discard damaged hats or replace broken parts with replacements from the original manufacturer.

3.5. HAND PROTECTION

Most accidents involving hands and arms can be classified under four main hazard categories:

- Chemicals
- Abrasions
- Cuts
- Heat/cold

There are several types of gloves that provide protection against and opposes corruption and pervasion to chemicals. Confiding in the type and concentration of the chemical, performance characteristics of the gloves, conditions and duration of use, hazards present, and the duration of time a chemical has been in contact with the glove, all gloves must be replaced periodically.

Gloves must be worn at any potential danger like chemicals, cuts, lacerations, abrasions, punctures, burns (heat/cold), biological materials, or harmful temperature extremes and when utilizing chemicals that are easily ingested through the skin and/or particularly hazardous. The correct utilization of hand protection can shield from potential chemical and physical hazards.

3.5.1. Selecting the Proper Gloves

Proper selection of the glove material is essential to the performance of the glove as a barrier to chemicals/biological materials/physical hazards. Several properties of both the glove material and the chemical/biological material/physical hazard with which it is to be used should influence the choice of the glove. Some of these properties include: permeability of the glove material, breakthrough time of the chemical, temperature of the chemical, type of the possible physical hazard, thickness of the glove material, and the amount of the chemical that can be absorbed by the glove material (solubility effect). Glove materials vary widely in respect to these properties; for instance, neoprene is good for protection against most common oils, aliphatic hydrocarbons, and certain other solvents, but is unsatisfactory for use against aromatic hydrocarbons, halogenated hydrocarbons, ketones, and many other solvents. Please see Chemwatch for selecting the proper gloves.

3.5.2. Double Gloving

“Double-gloving” is a common practice used with disposable gloves. Twofold layer of assurance is provided by wearing two pairs of gloves on each other. If the outer glove becomes contaminated, starts to degrade, or tears open, until removing and replacing it, the inner glove continues to offer protection. The best practice is to check outer gloves frequently, watching for signs of degradation (change of color, change of texture, tears, etc.). At the first sign of degradation or contamination, always remove and dispose of the contaminated ones immediately and double-glove with a new set. If the inner glove appears to have any contamination or degradation, remove both pairs of gloves, and double glove with a new pair.

It is desirable to double glove with two sets of gloves made from different materials when working with mixtures of chemicals. If one chemical infuses through the outer glove material, the inner gloves can still protect by this method. The type of the glove materials should be chosen depending on the chemical worked with.

3.5.3. Glove Removal Precautions

Removing disposable gloves depends on simple rules: Firstly, grab the cuff of the left glove with the gloved right hand and remove the left glove. After that, while holding the removed left glove with the gloved right hand, insert a finger under the cuff of the right glove and gently invert the right glove over the glove in the palm of your hand and dispose of them properly. Finally, wash your hands with soap and water (See Figure 3.2).

Figure 3.2 How to remove gloves
(Courtesy of GIT Laboratory Safety Manual)

3.5.4. Types of Gloves

Table 3.3 represents the types of gloves:

Table 3.3 Types of gloves		
Latex gloves	Resistant to ketones, alcohols, caustics, and organic acids.	
Nitrile gloves	Resistant to alcohols, caustics, organic acids, and some ketones.	
Cryogenic gloves	Cryogenic gloves are used to protect hands from extremely cold temperatures.	
PVA Gloves	Resistant to chlorinated solvents, petroleum solvents, and aromatics.	
Cut-resistant gloves	Cut resistant gloves are gloves designed to protect the wearer's hands from cuts while working with sharp tools.	
Heat-resistant gloves	Working with metal and glass forming and hot surfaces requires gloves that offer the highest level of protection against the multiple hazards of a high-heat workplace.	

(Images courtesy of Egebant)
Adopted from Cornell University, Environmental Health & Safety department.

3.5.4.1. Latex gloves

Natural Rubber Latex - Resistant to ketones, alcohols, caustics, and organic acids.

Due to the fact that latex gloves can degrade severely in seconds while in use with common chemicals, the use of them are not really encouraged. Latex contain several proteins, so latex gloves can also result in allergic reaction in some users. Symptoms can include nasal, eye, or sinus irritation, hives, shortness of breath, coughing, wheezing, or unexplained shock. Using latex gloves should be stopped if any of these symptoms become apparent.

The use of latex gloves is only appropriate for:

- Most biological materials.
- Non-hazardous chemicals.
- Cleanroom requirements.
- Medical or veterinary applications.

Very dilute, aqueous solutions containing < 1% for most hazardous chemicals or < 0.1% of a known or suspected human carcinogen.

3.5.4.2. Nitrile gloves

Nitrile - Resistant to alcohols, caustics, organic acids, and some ketones.

3.5.4.3. Cryogenic gloves

Cryogenic gloves are used to protect hands from extremely cold temperatures. These gloves should be used when handling dry ice and when dispensing or working with liquid nitrogen and other cryogenic liquids. For further information please consult Cryogenic Safety section.

3.5.4.4. PVA gloves

Polyvinyl alcohol (PVA) - Resistant to chlorinated solvents, petroleum solvents, and aromatics.

3.5.4.5. Cut-resistant gloves

Cut resistant gloves are gloves designed to protect the wearer's hands from cuts while working with sharp tools.

3.5.4.6. Heat resistant gloves

Thermal safety is also another part of personal protective equipment. Working with metal and glass forming and hot surfaces requires gloves that offer the highest level of protection against the multiple hazards of a high-heat workplace.

3.6. PROTECTIVE CLOTHING

Loose or torn clothing should be avoided without wearing a lab coat because of the ignition, absorption, and entanglement in machinery risks.

Dangling jewellery, finger rings or other tight jewellery and excessively long hair should also be avoided.

3.6.1. Lab Coats

When properly used, lab coats (Figure 3.3.a):

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

There are no design or test criteria specified in regulations or guidelines specific to lab coats. What this means is that:

- Lab coats are not tested for normal conditions that may be experienced in a research lab with respect to chemical use, or joined research activities.
- Manufacturers of the lab coats do not provide information about the capability of a lab coat for a combination of hazards. If a coat is “flame resistant”, it may not be chemical resistant or acid resistant.
- If a coat is sold as flame resistant, this means it is not tested involving flammable chemicals on the coat. The flame resistance test criteria includes simulation of the possibilities of a flash

fire, or electric arc flash, not a chemical fire. “Flame resistant” term refers to the characteristic of a fabric that avoids burning in air.

Figure 3.3 Lab coat (a) and apron (b)
(Courtesy of Egebant)

Lab coats should be provided for protection and convenience. They should be worn at all times in the lab areas. Due to the possible absorption and accumulation of chemicals in the material, lab coats should not be worn in the lunchroom or elsewhere outside the laboratory.

3.6.1.1. Choosing the right lab coat

Lab coats are made of different materials, and depending on the type of hazard in the lab, it is significant to select the lab coat. Determination of the type of hazard in the lab is the first step in this selection process.

Some questions to consider are the following:

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

One coat may not work for all lab operations. Users might need to provide a basic poly/cotton mixture coat for most operations, but have accessible lab coats of treated cotton or Nomex for work involving pyrophoric materials, extremely flammable chemicals, extensive amounts of flammable chemicals, or work around hot procedures or operations. If there is a possibility of a chemical splash, rubber apron over the flame resistant lab coat should also be used.

3.6.1.2. Flame resistant (FR) lab coats

Work with pyrophoric, spontaneously combustible, or extremely flammable chemicals presents an especially high potential for fire and burn risks to the skin. The use of fire retardant or fire resistant (FR) lab coats is recommended to provide additional skin protection where the individual will be working with these chemicals. The primary materials used for FR lab coats are FR-treated cotton or Nomex.

3.6.1.3. Lab coat use

When lab coats are in use, the following should be observed:

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

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

3.6.1.4. Lab coat cleaning

Lab coats must not be cleaned at home. For lab coat cleaning, please contact LS.

3.6.2. Aprons

In the case of some procedures in the laboratory, such as washing glassware, large quantities of corrosive liquids in open containers are handled. In this situation, plastic or rubber aprons should be worn over the lab coat.

A high-necked, calf- or ankle-length, rubberized laboratory apron (See Figure 3.3.b) or a long-sleeved, calf- or ankle-length, chemical- and fire-resistant laboratory coat should be worn whenever laboratory manipulation or experimentation is conducted.

3.7. RESPIRATORY PROTECTION

A respirator is a device designed to protect the wearer from inhalation of harmful substances.

When chosen correctly and used properly, respirators can protect the wearer from,

- Fumes and smokes (welding fume)
- Harmful dusts (lead, silica, and other heavy metals)
- Gases and vapors (chemical exposures)
- Oxygen deficiency (oxidation, displacement, and consumption)
- Biological hazards (tuberculosis, whooping cough, flu viruses)

3.7.1. Inspection

Users must inspect their respirators before and after use. Respirator inspections must include checking that;

- Sealing surface are clean and free of cracks and holes
- Rubber and elastic parts have good pliability and no signs of deterioration
- Inhalation and exhalation valves are clean and seated properly
- Straps are sufficiently elastic and free of worn areas
- If full face, face shield is cleaned and clear (no smudges, scratches, or other damage that may impede visibility)

Respirators that fail an inspection must be removed from service and replaced.

Before using a respirator, the wearer must perform a positive and negative pressure check. The wearer must ensure current facial condition will allow an effective seal (for example the wearer must be clean shaved).

Positive pressure check. Close off the exhalation valve with palms and exhale gently. No leakage outward around the seal should occur.

Negative pressure check. Close off the cartridges and inhale. The respirator should collapse slightly on the face. No leakage around the face seal should occur while maintaining a negative pressure inside the respirator for several seconds.

3.7.2. Maintenance

3.7.2.1. Cleaning

Respirators must be cleaned and disinfected after each use as follows:

- Remove filters or cartridges.
- Disassemble and wash with mild dishwashing detergent in warm water, using a soft brush.
- Thoroughly rinse to remove any detergent residue.
- When the cleaner used does not contain a disinfecting agent, respirator components must be immersed for two minutes in a sodium hypochlorite (30 mL household bleach in 7.5 L of water) solution, or other disinfectant. The solution used to clean the respirator(s) should contain some type of biocide for disinfection. Rinse in fresh, warm water.

Do not use organic solvents to clean a respirator or high heat to dry it, as this may damage the elastomeric face piece.

3.7.2.2. Cartridges and filters

- Change cartridges and filters according to the specific schedule provided with the authorization, or sooner if you experience an increased resistance in breathing or when you detect contaminant odors or taste while wearing your respirator.
- General guidance for organic vapor cartridges. Lab users who use respirators intermittently and perhaps in different environments should never reuse organic vapor cartridges after one use. This is due to chemical desorption of the vapors/gases and their migration through the cartridge charcoal bed. When this occurs, contaminants could be inhaled by the respirator wearer upon initial donning and the concentration could even be higher than contaminant concentrations found in the ambient workplace atmosphere.

3.7.2.3. Replacement and repairs

Repair of respirators may be done only by experienced personnel with parts designed for the specific respirator needing repair. No attempt may be made to replace parts or to make adjustments or repairs beyond the manufacturer’s recommendations.

3.7.3. Storage

- Store respirators away from dust, sunlight, heat, extreme cold, excessive moisture, damaging chemicals, or contamination.
- Filters and cartridges must be removed from the respirator and stored in separate bags to prevent cross contamination.
- Do not store items on top of respirators, which could deform the shape of the face piece.
- Do not store respirators in such places as lockers or tool boxes unless they are on a separate shelf or in carrying cases or cartons to preserve the shape of the face piece.
- Respirators must be packed and stored according to the manufacturer’s instructions.
- Never store a respirator within a fume hood or at a work bench where contaminants are present.

3.7.4. Maintenance and Care of Dust Masks

Dust masks must be maintained in a clean and sanitary condition. Users who wear dust masks must

- Store dust masks in a plastic bag or box in a secure location such as a locker or desk drawer, away from moisture and contamination.
- Not share dust masks with others.
- Not use a dust mask that is torn, distorted, or dirty.

3.7.5. Types of Masks

Table 3.4 displays the types of masks:

Table 3.4 Types of masks

Dust mask	The use of the term “dust” mask for the non-rigid soft felt mask is somewhat of a misnomer since, in modified forms, they can be used for other applications such as limited protection against paint fumes, moderate levels of organics, acid fumes, mercury, etc., although their biggest use is against nuisance dust.	
Half face respirator	The half-face cartridge respirator is the type most frequently used, especially in atmospheres in which there is little or no problem of irritation or absorption of material through the skin.	
Full face respirator	Full-face air-purifying respirators are similar in many respects to half-face respirators, with the obvious difference that the mask covers the upper part of the face, protecting the eyes.	

(Images courtesy of Egebant)

3.7.5.1. Dust mask

The use of the term "dust" mask for the non-rigid soft felt mask is somewhat of a misnomer since, in modified forms, they can be used for other applications such as limited protection against paint fumes, moderate levels of organics, acid fumes, mercury, etc., although their biggest use is against nuisance dust.

These units are the simplest form of the air-purifying respirator. These respirators normally should not be employed for hazardous dusts, but are helpful for exposures to inert or nuisance dust levels below 15 mg/m^3.

3.7.5.2. Half face respirator

The half-face cartridge respirator is the type most frequently used, especially in atmospheres in which there is little or no problem of irritation or absorption of material through the skin. The face piece of most of these units is molded of a flexible plastic or silicone rubber, which provides a seal to the face when properly adjusted. As noted earlier, facial hair between the mask and the face will prevent the seal from being effective, and it is not permitted for a person with a beard or extended sideburns in the area of the seal to be fitted with a respirator. Accommodation for individuals who wear glasses also must not break the seal to the face. The face pieces of most brands of these units are provided with receptacles for two sets of cartridges and/or filters. The respirators are certified as complete units, *i.e.,* the face piece equipped with specific filters. Cartridges from one vendor cannot be used on another manufacturer's face piece. The major advantage of this type of unit is that by interchanging cartridges and filters, or by using one or more additional filters and cartridges in series, a single face piece can be adapted to provide protection against a large variety of contaminants.

3.7.5.3. Full face respirator

Full-face air-purifying respirators are similar in many respects to half-face respirators, with the obvious difference that the mask covers the upper part of the face, protecting the eyes.

3.8. HEARING PROTECTION

Regarding possible noise hazards, there is a regulation about the Noise safety in Turkey. According to this regulation, the highest exposure value is $L_{EX, 8h}$ = 85 dB(A) and P_{peak} = 140 µ Pa.

If you work in a high noise area, wear hearing protection. Most hearing protection devices have an assigned rating that indicates the amount of protection provided.

Depending on your level of exposure, you may choose from the following devices (Figure 3.4):

- Disposable earplugs
- Reusable earplugs
- Headband plugs
- Sealed earmuffs

Earplugs may be better in hot, humid, or confined work areas. They may also be better for lab users who wear other PPE, such as safety glasses or hats. Earmuffs, on the other hand, may be better for users who move in and out of noisy areas, because the muffs are easier to remove. Before resorting to hearing protection, attempt to control noise levels through engineering or operational changes.

Figure 3.4 Headband/ear muff and ear plug (Courtesy of Egebant)

To avoid contamination, follow these guidelines when using earplugs:

- Wash your hands before inserting earplugs.
- Replace disposable earplugs after each use.
- Clean reusable earplugs after each use.

3.9. FOOT PROTECTION

In laboratories, laboratory support areas, and other areas where chemical, biological and physical hazards are present, foot protection should be supplied at all times. Wearing sandals or similar types of perforated or open-toed shoes when working with or around hazardous chemicals or physical hazards must be avoided.

This is due to the potential exposure to toxic chemicals and the potential associated with physical hazards such as dropping pieces of equipment or broken glass being present. In general, shoes should be comfortable, and leather shoes are preferable to cloth shoes due to the better chemical resistance of leather compared to cloth. Leather shoes also tend to absorb fewer chemicals than cloth shoes. However, leather shoes are not designed for long term exposure to direct contact with chemicals. In such instances, chemically resistant rubber boots are necessary.

In some cases, the use of steel-toed shoes (Figure 3.5) may be appropriate when heavy equipment or other items are involved. Chemically resistant boots or shoe covers may be required when working with large quantities of chemicals and the potential exists for large spills to occur.

Contact LS to obtain foot protection.

Figure 3.5 Steel-toed shoes and shoe cover
(Courtesy of Egebant)

References

- Furr, A. K. (2000). *CRC Handbook of Laboratory Safety*. (5th ed.). United States of America: CRC Press LLC.
- Georgia Institute of Technology Laboratory Safety Manual. (2013, April). Retrieved from https://www.ehs.gatech.edu/sites/default/files/aaa_lab_safety_manual_april_29_2013.pdf
- Cornell University Laboratory Safety Manual and Chemical Hygiene Plan. (2006, January). Retrieved from http://www.ehs.cornell.edu/NYSAES/CHP_January2006.pdf
- Lab Coat Selection, Use, and Care at MIT. (2013, September). Retrieved from https://labcoats.mit.edu/guidance
- Harvard University PPE Selection Guide. (2015, April). Retrieved from https://www.ehs.harvard.edu/sites/ehs.harvard.edu/files/ppe_selection_guide_by_task.pdf
- Stanford University Respiratory Protection Program. (2015, March). Retrieved from https://web.stanford.edu/dept/EHS/prod/mainrencon/occhealth/RPP_FAQs.pdf
- Texas A&M University Laboratory Safety Manual. (2009, February). Retrieved from https://ehsd.tamu.edu/EHS%20Helpful%20Docs/Laboratory%20Safety%20Manual.pdf
- University College London Personal Protective Equipment Policy & Guidance. (2015, March). Retrieved from http://www.ucl.ac.uk/medicalschool/msa/safety/docs/personalprotectiveequipment.pdf
- United States Department of Labor, Occupational Safety & Health Administration, Standards. (2015, March). Retrieved from https://www.osha.gov/pls/oshaweb/owastand.display_standard_group?p_toc_level=1&p_part_number=1910

4. ENGINEERING CONTROLS AND LABORATORY EQUIPMENT

After hygiene, engineering controls are the next most important means of controlling exposure to hazards. Engineering controls are anything that is built or installed to separate people from chemical, biological or physical hazards, and can include fume hoods, biosafety cabinets, glove boxes, local exhaust ventilation, safety shields, and proper storage facilities.

Hazardous chemicals should be handled and ventilated differently from general laboratory ventilation. Laboratory users should be aware of their chemicals using SDS, how to protect themselves and laboratory environment from hazardous exposures and consider the available engineering controls.

LS/LSS are responsible of keeping functional and maintenance of fume hood and other protective equipment. Infrastructure and emergency equipment such as emergency eye wash and showers, fire extinguishers and ventilation managed by Operation and Technical Services unit. However; laboratory users has responsibility of reporting the malfunctioning equipment as soon as malfunction realize.

4.1. FUME HOODS

Fume hoods are used to prevent hazardous and odorous chemical exposure release to laboratory, laboratory users and the user. Another substantial reason is limiting spill-affected area within hood and exhausting affected air. Inward air flow through the hood minimized material leakage out of the hood.

Fume hoods are substantial infrastructure element for handling hazardous materials . They should not be misused for the purposes such as garbage, storage of materials, equipment.

A fume hood should be used if a proposed chemical procedure exhibits any one of the following characteristics:

- Airborne concentrations might approach the action level (or permissible exposure limit) (see SDS from ChemWatch)
- Flammable vapors might approach one tenth of the lower explosion limit (see SDS from ChemWatch)
- Materials of unknown toxicity are used or generated
- The odor produced is annoying to laboratory occupants or adjacent units

Procedures that can generally be carried out safely outside the fume hood include those involving the following:

- Water-based solutions of salts, dilute acids, bases, or other reagents
- Very low volatility liquids or solids
- Closed systems that do not allow significant escape into the laboratory environment
- Extremely small quantities of otherwise problematic chemicals. The procedure itself must be evaluated for its potential to increase volatility or produce aerosols.

The fume composed of several elements which are given below:

Face – The face of the hood is the space where air capture occurs.

Sash – The sash is the glass “window” that moves through the hood face to protect the user and laboratory for the period of time in use.

Baffles – The baffles are positioned behind the hood and direct air in the suitable direction. The baffles can also be regulated according to altering vapor densities of chemicals (heavier than air and lighter than air).

Duct – The hood and the ventilation system is attached by the duct and it exhausts to the open air.

Air foil – The air foil is positioned at the bottom front edge of the hood and is a vent that keeps a minimum gap open at all times but more importantly gives aerodynamic properties that allow better, less turbulent air flow and better capture.

In specialized cases, fume hoods will contain exhaust treatment devices, such as water wash-down for perchloric acid use, or charcoal or HEPA filters for removal of particularly toxic or radioactive materials. Fume hoods must not be used for work with infectious agents.

4.1.1. Types of Hoods

Variable Air Volume (VAV) – VAV hoods maintain a constant velocity as the sash moves but changes the volume of air. This can be done by a variety of methods including changing motor speed or closing or opening baffles in the duct. Decrease in air usage at lower sash height provides huge amount of energy savings on heating and cooling.

Standard or Bypass – Air volume varies according to the movement of the sash so that as the sash lowered the velocity decreases. Even bypass hoods have similar design but they have an additional vent at the tpo so that as the sash lowered and the sash space is closed, top vent is simultaneously activated, even though the sash opening is getting smaller, the proportion of air volume flowing through the face is smaller and the velocity remains more constant. Although, performance of bypass hoods are better than standard hoods, they are worse than standard hoods in context of energy saving.

Auxiliary Air – These hoods additional air-injecting blower at the face of the hood. Auxiliary air type hoods are out-of-use owing to their lower performance than VAV and bypass hoods.

Ductless hoods – These hoods are not ducted to outside air but remove contaminants from the air and return it back to the room. HEPA filter, carbon adsorption or catalyst reaction filter may remove the contaminants. Filters should be used in recommended time of use given by the manufacturer. Appropriate filter choice according to your contaminant also plays important role. It is quite important that these elements work properly since the air is reticulated and exposure is eminent. Filter selection and proper working condition must be conducted by LS/LSS. LS/LSS should also consult with laboratory users to evaluate each chemical used in that hood. New chemicals should be informed to LS/LSS for evaluation. Unless the benefits outweigh the hazards and inconvenience because potential for problems, ductless hoods could pose danger. Also, ductless hoods are not indicated when using many liquid, non-aqueous chemicals since the vapors of these chemicals are heavier than air and ductless hoods do not generally have a rear baffle. As a general rule the use of ductless hoods is not recommended.

Clean hoods – Clean hoods are sometimes called laminar hoods but these are different from the type of hood mentioned below.

Design of these hoods are based on preventing the work area with HEPA filtered air from contamination. High incidence of air drawn to the hood is filtered and drop gently from the top of into the work area and small percentage (%10) is drawn through the face of the hood. Face velocities of clean hoods are lower than other hoods, however, the hood is designed to capture with high performance in this form. Due to this capture capability, it is important to have a visual capture test (such as a dry ice test) done on these hoods at least annually.

4.1.2. General Rules Regarding Laboratory Fume Hoods

Before using a fume hood:

- Measure the level of hazard declared by the material involved and use only hoods that have appropriate face velocity.
- Confirm that the fume hood is operational by testing the tell-tale (paper hanging from hood sash) periodically and air monitoring device if the hood is fitted with one. If there is no indicator, difficulty in visualizing, or not functioning, place a piece of paper to the sash in an area where it will not prevent the ongoing processes.
- If the fume hood is out of service, the fume should not be used under any circumstances.

General operational rules:

- Always work with the fume hood sash as low as possible (no higher than 50 cm). Low hood sash working increases the performance of the hood. Low sash position is not only energy saver but also have safety shield property during experiments.
- For optimum performance of the fume hood, There should be at least 15 cm distance between materials and face of the vents or baffle openings in the back of the hood should not blocked in any case (Figure 4.1).

- Any lab apparatus should be raised at least 2.5 cm above the work surface of the hood to improve airflow in the hood. Bench stands or items such as blocks, metal test tube racks, or other items that will not react with the chemical(s) in use should be used (Figure 4.2).
- Windows and doors should be kept closed within the lab and minimize traffic in front of the hood when the hood is operational. Quick movements should also be reduced while working in the hood, including opening and closing the sash. These steps mentioned above will help to prevent air currents, which can result in hazardous vapours being leaked from the hood and into the laboratory users' working area.

Other considerations:

- Fume hood should not used for evaporation of hazardous waste.
- For particularly hazardous substances or chemicals that can form toxic vapours, fumes, or dusts, the hood or equipment within the hood may have to be tailored with condensers, traps, or scrubbers in order to prevent the vapours, fumes, and dusts from being leaked into the laboratory area.
- Flammable liquid including containers must be grounded and interconnected each other while transferring these liquids to another container. Static electricity generation could lead to ignite these liquids abruptly.
- In case of chemical spill, area should be cleaned immediately or reported to LS/LSS if the volume of spill could not be handled easily. Working area and hood sash should be washed frequently and always be preserved a clean, dry and ready-to-work area.
- Only hands should be inside of the hood. Never put your head inside a functioning laboratory hood to monitor an experiment.
- The plane of the sash is the border between contaminated and uncontaminated zone. The sash must always be between the user and hood contents.
- All the equipment and other apparatus such as bottles, beakers, unrelated materials etc. should not be stored or located in the hood, hence the hood area is limited. If there is grill along the bottom slot or baffle in the back the hood, it also should be kept clean.
- Actively used materials could be allowed to place in the hood. Extraneous chemicals left in an active hood can contribute to a fire or explosion.
- Elevate any equipment that needs to remain in hoods on racks or feet to provide airflow under the equipment.
- Name and other necessary information about lab responsible student or personnel should be written in a visible location.
- Before the maintenance; all the materials should be removed and cleaned.
- Report suspected hood malfunctions promptly to LS/LSS. If the fume hood is not working properly, let other people in the lab know by hanging up a "Do Not Use" sign on the hood.
- Hoods operation shall be evaluated annually by SU LS/LSS or a qualified third party.

Specifications:

- Operation standard for general purpose hoods is 0.5 m/s ± 10%.
- Operation standard of hoods specialized for highly toxic or carcinogenic materials is 0.6 m/s ± 10%.
- Hoods should not, as a matter of course, operate above 0.75 m/s to prevent the potential for dangerous turbulence that could result in exposure to the user.
- Fume hood sash should be kept closed when you are away from the hood or leave the lab.
- Tampering with fume hoods/fume hood exhaust ducts by adding additional equipment on to the load of the hood or cutting/drilling into exhaust ducts without consulting with LSS is forbidden.

Figure 4.1 and 4.2 show the effect of material placement to working conditions:

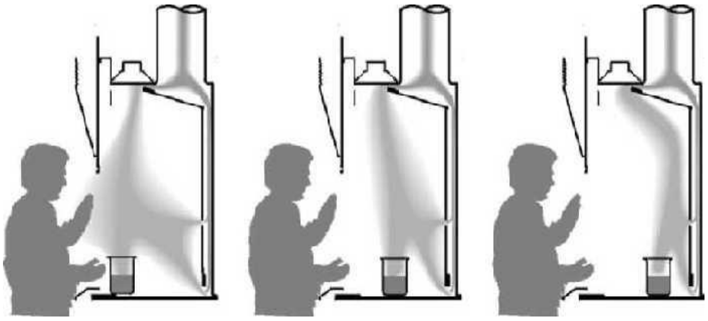


Figure 4.1 Effect of material placement: (L to R) bad placement, good placement, best placement

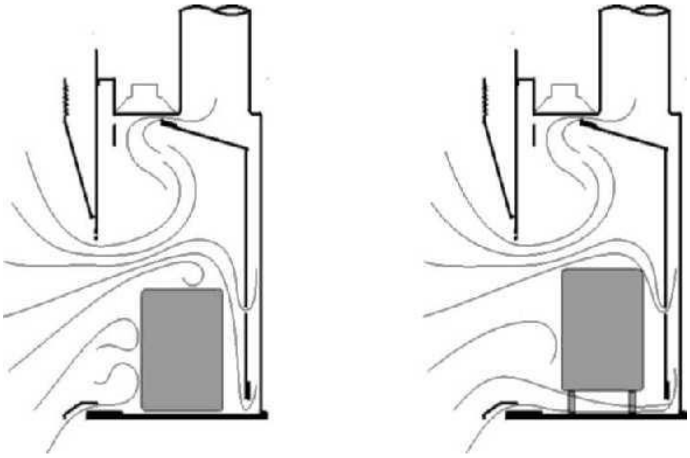


Figure 4.2 Effect of large equipment placement: (L to R) poor placement, and good placement (Courtesy of Dekolab)

4.1.3. Fume Hood Inspection and Testing Program

Annual testing and inspection of fume hoods are coordinated by LS/LSS and performed by the authorized company (manufacturer). The fume hood inspection program consists of a detailed preliminary inspection followed by annual standardized inspections for all fume hoods on campus. This initial inspection will offer baseline information including, but not limited to, hood utilization, category of hood, room and building information, and average face velocity capacities.

Follow-up inspections for appropriate procedure and face velocity (airflow) measurements will be performed on an annual basis and upon request by laboratory users. Upon accomplishment of each inspection, hoods will be categorized with an inspection sticker indicating face velocity, date inspected, and initials of the inspector. File including inspection datas will be kept in database.

Fume hood testing and inspection consist of the following:

- The face velocity will be tested for compliance with EN 14175 standard.
- A visual inspection using dry ice can be volunteered by users or LS/LSS in conjunction with face velocity measurements. Dry Ice Test can be found in the Appendix 4.1.
- If your fume hood is filled with equipment, experimental set up or any material which hinders the test, you will be contacted by LS/LSS for further information before your fume hood can be tested

A fume hood that has not passed the authorized company inspection and has a warning sign attached, even if the fume hood appears to have airflow is not allowed to operate. Laboratory users must arrange or coordinate with other available laboratories with operational fume hoods if their work necessitates the usage of a fume hood.

LSS will coordinate fume hood repairs with the Operational and Technical Services unit to ensure a timely and accurate repair process.

4.2. OTHER CAPTURE OR CONTAINMENT DEVICES

4.2.1. Biosafety Cabinets and Laminar Flow Hoods

Biosafety cabinets (BSC) are intended to protect the user from hazardous aerosols and are equipped with high efficiency particulate air (HEPA) filters that frequently recirculate air back into the lab. They are not capable of capturing hazardous gases and their baffles and inner workings are not generally chemical resistant. Using a BSC with a hazardous gas could not only ruin the cabinet, but it could result in injury to the user. Proper use of BSCs is described in the Biological Safety section.

Laminar flow hoods (LFHs) are work benches that continuously bathe the work area with clean, filtered air. Their primary purpose is to protect whatever is being worked on, or “product”, not the user. Some laminar flow hoods are also chemical benches which protect both the user and the products. These benches expel air via an exhaust ventilation system and do not recirculate it back into the lab.

Biosafety cabinets (BSCs) and laminar flow hoods are serviced and certified by a contracted vendor. Problems with BSLs or LFHs should be reported to the LS/LSS.

4.2.2. Local Exhaust Ventilation

People who have a need for local exhaust ventilation should contact LS/LSS for an evaluation to determine what type of system will work best for their process. Various forms of local exhaust ventilation are seen in Sabancı University labs and may have been designed and installed for specific processes. These include:

4.2.2.1. Elephant Trunk

Elephant trunk (Figure 4.3.a) is useful for small sources of emissions.

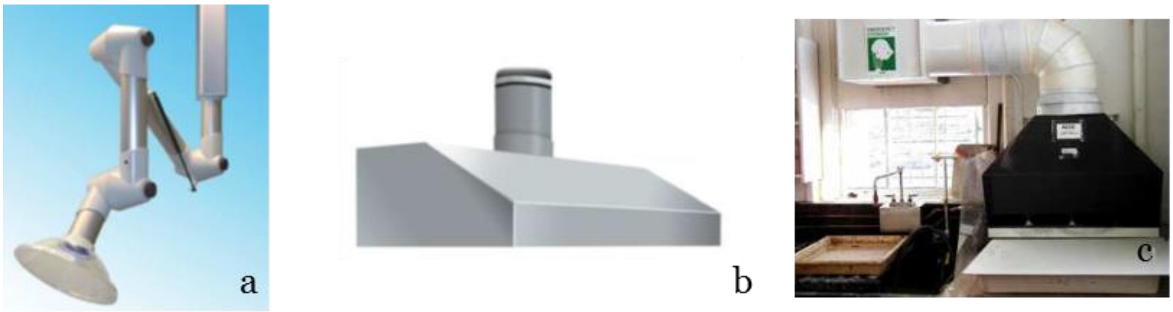


Figure 4.3 Elephant trunk (a), canopy (b), slot and plenum (c)
(Courtesy of Dekolab)

4.2.2.2. Canopy

Canopy (Figure 4.3.b) is useful for hot operations or to exhaust materials that are lighter than air.

4.2.2.3. Slot and Plenum

Slot and plenum (Figure 4.3.c) are useful for heavy vapors or particulates because they pull the contaminant backwards, away from the user, into the plenum before exhausting it up and out.

4.2.3. Glove Boxes

Glove boxes (or gloveboxes) are sealed container design to protect the user, the process or both. They usually includes at least one pair of gloves attached to the container. The user handles the materials inside using the gloves. Typically, a glove box has an antechamber that is used to materials transfer.

Configuration of the glove boxes depends on the application. Glove boxes can be under vacuum or positive pressure. Glove boxes under vacuum are designed to protect the operator and ambient environment from the materials or processes; glove boxes under positive pressure are intended to provide an inert atmosphere for the materials or processes. The glove box environment may be inert (e.g. nitrogen, argon, helium), sterile, dry, or otherwise controlled. Some glove boxes are equipped with filters (e.g. HEPA) while others vent to a fume hood duct or a dedicated duct. Various controllers, sensors and equipment such as pressure gauges, oxygen sensors, temperature controllers and purifiers could be attached to the glove box.

The term “glove box” is most often applied to containers used in chemical and electronic laboratories. Similar apparatus is present in pharmaceutical and biological applications. In biological applications, Class III biological safety cabinets are similar to glove boxes. A Class III cabinet is sealed with a non-opening window, gas tight, and manipulation is made through attached gloves. This cabinet enable to work with high risk agents and maximize the protection level for the operator and the environment. Box environment is HEPA-filtered and the air drain must be filtered through two HEPA filters. Negative pressure in the cabinet maintained by an independent, dedicated exhaust structure maintains airflow

A glove box should have maintenance and be inspected regularly to sustain its protection level for both sides. Manufacturers and regulatory recommendations about inspection and maintenance should be routinely implemented. Glove boxes which are dedicated to hazardous chemicals or processes are exempted from the routine inspection.

Another important and possible source of contamination risk is the glove boxes. These elements are particularly vulnerable. Gloves should be routinely examined for cuts, tears, cracking and pinhole leaks. If the gloves are defective, the gloves should be immediately changed. Glove box gloves also vary according to the application such as thickness, material, etc. Choose the right one for the glove box and application.

There are several tests that can be achieved on glove boxes, depending on the glove box and the application such as pressure decay (for positive pressure), rate of rise (for negative pressure), oxygen analysis, containment integrity, ventilation flow characterization, and cleanliness. Leakage can be identified using a mass spectrometer leak detector, ultrasound, the soap bubble method or use of an oxygen analyzer.

4.2.4. Safety Shields

Safety shields, such as the sliding sash of a fume hood, are designed to protect the personnel from sudden spattering or explosion release of highly concentrated acids, bases, oxidizers or reducing agents: Base requirement for reactions performed at vacuum or high pressure is safety shields. In addition to this, alteration of experimental procedure such as scaling up or first time experiment should also performed behind the safety shield.

4.2.5. Ventilated Storage Cabinets

These are cabinets (Figure 4.4) which are fitted with forced ventilation. They may be free-standing with their own extract system, or may be situated beneath a fume cupboard and attached to its duct. They are designed to safely store chemicals that give off noxious fumes and smells. These fumes are sucked away by the forced ventilation.

Ventilation of chemical storage cabinets may only be accomplished with prior approval by LSS.

For appropriate storage requirements of a particular chemical, please see ChemWatch.

Figure 4.4 Cabinets suitable for acid-base or solids chemicals storage (left) and cabinet suitable for combustible chemical storage (right) (Courtesy of Dekolab)

4.2.6. Compressed gas cabinets

Highly toxic or odorous gases should be used and stored in gas cabinets (Figure 4.5). In the event of a leak or rupture, a gas cabinet will prevent the gas from contaminating the laboratory.

Gas cabinets should be connected to laboratory exhaust ventilation using hard duct, rather than elephant tubing, since such tubing is more likely to develop leaks. Coaxial tubing should be used for delivering gas from the cylinder to the apparatus. Coaxial tubing consists of an internal tube containing the toxic gas, inside another tube. In between the two sets of tubing is nitrogen, which is maintained at a pressure higher than the delivery pressure of the toxic gas. This ensures that, in the event of a leak in the inner tubing, the gas will not leak into the room.

Figure 4.5 Compressed gas cabinet (Courtesy of Dekolab)

4.3. LABORATORY VENTILATION

Air pressure in research laboratories should be negative to the hallways and offices. When positive air pressure occurs, more air is being supplied to the room than what is being removed by the fume hood or general exhaust. This can result in air from the laboratory (including chemical vapors and dusts) being blown out into the hallway outside of the lab and chemical odors permeating the hallways and surrounding rooms.

Ensure the entrance door to the laboratory is closed.

If you notice odors that seem to be escaping from a lab, then please contact LS/LSS for assistance.

4.4. WATER PROTECTION

Water supply connected of feeded equipment or laboratory apparatus uses backflow protection or is connected to a faucet with a vacuum breaker. Backflow prevention and vacuum breakers for water used experimental process or with a piece of equipment provides protection against back flowing or and contaminating the laboratory's and building's water supply system. Chemical contamination and/or temperature extremes could be observed in case of improper backflow prevention

Common water protection problems encountered in labs are listed below:

- A tube attached to a faucet without a vacuum breaker,
- Improper tubing connections causing leakage,
- Drainage tubing hanging down into the sink.

These tubes can be immersed in wash water when the sink is stopped up and backflow into the faucet, contaminating the building's water supply.

4.5. ILLUMINATION, TEMPERATURE AND NOISE REGULATIONS

4.5.1. Illumination

Having a properly lighted work area is essential to working safely. A couple of key points to remember about proper lighting:

- Lighting should be adequate for safe illumination of all work areas. TS EN 12464-1: 2013; TS EN 12464-1.2011: 2012 standards apply here.
- Light bulbs that are mounted low and susceptible to contact should be guarded.
- If the risk of electrocution exists when changing light bulbs, switch the connected power source prior to changing the bulb.
- For proper disposal of fluorescent bulbs (universal waste), please call LS or create an inquiry by calling 9988.
- As an energy conservation measure, please remember to turn off your lights when you leave your lab.

4.5.2. Temperature

The temperature conditions are established within thermal comfort of the users, in accordance with TS EN 27243 standard.

4.5.3. Noise

Exposure to excessive noise can permanently damage your hearing. The Noise at Work Regulations (TS 2607 ISO 1999 standard, Turkish Standards Institution, (2005). TS 2607 (ISO 1999). Acoustics-Determination of occupational noise exposure and estimation of noise-induced hearing impairment, Turkey.) Require that assessment of noise levels must be made by LSS wherever there is a noisy environment. In any cases of excessive noise, steps must be taken to reduce this at source. If this is not practicable, then ear protection must be made available to users, who must wear it in any prescribed areas of high noise level.

4.6. EMERGENCY EYE WASH AND SHOWERS

All laboratories using hazardous chemicals, particularly corrosive chemicals, must have access to an eyewash and/or an emergency shower. Emergency eyewash and shower equipment must be readily accessible, free of obstructions and within immediate proximity to the hazard. The lid on the eyewash head must always be closed while not in use, to prevent dust particle accumulation.

This important piece of emergency equipment is periodically inspected by LS, please report a detected malfunction to LS immediately.

For more information please see Emergency Procedures section.

Eyewash station and emergency shower are displayed on the figure below (Figure 4.6):

Figure 4.6 Eyewash station and emergency shower
(Courtesy of Dekolab)

4.7. INSTRUMENTS

4.7.1. Centrifuges

Only trained users should operate centrifuges. They must be properly installed according to manufacturer recommendations. It is important that the load is balanced each time the centrifuge is used and that the lid is closed while the rotor is in motion. The disconnect switch must be working properly to shut off the equipment when the top is opened, and the manufacturer's instructions for safe operating speeds must be followed.

Take the following precautions when operating and inspecting centrifuge rotors:

- Balance the load each time the centrifuge is used and also pay extra attention for high-speed centrifuges (balance them in mg levels). The disconnect switch should automatically shut off the equipment when the top is opened.
- Do not overfill the centrifuge tubes (fill 1/3 only). Ensure that they are hung properly.
- Ensure that the lid is closed before starting the centrifuge.
- Do not overload a rotor beyond the rotor's maximum mass without reducing the rated rotor speed.
- Follow the manufacturer's instructions for safe operating speeds. Do not run a rotor beyond its maximum rated speed.
- Check O-rings and grease the seals routinely with vacuum grease.
- Do not use harsh detergents to clean the rotors, especially aluminum rotors. Use a mild detergent and rinse with deionized water, if possible.
- Follow the manufacturer's guidelines for when to retire a rotor.
- For flammable and/or hazardous materials, keep the centrifuge under negative pressure to a suitable exhaust system.
- Keep a usage and maintenance log.
- Always use the rotor specified by the manufacturer.
- Inspect the components of the centrifuge each time it is used.
- Look for signs of corrosion of the rotors. Metal fatigue will eventually cause any rotor to fail.
- Ensure that the coating on the rotor is not damaged.
- Check the cone area for cracks, because this area is highly stressed during rotation.
- Look for corrosion or cracks in the tube cavity.

4.7.2. Heating Devices and Thermal Safety

Most labs use at least one type of heating device, such as ovens, hot plates, heating mantles and tapes, oil baths, salt baths, sand baths, air baths, hot-tube furnaces, hot-air guns and microwave ovens. Steam-heated devices are generally preferred whenever temperatures of 100 °C or less are required because they do not present shock or spark risks and can be left unattended with assurance that their temperature will never exceed 100°C. Ensure the supply of water for steam generation is sufficient prior to leaving the reaction for any extended period of time.

When working with heating devices, consider the following general precautions:

- The actual heating element in any laboratory heating device should be enclosed in such a fashion as to prevent a laboratory user or any metallic conductor from accidentally touching the wire carrying the electric current.

- If a heating device becomes so worn or damaged that its heating element is exposed, repair the device before it is used again or discard the device.
- Use a variable autotransformer on a laboratory heating device to control the input voltage by supplying some fraction of the total line voltage, typically 220 V.
- Locate the external cases of all variable autotransformers where water and other chemicals cannot be spilled onto them and where they will not be exposed to flammable liquids or vapors.
- Fail-safe devices can prevent fires or explosions that may arise if the temperature of a reaction increases significantly because of a change in line voltage, the accidental loss of reaction solvent or loss of cooling. Some devices will turn off the electric power if the temperature of the heating device exceeds some preset limit or if the flow of cooling water through a condenser is stopped owing to the loss of water pressure or loosening of the water supply hose to a condenser.

Please see Personal Protective Equipment section for necessary thermal protection and Emergency Procedures for thermal burn kit description.

4.7.2.1. Ovens

Electrically heated ovens are commonly used in the laboratory to remove water or other solvents from chemical samples and to dry laboratory glassware.

Laboratory ovens are constructed such that their heating elements and their temperature controls are physically separated from their interior atmospheres.

Laboratory ovens rarely have a provision for preventing the discharge of the substances volatilized in them. Connecting the oven vent directly to an exhaust system can reduce the possibility of substances escaping into the lab or an explosive concentration developing within the oven.

- Do not use ovens to dry any chemical sample that might pose a hazard because of acute or chronic toxicity unless special precautions have been taken to ensure continuous venting of the atmosphere inside the oven.
- To avoid explosion, rinse glassware with distilled water after rinsing with organic solvents before drying it in an oven.
- Do not dry glassware containing organic compounds in an unvented oven.

Bimetallic strip thermometers are preferred for monitoring oven temperatures. Do not mount mercury thermometers through holes in the top of ovens so that the bulb hangs into the oven. If a mercury thermometer is broken in an oven of any type, turn off and close the oven immediately. Keep it closed until cool. Remove all mercury from the cold oven with the use of appropriate cleaning equipment and procedures in order to avoid mercury exposure.

4.7.2.2. Hot Plates

Laboratory hot plates are normally used for heating solutions to 100 °C or above when inherently safer steam baths cannot be used. Ensure any newly purchased hot plates are designed in a way that avoids electrical sparks. Older hot plates pose an electrical spark hazard arising from either the on-off switch located on the hot plate, the bimetallic thermostat used to regulate the temperature or both.

In addition to the spark hazard, old and corroded bimetallic thermostats in these devices can eventually fuse shut and deliver full, continuous current to a hot plate.

- Do not store volatile flammable materials near a hot plate.
- Limit use of older hot plates for flammable materials.
- Check for corrosion of thermostats. Corroded bimetallic thermostats can be repaired or reconfigured to avoid spark hazards. Contact LS/LSS for more information

4.7.2.3. Heating Mantles

Heating mantles are commonly used for heating round-bottomed flasks, reaction kettles and related reaction vessels. These mantles enclose a heating element in a series of layers of fiberglass cloth. As long as the fiberglass coating is not worn or broken, and as long as no water or other chemicals are spilled into the mantle, heating mantles pose no shock hazard.

Always use a heating mantle with a variable autotransformer to control the input voltage. Never plug them directly into a 220 V line.

Be careful not to exceed the input voltage recommended by the mantle manufacturer. Higher voltages will cause it to overheat, melt the fiberglass insulation and expose the bare heating element.

If the heating mantle has an outer metal case that provides physical protection against damage to the fiberglass, it is good practice to ground the outer metal case to protect against an electric shock if the heating element inside the mantle shorts against the metal case.

4.7.2.4. Oil, Salt and Sand Baths

Electrically heated oil baths are usually used to heat small or irregularly shaped vessels and to provide stable and accurate temperature. Saturated paraffin oil is suitable below 200 °C; silicon oil is stable until 300 °C. Molten salt baths, like hot oil baths, offer the advantages of good heat transfer, but have a higher operating range (e.g., 200 to 425 °C) and may have a high thermal stability (e.g., 540 °C). There are several precautions to take when working with these types of heating devices:

- When using oil, salt, or sand baths, water spill or any volatile substance contact to the baths result in splattering of hot material over wide area and serious injuries.
- Inappropriate applications or utilization of the bath could cause smoke generation or start fire from overheating of oil.
- Always measure environmental temperature in oil baths by using a thermometer or other thermal sensing devices to ensure that flash point of the oil is below the flash point.
- Fit oil baths without temperature monitoring that will shut the electric power if the bath overheats.
- Mix oil baths well to ensure that there are no “hot spots” around the elements that take the surrounding oil to unacceptable temperatures.
- Hold hot oil in a container that can withstand any accidental physical contact.
- Mount baths should be kept on a stable horizontal support such as a laboratory jack that can be raised or lowered without danger of the bath tipping over. Iron rings are not suitable supports for hot baths.
- Clamp equipment should be placed on suitable height above the hot bath. This precaution provide replacing the bath with cooling bath in case of overheating without any readjustment steps.
- Secondary container should be obtained in the event of a spill of hot oil.
- Heat-resistant gloves must be worn when handling a hot bath.
- The reaction container used in a molten salt bath must be able to withstand a very high heating rates and temperature above the melting point of salt.
- Hygroscopic nature of salt baths can cause hazardous splattering if the absorbed water vaporizes during heat-up. Salt baths should be kept away from moisture.

4.7.2.5. Hot Air Baths and Tube Furnaces

Hot air baths are used in the lab as heating devices. Nitrogen is preferred for reactions involving flammable materials. Electrically heated air baths are frequently used to heat small or irregularly shaped vessels. One drawback of the hot air bath is that they have a low heat capacity. As a result, these baths normally have to be heated to 100 ˚C or more above the target temperature. Tube furnaces are often used for high-temperature reactions under pressure. Consider the following when working with either apparatus:

- Ensure that the heating element is completely enclosed.
- For air baths constructed of glass, wrap the vessel with heat resistant tape to contain the glass if it should break.
- Sand baths are generally preferable to air baths.
- For tube furnaces, carefully select glassware and metal tubes and joints to ensure they are able to withstand the pressure.
- Follow safe practices outlined for both Electrical Safety and Pressure and Vacuum Systems sections.

4.7.2.6. Heat Guns

Laboratory heat guns are constructed with a motor-driven fan that blows air over an electrically heated filament. They are frequently used to dry glassware or to heat the upper parts of a distillation apparatus during distillation of high-boiling materials and to develop thin-layer chromatography (TLC) plates.

The following hazards may occur:

- The heating element in a heat gun typically becomes extremely hot during use; however, the lack of a visible flame can create a false sense of security or false impression of safety and while the danger zone is invisible, it is very active. The combination of sparks and forced ventilation over a glowing filament may lead to fire and/or explosion.
- Heat guns operate at lower air speeds and produce temperature as high as 650 ˚C, hot enough to melt some types of glass.

- The power switches and fan motors are not usually spark-free and can pose a serious ignition hazard.

Several rules and tips for using heat gun are given below:

- Heat gun should be away from any combustible or flammable materials including open containers of flammable liquids, flammable vapors or hoods used to control flammable vapors/atmospheres.
- Heat flow direction should be checked.
- Before you put the heat gun on any surface, the heat gun must switched off.
- Heat gun must be unplugged when not in use, especially if the lab is unoccupied.
- There must be at least one centimetre distance between working distance and outlet of the heat gun.
- Heat should cool down before the storage.
- Try not to touch any metal surfaces on heat gun with skin or fabric.
- Heat flow direction must not be directed to any one's body.
- Do not look down the nozzle while the gun is operational.
- Nozzle of the gun should not tampered with anything.
- Never block the inlet grill or obstruct the air flow of the unit while in operation.
- Extension cords are prohibited to power a heat gun. High current equipment can pose risk of overheating and electrocution.
- All samples must be hold with forceps while heat gun is functioning.

4.7.2.7. Microwave Ovens

Microwave heating presents several potential hazards not commonly encountered with other heating methods: extremely rapid temperature and pressure rise, liquid superheating, arcing, and microwave leakage. Microwave ovens designed for the laboratory have built-in safety features and operation procedures to mitigate or eliminate these hazards. Microwave ovens used in the laboratory may pose several different types of hazards.

As with most electrical apparatus, there is the risk of generating sparks that can ignite flammable vapors.

- Metals placed inside the microwave oven may produce an arc that can ignite flammable materials.
- Materials placed inside the oven may overheat and ignite.
- Sealed containers, even if loosely sealed, can build pressure upon expansion during heating, creating a risk of container rupture.

To minimize the risk of these hazards:

- Never operate microwave ovens with doors open in order to avoid exposure to microwaves.
- Do not place wires and other objects between the sealing surface and the door on the front of the oven. The sealing surfaces must be kept absolutely clean.
- Never use a microwave oven for both laboratory use and food preparation.
- Electrically ground the microwave. If use of an extension cord is necessary, only a three-wire cord with a rating equal to or greater than that for the oven should be used.
- Do not use metal containers and metal-containing objects (e.g., stir bars) in the microwave. They can cause arcing.
- Do not heat sealed containers in the microwave oven. Even heating a container with a loosened cap or lid poses a significant risk since microwave ovens can heat material very quickly and containers can explode.
- Remove screw caps from containers being microwaved. If the sterility of the contents must be preserved, use cotton or foam plugs. Otherwise plug the container with kimwipes to reduce splash potential.
- Do not modify a microwave for experimental use.

4.7.3. Pressure and Vacuum Systems

Working with hazardous chemicals at high or low pressures requires planning and special precautions. Procedures should be implemented to protect against explosion or implosion through appropriate equipment selection and the use of safety shields. Care should be taken to select glass apparatus that can safely withstand designated pressure extremes.

High Pressure Vessels

- Only perform high-pressure processes in pressure vessels suitably designated for the process, properly categorized and installed, and protected by pressure-relief and required control equipment.
- Vessels must be withstand the stresses encountered at the intended working temperatures and pressures and must not corrode or otherwise react when in contact with the materials it contains.
- Provide essential high equipment to the systems designed for use at elevated temperatures with a positive temperature controller. Avoid using a manual temperature control, such as a Variac. Use a back-up temperature controller capable of shutting the system down.
- Working conditions of all pressure equipment determines the frequency of the inspection and assessment. Before each use, visual inspection should be performed.

Vacuum Apparatus

Vacuum work can result in an implosion and the possible hazards of flying glass, splattering chemicals and fire. All vacuum operations must be set up and operated with careful consideration of the potential risks. Equipment at reduced pressure is especially prone to rapid pressure. Such conditions can force liquids through an apparatus, sometimes with undesirable consequences.

- Use personal protective equipment, such as safety glasses or chemical goggles, face shields, and/or an explosion shield to protect against the hazards of vacuum procedures, and the procedure should be carried out inside a hood.
- Do not allow water, solvents and corrosive gases to be drawn into vacuum systems. Protect pumps with cold traps and vent their exhaust into an exhaust hood.
- Assemble vacuum apparatus in a manner that avoids strain, particularly to the neck of the flask.
- Avoid putting pressure on a vacuum line to prevent stopcocks from popping out or glass apparatus from exploding.
- Place vacuum apparatus in such a way that the possibility of being accidentally hit is minimized. If necessary, place transparent plastic around it to prevent injury from flying glass in case of an explosion.

Vacuum Trapping

A trap must be placed in between the vacuum device and experimental set-up. The vacuum trap increase the lifetime of the pump. In addition to this potential detrimental effects of the material piping through experimental set-up to laboratory environment could be and prevented.

Improper trapping also could cause contamination of the laboratory environment, exposure to maintenance staff during the routine inspections.

Proper Trapping Techniques

- Filtration and traps starting from experimental apparatus to the vacuum source could decrease contamination risk.
- Filtration for particulates is exact solution to trap the particles in generated size range.
- A filter flask at room temperature is sufficient for most aqueous or non-volatile liquids to prevent liquids from getting to the vacuum source.
- Cold trap is also appropriate for solvent and other volatile liquids and decreasing the trap temperature to condensation level is key to condense vapors generated. This step is followed by a filter flask capable of collecting fluid that could be aspirated out of the cold trap.
- Sorbent canister or a scrubbing device is suitable for highly reactive, corrosive or toxic gases.

4.7.3.1. *Cold Traps*

For most volatile liquids, a cold trap formulas such as using a slush of dry ice and either isopropanol (IPA) or ethanol is sufficient (to -78 °C) to condense most of the vapor. Acetone usage for trapping is prohibited. Ethanol and isopropanol are economical choices and less likely to foam.

Liquid nitrogen may only be a choice if the equipment is sealed or evacuated, and then only with extreme caution. If the system is unwrapped while the cooling bath is still in contact with trap, condensation of oxygen from the atmosphere intiate or trigger the reaction with organic compounds.

4.7.3.2. *Glass Vessels*

Although glass vessels are frequently used in pressure and vacuum systems, they can explode or implode violently, either spontaneously from stress failure or from an accidental blow.

- Pressure and vacuum processes in glass vessels should be performed behind adequate shielding.
- Glass vessel should be chosen depending on proposed process.
- Glass vessels should be inspected visually for star cracks, scratches or etching marks before each use. Crack formation and propagation is directly related with defects. Material failure risk increase and vessel could cause chemical leakage.
- Glass centrifuge tubes must be sealed with rubber stoppers clamped in place. Wrap the vessel with friction tape and shield with a metal screen. Alternatively, wrap with friction tape and surround the vessel with multiple layers of loose cloth, then clamp behind a safety shield.
- Glass tubes with high-pressure sealers should be filled by % 75 of its volume.
- Sealed bottles and tubes of flammable materials should be enclosed in cloth, placed behind a safety shield, and then cooled slowly, first with an ice bath, then with dry ice.
- Never rely on corks, rubber stoppers or plastic tubing as pressure-relief devices.
- Glass vacuum desiccators should be made of Pyrex or similar glass and wrapped partially with friction tape to guard against flying glass. Plastic dessicators are a good alternative to glass, but still require shielding.
- Never carry or move an evacuated dessicator.

4.7.3.3. Dewar Flasks

Dewar flasks are sealed under vacuum to provide better insulation. However; this equipment could easily collapse from thermal shock or slight mechanical shock.

- Shield flasks with friction tape or enclose in a wooden or metal container to reduce the risk of flying glass.
- Metal flasks are more durable if there is a significant possibility of breakage.
- Styrofoam buckets are temporary solution in case of lack of Dewar flask.

4.7.3.4. Rotary Evaporators

Rotary evaporators can fail under certain conditions. Since glass components of some evaporators could cause serious hazard. Glass made modules of the rotary evaporator should be made of Pyrex or similar glass. Glass vessels should be completely sealed off in a shield to protect against flying glass should the components collapse. Rotation speed and vacuum level of solvent containing flask must be gradually altered in evaporation process.

4.7.4. Stirring and Mixing Devices

The stirring and mixing equipment located in many laboratories include stirring motors, magnetic stirrers, shakers, small pumps for fluids and rotary evaporators for solvent removal. These devices are vital for routine laboratory processes and utilized in a hood. It is quite important that devices could generate electrical sparks.

Spark-free induction motors in power stirring and mixing devices or any other rotating equipment is exact solution for laboratory operations to avoid from electrical sparks. Most of the commercial devices meet this criteria, their on-off switches and rheostat-type speed controls can generate an electrical spark because they have exposed electrical conductors. Do not control speed of an induction motor operating under a load without a variable autotransformer. For more information see Electrical Safety.

The costs of stirrer breakdown, electrical overload or blockage of the motion of the stirring impeller should be taken in consideration due to long operation periods of especially stirring motors and magnetic stirrers without attention.

4.7.5. Refrigerators and Freezers

Refrigerators that are used as chemical storage must be labelled and dedicated for specific purposes. Vapor release from the content in the refrigerator, cross-contamination of the chemicals and spillage poses risk to lab personel and laboratory zone.

4.7.5.1. General Purpose

General laboratory refrigerators and freezers are domestic use units that are traditionally used to store food and beverages. While not usually suitable for a laboratory environment, they may be used for storing aqueous solutions. No flammable materials should be stored in these units.

4.7.5.2. Flammable

Flammable material refrigerators and freezers are designed for the storage of flammable solids and liquids. There is no internal switching or wiring that can arc, spark, or generate a source of ignition. The compressor and other circuits usually are located at the top of the unit to reduce the potential for ignition of flammable vapors. These refrigerators also incorporate features such as thresholds, self-closing doors, and magnetic door gaskets. Special inner shell materials limit damage should an exothermic reaction occur within the storage compartment. Be sure to observe flammable storage units, which should be listed on the label of the unit.

4.7.5.3. Explosion Proof

These units are designed to be operated in areas where the atmosphere outside of the unit could become explosive. Please contact LS/LSS if you feel the need for one of these units.

4.7.5.4. Food and Drink

The storage of food or drinks store in laboratory refrigerators containing reagents, samples, and any other research materials is absolutely forbidden.

Safe Handling and Operating Procedures

- Label all materials with the contents, owner, date of acquisition, and any associated hazards. Readily identifiable coding to a reference document (laboratory notebook, posted inventory, etc.) may be used.
- Follow all chemical compatibility storage guidelines (see ChemWatch).
- All materials must be properly capped and sealed. Avoid use of foil or parafilm as a primary method for sealing the container.
- Shelves must be compatible with the materials stored and secondary containment should be used when storing liquids.
- Remember that power outages will cause a rise in temperature within the unit. This may lead to energetic decomposition. Please keep this in mind and use emergency power outlets where available.
- Avoid using frost-free refrigerators and freezers.

References

- Cornell University EH&S. *Cornell University EH&S Laboratory Safety Manual and Chemical Hygiene Plan Engineering Controls* (2015, March). Retrieved from https://sp.ehs.cornell.edu/lab-research-safety/laboratory-safety-manual/Pages/ch2.aspx
- University of Bristol Health and Safety Office (July 2012). *University of Bristol Health and Safety Office Fume Cupboard Guidance* (2015, March). Retrieved from http://www.bristol.ac.uk/safety/media/gn/fume-cupboards-gn.pdf
- Jürgen Liebsch – Waldner Labor. EN 14175 – Requirements for Fume Cupboards (2015, March). Retrieved from http://www.strumelab.com/all-prodotti/LE CAPPE WALDNER EN-14175.pdf
- German Institute for Standardization (2012). *DIN Standards Committee Laboratory Devices and Installations*. (2015, March). Retrieved from http://www.fnla.din.de/sixcms_upload/media/2710/20_Liebsch - EN14175-7.pdf
- Schneider Elektronik. *Schneider Elektronik Standards and Guidelines Chapter 12* (2015, March). Retrieved from http://www.schneiderelektronik.com/download/LabPlanningManual_12_en.pdf
- Dekolab.com (2016). *DekoLAB* (2015, March). Retrieved from http://www.dekolab.com/
- The University of Chicago. *The University of Chicago Environmental Health and Safety Heat Guns – Safety Talk* (2015, March). Retrieved from https://safety.uchicago.edu/files/Heat Gun Safety.pdf
- TC Resmî Gazete. (17 July 2013). *İŞYERİ BİNA VE EKLENTİLERİNDE ALINACAK SAĞLIK VE GÜVENLİK ÖNLEMLERİNE İLİŞKİN YÖNETMELİK* (2015, March). Retrieved from http://www.resmigazete.gov.tr/eskiler/2013/07/20130717-2.htm
- TC Resmî Gazete. (28 July 2013). *ÇALIŞANLARIN GÜRÜLTÜ İLE İLGİLİ RİSKLERDEN KORUNMALARINA DAİR YÖNETMELİK* (2015, March). Retrieved from http://www.resmigazete.gov.tr/eskiler/2013/07/20130728-11.htm

5. ADMINISTRATIVE CONTROLS

Administrative controls include policies and procedures that help develop a safe laboratory work practices. It sets a standard of measures within a laboratory. These measures are taken to prevent accidents and hazards that do not involve engineering controls or PPE. All users working in the laboratories should adhere administrative regulations implemented by faculty. Along with LS, Responsible Faculty Member is in charge to make sure that lab users are aware of all possible hazards in a laboratory, including but not limited to chemical biological, physical, and electrical hazards. For further information, see the Safety Training section.

Faculty programs are in charge to develop regulations and guidelines to develop a safety system to protect lab users against several hazards arising from several sources such as hazardous chemicals and physical hazards.

Faculty programs are strongly encouraged to integrate the rules and regulations explained in this manual, besides meeting the regulatory requirements. This laboratory safety manual deals with minimum requirements to meet safe laboratory standard criteria. In addition to these regulations, faculty programs, Responsible Faculty Member and LS/LSS have the authority to implement more detailed policies.

5.1. ORIENTATION AND TRAINING

All newly arrived employees/students are obliged to go through mandatory orientation conducted by laboratory specialist (see laboratory specific orientation form, Appendix 5.1. upon assessment of training needs of the individual conducted by laboratory safety specialist and having successfully completed the training. Newcomers are required to contact the laboratory safety specialist and undergo orientation upon arrival in order to acquire access to laboratory facilities and become familiar with university policy. For more information please refer to Safety Training section of this handbook.

5.2. STANDARD OPERATING PROCEDURES (SOPs)

The Governmental Safety Regulation requires that the general practice include specific elements and measures to ensure users' protection in the laboratory. One of these measures is standard operating procedures (SOPs) "relevant to safety and health considerations to be followed when laboratory work involves the use of hazardous chemicals."

SOPs can be presented as stand-alone documents or as supplementary information to a research notebook or research proposals. SOPs ensure that a process is performed meeting required health and safety measures.

An SOP should involve the items listed below:

- The chemicals involved and their hazards.
- Special hazards and circumstances.
- Use of engineering controls (such as fume hoods).
- Required PPE.
- Spill response measures.
- Waste disposal procedures.
- Decontamination procedures.
- Description of how to perform the experiment or operation.

In addition to preparing SOPs for working with hazardous chemicals as a minimum requirement of laboratory standard, LSs are encouraged to develop additional SOPs regarding operation of each piece of equipment present in the laboratory that poses the hazards related to working with the equipment. Some examples to this include:

- *Safe use and considerations of lasers.*
- *Use of cryogenic liquids and fill procedures.*
- *Use of equipment with high voltage.*

An SOP does not need to be written as a long dissertation. It is advisable to refer other sources of information. Some examples of SOPs include:

"Please see page 16 in the operator’s manual that can be found in file cabinet”. “Please review the chemical and physical hazards by reading its SDS (see ChemWatch) before using this chemical. “ Appropriate personal protective equipment can be selected by reviewing lab safety handbook, personal protective equipment section.”

While developing SOPs, laboratories can ask LS and LSS to assist. It is the responsibility of each laboratory to prepare SOPs and to make sure that procedures presented in are adequate to protect lab users who use hazardous chemicals. Due to the complexity of research conducted in a laboratory, LS and LSS are not in charge to prepare SOPs, but help improve them.

Responsible Faculty Member and LS/LSS are responsible for making sure that prepared SOPs are in agreement with health and safety considerations and involve necessary information about hazardous chemicals. They are also responsible for making sure that PPE and engineering controls meet the criteria to prevent exposure. Moreover, Responsible Faculty Member and LS/LSS should ensure that lab users had the necessary training on SOPs prepared.

5.3. SAFETY SIGNS

All laboratories are equipped with a safety board on every entrance door indicating hazards within the laboratory, general rules and required personal protective equipment (Figure 5.1). Furthermore, specific hazard and emergency area locations are indicated by individual sign boards/labels within the laboratory. All users are obliged to follow the rules and precaution measures indicated on these signs.

Figure 5.1 Safety sign board

5.4. PROCEDURAL CONTROLS

Procedural controls are useful to establish best management practices in a laboratory. These practices are useful in maintaining health and safety measures. In addition, they help increase the productivity in the laboratory by increasing the efficient use of lab space and the reliability of experiments (since contamination risk is less). By raising the awareness of lab users about health and safety regulations, implementation of best management practices also result in a decrease in number of accidents, injuries and spills. In this way, the overall responsibility of LS/LSS and Responsible Faculty Member also decreases. In summary, following practices are key to impose a safe work behaviour and help spread a safety culture within the laboratory.

5.5. HOUSEKEEPING

Housekeeping practices add up to general condition and appearance of a laboratory. These include:

- Lab users should keep all areas of the lab free of trash, unused chemical containers, clutter and extraneous equipment. Lab areas include benches, hoods, refrigerators, cabinets, chemical storage cabinets, sinks, trash cans, etc.
- When not in use, containers of chemicals should be kept closed.
- All chemicals spills should be cleaned up as soon as possible. Additional splashes on the equipment, cabinets, doors, and benches around should also be checked while cleaning up the spill. Please refer to Chemical Spill section for more information on cleaning up spills.
- Areas around emergency exits, emergency equipment and devices should always be kept tidy. This rule also applies for eyewash/emergency showers, electric power panels, fire extinguishers, and spill cleanup supplies.
- As required, there should be a minimum 1-meter of space between benches and equipment. Emergency exits should be kept clear of any obstacles such as bottles, boxes, equipment, electric cords, etc. Never store combustible materials in exits, corridors or stairways.
- Heavy and bulky chemicals should be stored close to floor. The sprinkles should not be covered. There must be at least 45 cm distance between sprinkle and any item in the lab.
- Chairs and countertops are not intended to be used as stairs. Always use a stepladder to reach overhead items.

In summary, good housekeeping has obvious health and safety benefits and can have a positive mental effect on laboratory users who work in a clean environment, which can lead to increased productivity.

It should also be noted that, whether positive or negative, the first impression of the general condition of a lab has the most significant impact on a lab inspection test carried out by an agency.

Responsible Faculty Member and LS/LSS are responsible for maintaining a clean and healthy working environment and good housekeeping practices in the labs under their supervision.

5.6. PERSONAL HYGIENE

Some general guidelines that should always be followed include:

- Eating, drinking, chewing gum or applying cosmetics in a lab is not allowed.
- Food or drinks cannot be stored in lab refrigerators used to store chemicals.
- Pipetting by mouth is strictly forbidden. This may give rise to ingestion of chemicals or inhalation of their vapor. A suction bulb should be used for pipetting purposes.
- Hair should be tied all the time. Loose clothing is preferred and wearing jewellery is not allowed.
- Always wear a lab coat while working with chemicals.
- Do not wear shorts and sandals in the lab, particularly when someone is using corrosive chemicals. Exposure may result in skin corrosion and burns. Dropped pieces or broken glass may cause injuries.
- In case of a chemical contamination, lab coats, gloves and other PPE should immediately be removed. Further chemical exposure may propagate from this equipment.
- Once contaminated PPE was removed, affected area should vigorously be washed with water for at least 15 minutes.
- Before leaving the lab, lab coat, scrubs, gloves, and other PPE (gloves particularly) should be removed. PPE should not be worn outside lab area, particularly in the places where food and drink are served.
- Wash your hand after removing the gloves and before leaving the lab. Do not touch other items such as phone, turning door knobs or do not use elevator before washing your hands.
- Lab coats must not be cleaned at home. For lab coat cleaning, please contact LS.
- Smoking is prohibited in all lab areas.

Good chemical hygiene practices include the use of personal protective equipment (PPE) and good personal hygiene habits. Although PPE can offer a barrier of protection against chemicals and biological materials, good personal hygiene habits are essential to prevent chemical exposure, even when using PPE.

5.7. EATING, DRINKING AND APPLYING COSMETICS IN THE LAB

Food ingestion and chemically contaminated drinks are sources of chemical exposure. Bringing food or beverages or storing in chemical refrigerators or cabinets them causes such contamination. Storing food or beverages in chemical cabinets/refrigerators facilitate chemical absorption by vapor. Thus, chemical exposure takes place upon consuming food or beverages stored with chemicals. Therefore, eating or drinking in the lab is strictly forbidden.

Along with food and beverages, cosmetic products also have potential to absorb chemical vapor and dust. Applying cosmetics in the lab, including hand lotions, also enables chemical absorption and is another source of skin exposure, particularly in the areas where hazardous chemicals are stored.

To prevent exposure to hazardous chemicals through ingestion, do not eat, drink, chew gum, or apply cosmetics in areas where hazardous chemicals are used. Wash your hands thoroughly after using any chemicals or other laboratory materials, even if you were wearing gloves, and especially before eating or drinking.

It should be noted that, although several chemicals show acute effects of exposure, effect of certain chemicals might not be seen in a long term even though exposed repeatedly (chronic exposure). Chemical exposure both by food beverages and/or cosmetics may have short term and long term effects.

5.8. WORKING ALONE

Working alone is prohibited for research purposes, particularly involving hazardous chemicals and experimental procedures. Otherwise, LS or Responsible Faculty Member should prepare guidelines and standard operating procedures (see Standart Operating Procedures section) highlighting working alone principles, notifying procedures and instances when working alone is strictly forbidden. In cases where working alone is a must, LS/LSS or Responsible Faculty Member should approve the work and experimental setup. Whole procedure should be monitored by surveillance system.

It is strongly advisable to notify someone in the working area, in the next room or in the same floor. A “buddy system” may be established where buddy person performs routine checks on alone users periodically. This is to make sure that a safe experimental procedure is followed. Routine checks may be carried out either by physically or via a phone. A buddy should not be in the same room when the person working alone is carrying out a highly hazardous work. Visual check systems is another option to make sure that working alone is being performed safely or to determine if help is needed.

If an emergency event takes place that involves highly hazardous chemicals and buddy had to leave the lab before the end of experimental procedure, the buddy should notify security (7555). Notification includes name of the person working alone, location of the accident and the time of accident. In addition, buddy warns the person conducting the experiment involving hazardous chemicals so that the person can finish the experiment in the safest manner possible and inform security personnel on the latest condition of the experiment. It is strictly forbidden to use security personnel as a buddy. This will impair the safety of all the people involved.

Please note: For rooms that are locked due to security needs, prior arrangements are required to allow the designated buddy access. It is also important to understand that if the door to the lab does not have a window, or if the window is covered, then there is a chance that if something happened to a person working alone in a locked lab, then they may not be discovered until someone else from the lab goes into the room (which could be a day or more later).

Instances when working alone is permitted includes:

- Office work
- Housekeeping activities
- Assembly or modification of laboratory apparatus. Here, no chemical, electrical, or other physical hazards should be present.
- Routine lab functions as a part of a standard operating procedure.

Instances when a “buddy system” is needed includes:

- Toxic or otherwise hazardous chemicals included experiments
- Experiments involving high-pressure equipment
- Experiments involving large quantities of cryogenic materials
- Experiments involving work with unstable (explosives) materials

- Experiments involving Class 3 or 4 Lasers
- Transfer of large quantities of flammable materials, acids, bases, and other hazardous materials
- Changing out compressed gas cylinders containing hazardous materials

Setting up procedures and policies for working alone is LS's or Responsible Faculty Member's responsibility. Every lab user working under corresponding faculty member's supervision should follow these procedures and policies.

5.9. PHONES IN LABS

It is strongly advised to establish a communication tool in the lab in order to inform authorities in an emergency situation. This can be done by various means including a wired phone or a cellular phone (if available), or by a two-way radio. It is advised to post a sign highlighting the location of the nearest phone if there's no phone available in the lab.

5.10. UNATTENDED OPERATIONS

Safeguards should be set around an unattended operation in the lab. If it is unavoidable to perform an unattended operation, lab users are asked to stick to the guidelines explained below.

For unattended operations involving highly hazardous materials, a light should be left on and an appropriate warning/explanation sign should be placed on the laboratory door, or in a conspicuous place that could be easily seen without putting someone else in danger in the event of an emergency.

Warning signs for unattended operations should include information regarding:

- The nature of the experiment.
- The chemicals used.
- Potential hazards (electrical, heat, etc.)
- The name of the person conducting the experiment and a contact number. A secondary name and contact number is also recommended.

It is important to consider potential risks of hazard that may take place when leaving an experiment unattended. Some precautions that may be taken include:

- Using secondary containments to prevent spills.
- Using safety shields and keeping the hood sash closed to contain chemicals and glass in case an explosion occurs.
- Removing idle chemicals or equipment or items that has the potential to react with the chemicals or other materials being used in the experiment.
- Using automatic shutoff devices to prevent accidents such as loss of cooling water shutoff, over-temperature shutoff, etc.
- Using emergency power outlets for those pieces of equipment that could be negatively affected in the event electric service or other city utilities are interrupted.

Setting up procedures and policies for unattended operations is LS's or Responsible Faculty Member's responsibility. Every lab user working under corresponding faculty member's supervision should follow these procedures and policies.

5.11. ACCESS TO LABORATORIES

Access to SU laboratories, workshops and other work areas housing hazardous materials or machinery is restricted to SU Faculty, staff, students, or other people on official business.

Necessary training is mandatory prior to laboratory access for all users. Access to laboratories is either through SU ID card or key system. Card activation is done for any particular laboratory through contact with LS. For all students, Responsible Faculty Member approval is required, apart from mandatory training. Laboratory keys can also be obtained from LS.

Visitors And Children In Labs

Non-lab members, particularly children under age of 16 are not allowed to access laboratories or other hazardous work places. Some exceptions to this rule are tours, open houses or university related business. LS and/or Responsible Faculty Member should authorize these instances. All children under age of 16 should be under supervision during lab visits.

Visiting Scientists And Other Similar Users

Some potential risks associated with visiting scientists and their usage of lab area and equipment includes: conflict of interest and intellectual property rights, physical injuries, and unwitting damage of property. Our faculty provides health and safety trainings to all lab users including visiting scientist prior to giving lab access to labs or equipment. Visiting scientists are asked to attend these trainings so that LS will provide lab/equipment access.

In case of a potential physical or health hazard incident, program chairperson, Responsible Faculty Member and LS are responsible of restriction of access of visitors or children to lab areas.

Pets in Labs

Pets are prohibited in laboratory facilities.

5.12. CHEMICAL PURCHASING

The chemical inventory should be searched and existing chemicals should be used prior to ordering any chemical. SU has an institutional subscription to the ChemWatch chemical inventory system that can help facilitate maintaining a chemical inventory. Everybody in the laboratory is obliged to attend ChemWatch Training and use it.

All purchased chemicals, with detailed specifications, amounts and placed location, must be reported to LS immediately upon arrival, so that they are registered to ChemWatch.

Chemicals should be ordered in the smallest size possible that is necessary to carry out the experimental procedure. “Might be needed in the future” is an incorrect approach to order chemicals. Lab users should only order the amount they need.

There are several chemicals that require special approval to order. For those chemicals, please contact LS/LSS for further details. Note that building may restrict the amount of certain chemicals that can be stored in any room of the building. Further information can be obtained from ChemWatch.

5.13. ORDERING NEW EQUIPMENT

Lab users should communicate with LS/LSS and Operational and Technical Services upon purchasing and installing large equipment, particularly those using faculty’s electric, water or gas services. It has to be made sure that faculty has sufficient sources to support this new piece of equipment. It should be noted faculty is not obliged to provide necessary infrastructure to install new purchased equipment. Lab users should communicate in advance with appropriate university units (such as Operational and Technical Services and LS/LSS) to determine and provide additional resources and potential issues so that building’s infrastructure is made ready for installation.

An example to this situation is the installation of fume hoods. As certain pieces of equipment such as fume hoods require special installation conditions and directly effects building ventilation system, lab users cannot decide alone and install these type of equipment with a third party contractor. They have to consult Operational and Technical Services and LS and LSS. Being proactive and consulting corresponding university units in advance is strongly encouraged.

5.14. WORK ORDERS AND TICKET REQUESTS

For an equipment maintenance or repair lab users should consult Responsible Faculty Member or LS/LSS. These responsible people will take care of the paperwork with Operational and Technical Services and have the maintenance/repair process initiated. Faculty rules strictly forbid lab users repair utility services (electrical, plumbing, or gas issues) by themselves. Qualified personnel handle repairs only.

All chemicals, lab equipment and apparatus should be removed from hoods during maintenance or repair. Lab users must make sure that the work area is clean and free of hazardous chemicals. It is lab users’ responsibility to leave the hood safe for maintenance users and inform the users about potential hazards present around their working area.

5.15. CHANGES IN LAB OCCUPANCY

In case of a lab occupancy change situation such as retiring of a faculty, new coming faculty member, new coming LS, graduating student or facility renovation, the occupant should inform her/his successor about potential issues and hazards.

Failure to address the change in occupancy can result in:

- Old, unlabelled chemicals, samples, or hazardous waste being left behind in refrigerators, freezers, and cabinets.
- Valuable furniture or equipment being moved or thrown away.
- Unknown chemical spills or contamination being present.

These issues can result in costly remediation efforts and wasted resources for both the faculty and the university.

If you are planning to leave your laboratory or if you know of a research group or students that are planning to leave, there are a few simple steps that can be followed to ensure a smooth transition:

- Notify your LS and LSS well in advance of the planned move.
- Ensure all chemical containers are properly labelled.
- Properly dispose of any hazardous and chemical waste left in the laboratory.
- Ensure all chemical spills and contamination has been cleaned up.
- The established checkout protocol (see Appendix 5.2.) is to be strictly followed by graduate students before leaving University Facilities.

5.16. LABORATORY DESIGN AND CONSTRUCTION

Taking health and safety considerations is the key to provide best service during construction/renovation process. These measures should be taken in advance during the design process prior to construction process. Following information need to be given to LS and LSS before starting a new lab construction:

- Contact name, phone number, email
- Program, building and room(s) the project will occur in
- Expected start date for project
- The proposed equipment to be installed - fume hoods, biosafety cabinet, other capture devices, eyewash and emergency shower, toxic gas cabinet and monitoring devices, etc.

NOTE: A list of chemicals, including approximate usage (weekly/monthly) and storage quantities will be needed during the process to ensure proper ventilation rates and engineering controls.

5.17. VENTILATION RATES

Ventilation rates of the labs are determined with respect to number of people occupying the lab and type of research conducted. This is done as a measure of energy conservation. Lab users should notify LS and LSS if a new researcher comes to lab and function of the room changes, so that LS and LSS will check the ventilation rate.

A properly operating fume hood creates negative pressure in the lab. It removes more air from the room than is being supplied. On the contrary, a positive pressure is where more air being supplied to the room than is being removed. When this takes place, dirty air in the laboratory, which includes chemical vapor and dust, is blown outside of the lab into the halls. This can result in chemical odors permeating the hallways and surrounding rooms and may also negatively effect fume hood performance. Lab users should routinely check the air pressure of the lab and compare it to the hallway.

Laboratory users can perform a quick check of the air pressure in their labs by using modified version of the dry ice test procedure (see Appendix 4.1). If you discover your lab to be under positive air pressure, then please contact LSS for assistance.

5.18. ENERGY CONSERVATION IN LABORATORIES

Laboratories consume a lot of energy. The amount of energy consumed in a lab facility is much more than the energy use of an average non-lab academic building. This is mainly because there are multitude of heated and cooled, one-pass air for ventilation and fume hoods; electrically operated fans, specialized lab equipment; and large quantities of water and process-chilled water. In addition, some laboratories use large quantities of natural gas.

Technological advances in facility design resulted in considerable amount of energy savings in new constructed lab facilities. An example to this is computer controlled lab buildings. On the other hand, these energy saving initiatives are meaningful only when people in the lab help improve the energy conservation efforts.

Some of the very easy actions that may be taken to help reduce the energy consumption in the laboratory include:

- Turn off the lights when you leave the lab during the day or at the end of every day. Putting a setback (turn off themselves after a few minutes) is an efficient alternative to this.
- Before leaving the lab, make sure that you turned off all electrical devices if they're idle.
- Use timers to turn other pieces of equipment on and off automatically.
- Turn off your computer's monitor when not in use. The monitor consumes over half of the energy used by the average computer. Turning your computer's energy saving features on is an alternative to that.
- Keep the sash closed on your fume hood, especially if you have a Variable Air Volume (VAV) type fume hood. This promotes both energy conservation and safety. Keeping your VAV hood sash closed can cut the air volume and cost by two thirds!
- Rooms that are too hot or too cool may be due to faulty thermostats or other controls that are malfunctioning or have drifted from set points, resulting in wasted energy as well as uncomfortable conditions for you. If you experience these problems, then contact LS or operational and technical services for assistance.
- Report drips of water from sink taps, chilled water connections or reverse osmosis (RO) faucets.

5.19. RESEARCH AREA INSPECTIONS

There is well-established laboratory health and safety standards to that regulate labs and other research areas. LSS conducts routine inspections in all research areas of the faculty to check if these regulations are applied.

Research areas are strongly encouraged to conduct their own self-inspections prior to LSS conducting an inspection of their research area to address any potential issues before the LSS inspection and to provide a training opportunity for researchers.

The main purpose of these inspections is to help Responsible Faculty Members and LS identify potential regulatory compliances or other problems that may affect lab users health and safety. This way, potential risks of health and safety hazards are also identified and unreasonable risks to both lab users and the rest of campus community are prevented. It is LSS' responsibility to schedule such inspections.

Inspection checklist followed by LSS is provided in Appendix 5.3.

Self-inspections

Self-inspection system helps create a safety culture within the lab. It is an important part of lab safety regulations. It provides several benefits including:

- Raising the level of awareness of laboratory users.
- Determining the level of compliance with state and federal regulations.
- Identifying and eliminating potential risks prior to an official inspection carried out by government officials.
- Enabling lab specific training by identifying potential risks. Train the other lab users on these risks.
- Serving as a regular health and safety check of laboratory facilities.
- Serving as an outlet for Faculty, staff, and student concerns.

A self-inspection is recommended in following periods:

- On a daily basis in terms of housekeeping
- On a weekly basis by walk-throughs or collective clean-ups
- The ideal period for self-inspection is once in a month. For monthly inspection, an inspection checklist may be used. It is also recommended to ask Responsible Faculty Member or other researchers to join your monthly self-inspection.
- LSS is required in self-inspections at least once per semester. LSS utilizes her/his own inspection checklist.

There are multitude of benefits of regular self-inspection in terms of lab user's health and safety. In addition to that, these inspections may also reduce legal liabilities since it is another chance to identify potential risks in the lab.

Inspections by Regulatory Agencies

These inspections can occur any time. In order to be prepared for official inspections, it is important to understand what regulations apply to laboratories. This handbook helps you to understand and apply these regulations in your laboratory. You can call LSS for any further information.

If inspector shows up in your work area unescorted, ask them to please wait and contact LSS immediately.

5.20. LABORATORY SECURITY

Laboratories need to take specific actions in order to provide security against theft of highly hazardous materials, valuable equipment, and to ensure compliance with government regulations. Each unit (programme and research group) is encouraged to review and develop procedures to ensure the security of all hazardous materials in their area of responsibility.

Each laboratory implements their own means of security, *i.e.* locking up controlled substances, syringes and needles, and radioactive materials. It is Responsible Faculty Member's responsibility to assess the risks of a chemical and take security measures accordingly. The main purpose here is to prevent theft of dangerous chemicals. The easiest way to increase the security is to make sure that lab door is locked when you leave the unattended.

The Responsible Faculty Member is advised to determine the precautions necessary for the particular laboratory, and the determined set of rules is to be followed by all users in this laboratory.

Security Guidelines

Security guidelines are to eliminate the risk of removal of any hazardous material from laboratory. These include:

- Note that, although they are related, laboratory security is different from laboratory safety. The main purpose of lab security is to protect hazardous chemicals.
- Access to the areas where hazardous chemicals are used and stored should be controlled and limited. Limitation may also include some off-hours or granting access only to lab users authorized by Responsible Faculty Member.
- Freezers, refrigerators, storage cabinets, and other containers of biological agents, hazardous chemicals and radioactive materials should always be kept locked.
- Hazardous materials should always be secured and never be left unattended. The most important precaution to this is to lock laboratory door when unattended.
- Note: If users work alone and use the buddy system with someone outside of the research group, allowing access for that individual will need to be addressed prior to the initiation of working alone.
- Be aware of who is in the laboratory at all times. Approach anyone who you don't recognize and appears to be wandering in laboratory areas and hallways and ask if you can help direct them.
- A log sheet system may be used to secure highly hazardous chemicals. A periodic inventory check of hazardous chemicals is strongly advised. Any missing chemical should be immediately reported to LSS.
- Follow new chemicals ordering procedure; be aware of what new chemicals will be brought to your lab area. Packages of potentially infectious materials are only opened in biological cabinets.
- Use emergency plan for reporting incidents. Be sure to include the lab's emergency contact information on located on or near your laboratory door.
- Be aware of the classes of security risks of hazardous chemicals. Laboratory users should be aware of the highly hazardous materials or other special materials of concern.

Pay special attention to the following:

- Common labs
- Unrestricted access to toxic chemicals
- Unlocked support rooms
- Toxic gas security

- Unsecured biological materials and waste
- Access to controlled substances
- Changes in chemical inventory
- Storeroom security
- Chemical waste collection areas
- Unusual activities

Many of the laboratory supply catalogs carry information and products such as various locks, lock boxes, and other security devices for chemical storage in laboratories. For more information, you can contact LS/LSS for assistance or consult with the Operational and Technical Services about security devices.

References

- University of Cornell, Laboratory Safety Manual and Chemical Hygiene Plan, Chapter 4, Administrative Controls (2015, March). Retrieved from https://sp.ehs.cornell.edu/lab-research-safety/laboratory-safety-manual/Pages/ch4.aspx

6. GLASSWARE SAFETY

Glassware is designed for a specific purpose. It ought to just be utilized for that reason. "Makeshift" device might be flimsy and could prompt mishaps and wounds.

While selecting glassware, decide the compatibility of the glass with the chemicals or procedure. Several chemicals react with glass or cause harm (etch) glass. On the off chance that your procedure includes temperature or pressure changes, make sure the glassware can withstand the progressions.

Volatile materials expand upon heating and result in explosion. An exothermic reaction takes place upon mixing sulfuric acid with water inside a barrel, bringing about the heat from the reaction to break the base of the vessel. Do not mix sulfuric acid inside a cylinder.

Hydrofluoric acid, hot phosphoric acid and strong hot alkalis attack and etch glassware. Do not use glass to carry out these processes.

6.1. INSPECTING GLASSWARE BEFORE USE

Before working with glassware, dependably review it for imperfections. In the event that defects are found, glass ought to be expelled from administration. Scratches in glass can develop to cracks with time. Discard imperfect glassware if repairing is impractical.

6.2. SAFE HANDLING AND STORAGE

Proper handling of glassware can reduce the risk of injury and accident.

- Never convey a flask by its neck. Never convey a beaker close by.
- Always carry glassware with two hands (support underneath with one hand).
- Appropriate gloves should be worn in case if there's a risk of breakage (e.g. embedding a glass bar), chemical contamination, or thermal hazard.
- When handling hot or cold glassware, always wear heat resistant gloves.
- Do not apply high pressure on glassware. Stabilize glassware by a clamp and platform to alleviate weight.
- Avoid over tightening and breakage while clamping the glassware. Use coated clamps to anticipate glass-to-metal contact.
- Neck clamps should not be utilized as primary support for vessels bigger than 500 mL.
- Ground-glass joints are made for a flawless fit and might stick infrequently.
- Never apply excess force on a joint free. It can bring the glass about to break.
- Lubricate surfaces using grease or use a Teflon sleeve.
- A heat gun can delicately release the joints.
- Never heat or cool glassware unless it is intended for those procedures.
- Round-bottom flasks are best for boiling fluids.
- Never set hot glass on a cold benchtop.

When storing glassware, remember to:

- Keep it away from shelf edges.
- Place glassware toward the back of benches or hoods. (Remember: Fume hoods and biosafety cabinets should not be used for storage.)
- Don't let instruments roll around in drawers (use drawer pads).

6.3. WORKING WITH GLASS RODS OR TUBING

Setting up apparatus can involve pushing glass tubes through a cork or stopper. Users sometimes require a glass Pasteur pipette to rubber tubing attached for aspiration. These types of procedures possess high risk of injury to your hands if the glass tube, rod, or pipette breaks.

Some highlights to remember when working with glass rods, tubes or pipettes:

- Make sure that the glassware shafts of different connected glass materials fit with each other.
- Do not apply excessive force on a glass to put it into a place.
- Gently twist the glass material into place.
- Always lubricate the connections. You can use water, soapy water, or glycerin as lubricant. Using oil or grease is not advised.
- Wear cut resistant gloves when possible.

6.4. VACUUM AND PRESSURE OPERATIONS

Some glassware and processes can possess extra safety risks. Therefore, make sure you have had the relevant training prior to working with these kinds of specialized equipments or processes.

Vacuum or pressure operations can damage glassware severely. In such applications, walls of the container must be strong enough to withstand the changes in pressure. If the container is not able to withstand, the container may be broken. For those applications, a round bottomed or thick-walled flask must be employed. Glassware designed for vacuum or pressure operations are able to withstand certain pressure limits. Do not use glassware under pressure that it is more than it was designed to withstand.

Glassware that has been through repairs or has visible defects, flaw or damage should not be employed for vacuum systems applications. They are prone to break through thermal shock. It is important to check the glassware for flaws or defects prior to use.

Protective measures must be taken when setting up a vacuum system include:

- Put all vacuum apparatus inside a fume hood or behind a blast shield (Remember to use the fume hood in the lowest possible sash level).
- If possible, use PVC coated glassware. If not, cover flasks, dewars, and desiccators with a tape or mesh.
- Always wear appropriate personal protective equipment (safety goggles, face shield, and gloves).

Heating and Cooling Glassware

To determine safe temperature range of use, check with the manufacturer of glassware. Some glassware is intended to be used in to certain high and low temperatures. Using this glassware outside of their safe ranges may cause damage or breakage.

- Always keep an eye on evaporation process. A vessel may easily crack during evaporation.
- Never place hot glassware on cold or wet surfaces since it may be broken due to rapid temperature change.
- Never heat etched, cracked, nicked or chipped glassware.
- Never heat thick-walled glassware (e.g. bottles and jars) over a direct flame. Do not heat glassware directly on electrical heating elements.
- Do not try looking into a vessel being heated as evaporating material can damage your eye/skin.
- Unless mentioned otherwise, glassware should be cooled down slowly to prevent breakage.
- Pay extra attention while taking glassware out of low-temperature freezers (-70 to -150 ˚C) to prevent cracking and/or thermal shock. As a safe method, put the glassware under cold running water until thawing takes place. Do not transfer from the freezer directly into warm water baths.
- Remember that the flame of a Bunsen burner should touch the glass only below the liquid level. A ceramic wire gauze may help diffuse the flame therefore provide a more even heat.
- Hot plates used to heat the glassware should always be larger than the bottom of the vessel. Never heat thick-walled glassware (e.g. jars, bottles, cylinders, and filter flasks) on hot plates.
- Make sure that only the necessary setting is activated when using a hot/stir plates (i.e. if you do not intend to heat, make sure the hot plate is turned off.

6.5. CLEANING AND DRYING GLASSWARE

Good lab practices require the use of clean glassware. Glass must be both physically and chemically clean; even sterile for many cases. Most of the glassware accidents take place during cleaning. Following are some important reminders to wash and dry glassware:

- Personal protective equipments, especially eye protection goggles and chemically resistant gloves should be worn during washing.
- After using, glassware should be washed as quickly as possible. As the glassware left unwashed longer, it takes long time to clean. If necessary, use harder cleaning apparatus and keep and leave glassware in soapy water.
- Do not overload sinks, dishwashers, or soaking bins.
- Keep glassware clear of the sides of the sink.
- Do not use worn out brushes as they may scratch the glass.
- In case if you need to use caustic for cleaning purposes, it is advised to ask help from an experienced lab user in the safe usage of caustic cleaning agents, especially prior to using aqua-regia, chromic acid or other reactive solutions.
- Leave glassware drying on towels, lined basket, or slip-resistant pads. Place glassware away from the edge of the bench. Large containers may be hung on pegs to dry.
- Pipettes and tips may be cleaned in a cylinder or tall jar of water with appropriate disinfectant (e.g. for biologically contaminated tips). To prevent tips from breakage, you may put a cotton pad or glass wool at the bottom.
- To remove any residue or loose particles, new glassware should be washed prior to use.

6.6. DISPOSAL AND SPILL CLEAN-UP

Spills and Broken Glass

Glass is fragile and breaks easily. Care should be taken to reduce the risks of health when a glass breaks.

- If something is falling, let it drop! Trying to catch it may result in glassware to be broken in your hand.
- While handling broken glass, wear cut-resistant gloves whenever possible. Disposal nitrile or latex gloves should never be worn. Glass will cut through those gloves.
- When cleaning broken glass, use mechanical means to pick up the pieces.
- Do not pick up broken glass with bare hand. Use tongs, tweezers, or forceps to collect broken glass pieces.

Disposal

Proper disposal of broken glass ensures safety of others. In case of dealing with contaminated broken glass:

- Collect broken glass in a rigid, puncture-resistant container (e.g. sharps container).
- Place biologically contaminated broken glass in a closed and sealed container and put in biohazardous waste box for disposal.
- Place chemically contaminated broken glass in a closed and sealed containers.
- Dispose uncontaminated broken glass of in a broken glass box or uncontaminated waste box.

For more information please see Waste Management section.

References

- University of Vermont, Safety in Laboratories, Identifying the Hazards: Safe Handling of Glassware. (2015, March). Retrieved from http://www.uvm.edu/safety/lab/safe-handling-of-glassware

7. BIOLOGICAL SAFETY

7.1. BIOLOGICAL SAFETY LEVELS

A biosafety level is the level of the biocontainment precautions required to isolate dangerous biological agents in an enclosed facility. The levels of containment range from the lowest biosafety level 1 to the highest at level 4. In the United States, the Centers for Disease Control and Prevention (CDC) have specified these levels. In the European Union, the same biosafety levels are defined in a directive. Sabanci University is following the same directive in accordance with Turkish biological safety regulation.

The term "containment" is used in describing safe methods for managing infectious materials in the laboratory environment where they are being handled or maintained. The purpose of containment is to reduce or eliminate exposure of laboratory users, other people, and the outside environment to potentially hazardous agents.

Biocontainment can be classified by the relative danger to the surrounding environment as biological safety levels (BSL). As of 2006, there are four safety levels. These are called BSL1 through BSL4.

7.1.1. Biosafety Level 1

This level is suitable for work involving well-characterized agents not known to consistently cause disease in healthy adult humans, and of minimal potential hazard to laboratory users and the environment (CDC, 1997). It includes several kinds of bacteria and viruses including canine hepatitis, Escherichia coli, varicella (chicken pox), as well as some cell cultures and non-infectious bacteria. At this level precautions against the biohazardous materials in question are minimal, most likely involving gloves and some sort of facial protection. The laboratory is not necessarily separated from the general traffic patterns in the building. Work is generally conducted on open benchtops using standard microbiological practices. Usually, contaminated materials are left in open (but separately indicated) rubbish receptacles. Decontamination procedures for this level are similar in most respects to modern precautions against everyday microorganisms (i.e., washing one's hands with anti-bacterial soap, washing all exposed surfaces of the lab with disinfectants, etc.). In a lab environment all materials used for cell and/or bacteria cultures are decontaminated via autoclave. Laboratory users have specific training in the procedures conducted in the laboratory and are supervised by a scientist with general training in microbiology or a related science.

7.1.2. Biosafety Level 2

This level is similar to Biosafety Level 1 and is suitable for work involving agents of moderate potential hazard to personnel and the environment. It includes various bacteria and viruses that cause only mild disease to humans, or are difficult to contract via aerosol in a lab setting, such as C. diff, hepatitis A, B, and C, influenza A, Lyme disease, dengue fever, Salmonella, mumps, Bacillus subtilis, measles, HIV, scrapie, MRSA, VRSA, etc. Genetically modified organisms have also been classified as level 2 organisms, even if they pose no direct threat to humans. This designation is used to limit the release of modified organisms into the environment. Approval by the FDA is required to release these organisms. An example is genetically modified food crops. BSL-2 differs from BSL-1 in that:

- Laboratory users have specific training in handling pathogenic agents and are directed by scientists with advanced training;
- Access to the laboratory is limited when work is being conducted;
- Extreme precautions are taken with contaminated sharp items; and
- Certain procedures in which infectious aerosols or splashes may be created are conducted in biological safety cabinets or other physical containment equipment.

7.1.3. Biosafety Level 3

This level is applicable to clinical, diagnostic, teaching, research, or production facilities in which work is done with indigenous or exotic agents which may cause serious or potentially lethal disease after inhalation. It includes various bacteria and viruses that can cause severe to fatal disease in humans, but for which vaccines or other treatment exist, such as Mycobacterium tuberculosis, Bacillus anthracis, West Nile virus, Venezuelan equine encephalitis virus, Eastern equine encephalitis virus, Hendra virus, SARS corona virus, Salmonella typhi, Coxiella burnetii, Rift Valley fever virus, Rickettsia rickettsia, and yellow fever virus.

Laboratory users have specific training in handling pathogenic and potentially lethal agents, and are supervised by competent scientists who are experienced in working with these agents. This is considered a neutral or warm zone.

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.

It is recognized, however, that some existing facilities may not have all the facility features recommended for Biosafety Level 3 (*i.e.*, double-door access zone and sealed penetrations). In this circumstance, an acceptable level of safety for the conduct of routine procedures, (e.g., diagnostic procedures involving the propagation of an agent for identification, typing, susceptibility testing, etc.), may be achieved in a biosafety level 2 facility, providing:

- The filtered exhaust air from the laboratory room is discharged to the outdoors,
- The ventilation to the laboratory is balanced to provide directional airflow into the room,
- Access to the laboratory is restricted when work is in progress, and
- The recommended standard microbiological practices, special practices, and safety equipment for biosafety level 3 are rigorously followed.

7.1.4. Biosafety Level 4

This level is required for work with dangerous and exotic agents that pose a high individual risk of aerosol-transmitted laboratory infections, agents which cause severe to fatal disease in humans for which vaccines or other treatments are not available, such as Bolivian and Argentine haemorrhagic fevers, Marburg virus, Ebola virus, Lassa fever, Crimean-Congo haemorrhagic fever, and other various haemorrhagic diseases. When dealing with biological hazards at this level, the use of a Hazmat suit and a self-contained oxygen supply is mandatory. The entrance and exit of a Level 4 biolab will contain multiple showers, a vacuum room, an ultraviolet light room, and other safety precautions designed to destroy all traces of the biohazard. Multiple airlocks are employed and are electronically secured to prevent both doors opening at the same time. All air and water service going to and coming from a biosafety level 4 lab will undergo similar decontamination procedures to eliminate the possibility of an accidental release.

Agents with a close or identical antigenic relationship to Biosafety Level 4 agents are handled at this level until sufficient data is obtained either to confirm continued work at this level, or to work with them at a lower level.

Laboratory users have specific and thorough training in handling extremely hazardous infectious agents and they understand the primary and secondary containment functions of the standard and special practices, the containment equipment, and the laboratory design characteristics. They are supervised by qualified scientists who are trained and experienced in working with these agents. Access to the laboratory is strictly controlled by the laboratory director.

The facility is either in a separate building or in a controlled area within a building, which is completely isolated from all other areas of the building. A specific facility operations manual is prepared or adopted. Building protocols for preventing contamination often use negatively pressurized facilities, which, if compromised, would severely inhibit the containment of an outbreak of aerosol pathogens.

Within work areas of the facility, all activities are confined to Class III biological safety cabinets, or Class II biological safety cabinets used with one-piece positive pressure personnel suits ventilated by a life support system. The Biosafety Level 4 laboratory has special engineering and design features to prevent microorganisms from being disseminated into the environment. The laboratory is kept at negative air pressure, so that air flows into the room if the barrier is penetrated or breached. Furthermore, an airlock is used during personnel entry and exit. Table 7.1. summarizes the biosafety levels.

Table 7.1 Biosafety levels

Biosafety Level	*1*	*2*	*3*	*4*
Infectious Agents	Unlikely to cause disease in healthy workers or animals Low individual and community risk	Can cause human or animal disease but unlikely to be a serious hazard Moderate individual risk, limited community risk Effective treatments available	Cause serious human or animal disease but not ordinarily spread by casual contact High individual risk, low community risk	Cause very serious human or animal disease, often untreatable and transmitted High individual risk, high community risk
Examples of infectious agents in this risk level		E. coli, California encephalitis viruses, many influenza viruses	Anthrax, Q fever, tuberculosis, Hantaviruses, human immuno-deficiency viruses	Ebola viruses, Herpes B virus (Monkey virus), foot and mouth disease
Facilities	Standard well-designed experimental animal and laboratory facilities	Level 1 plus: Separate laboratory, room surfaces impervious and readily cleaned, biohazard sign	Level 2 plus: Controlled access double door entry and body shower, air pressure must be negative at all times, no recirculation, HEPA filtration, backup power	Specialized, secure, completely self-contained unit with specialized ventilation, fully monitored; air lock entry and exit,
Safety Equipment	Handwashing facilities, laboratory coats	Level 1 plus: autoclave, HEPA filtered class I or II biological safety cabinet, personal protective equipment	Level 2 plus: Autoclave, HEPA filtered class II biological safety cabinet, personal protective equipment to include solid front laboratory clothing, head covers, dedicated footwear, and gloves, appropriate respiratory protection	Class III biological safety cabinets, positive pressure ventilated suits
Procedures	Basic safe laboratory practices	Use of personal protective equipment laboratory coat worn only in the laboratory, gloves, decontamination	Users fully trained, written protocols; showers, wastes disposed of as contaminated, use of biological safety cabinets, personal protective devices	Access only to certified staff, rigorous sterilization / decontamination procedures

Adopted from Canadian Council on Animal Care.

7.1.5. Risk Assessment

For typical laboratory operations, biosafety level classifications are convenient. Based on laboratory specific conditions, the Responsible Faculty Member or LS/LSS is in charge of implementing more (or less) strict practices. Risk assessment decisions count for the following:

- Pathogenicity - the ability of an organism to cause disease.
- Virulence - the severity of disease.
- Transmission route - parenteral, ingestion, mucous membrane exposure, or inhalation. Organisms such as M. tuberculosis require more strict control than organisms that are transmitted via direct contact, e.g., HBV.

- Agent stability - survival in environment or otherwise prolonged viability (spore formation).
- Infectious dose - the dose required to cause infection in humans or animals (ID 50 refers to the dose needed to infect 50 % of the exposed population).
- Antibiotic resistance.
- The use of recombinant DNA - any of the above risk factors and modifications should be taken into consideration.

All of the above factors are inherent to a particular microbe; external factors to be considered in a risk assessment include:

- Titer/volume of material used - titer may increase several orders of magnitude compared to levels in clinical samples, upon culturing.
- Availability of effective treatment or vaccine.
- Nature of activities - e.g., potential for splashes, volume used, skills and training level of the users.
- Health status of the lab user - such as immune status, pregnancy, vaccination status.

7.2. TISSUE CULTURES AND CELL LINES

Cell lines obtained from commercial sources may become contaminated with adventitious agents while used in the laboratory. The extent of screening varies among providers and while most test for bacteria, mycoplasma, and fungi, they do not routinely include testing for viruses other than those categorized as “Bloodborne Pathogens”.

Cell cultures known to contain an infectious agent or oncogenic virus should be manipulated at the Biosafety Level appropriate for the agent, usually BSL-2.

For activities with materials not known to contain infectious agents, the following hazard classification applies:

BSL-1 is appropriate for well-established lines of cells of sub-primate origin if they do not harbour a primate virus and are free of bacteria, fungi, and mycoplasma. However, working with these materials at BSL-2 is recommended because of the additional degree of protection from contamination provided by BSL-2 practices, particularly the use of a Biological Safety Cabinet.

BSL-2 is appropriate for activities with: all primate cell lines, even well established ones, all cells derived from primate lymphoid or tumor tissues; all primate tissue; all human clinical material; cultured cells new to the laboratory until proven contaminant-free; and, cells exposed to or transformed by a primate oncogenic virus.

These activities and the use of any cells purposely infected with or suspected of harbouring agents defined as bloodborne pathogens are covered by the Bloodborne Pathogens Standard (in accordance with CDC). Laboratories using human cell strains (non-transformed cells) propagated from primary explants must also comply with the Standard because they are considered “unfixed human tissue” which is covered by the regulation.

7.3. SAFETY DATA SHEETS FOR INFECTIOUS SUBSTANCES

Safety data sheets (SDS), for chemical products have been available to lab users for many years. However because many laboratory users, whether in research, public health, teaching, etc., are exposed to not only chemicals but infectious substances as well, there was a large gap in the readily available safety literature for lab members. These SDS are produced for personnel working in the life sciences as quick safety reference material relating to infectious micro-organisms. Sabanci University employs ChemWatch software for SDS reference documents generation.

The SDS are organized to contain health hazard information such as infectious dose, viability (including decontamination), medical information, laboratory hazard, recommended precautions, handling information and spill procedures. The intent of these documents is to provide a safety resource for laboratory users working with these infectious substances. Because these users are usually working in a scientific setting and are potentially exposed to much higher concentrations of these human pathogens than the general public, the terminology in these SDS is technical and detailed, containing information that is relevant specifically to the laboratory setting. It is hoped along with good laboratory practices, these SDS will help provide a safer, healthier environment for everyone working with infectious substances.

7.4. ENGINEERING CONTROLS AND LABORATORY EQUIPMENT

Engineering controls are devices and equipment that isolate the possible hazards and compensate for user errors. They function with a minimum of user input.

In addition to electrical and mechanical considerations, laboratory equipment may end up with hazards related to the materials used in them. Therefore, before using some equipment, training is required for operational aspects.

Be sure that manuals are readily accessible and when in doubt, contact a customer service representative. Do-it-yourself fixes are not only dangerous but may invalidate warranties. Responsible Faculty Member or LS/LSS are responsible for ensuring that new users are familiar with the safe operation of equipment.

There also may be specific requirements for moving sophisticated machinery in which case a customer service official should be contacted or the users' manual carefully reviewed.

The biosafety-relevant engineering controls and laboratory equipment are described as follows:

7.4.1. Biological Safety Cabinets (BSCs)

Biosafety cabinets are the essential engineering control for the minimization of exposure to potentially infectious materials. For protecting researchers and the environment from aerosolized microorganisms, BSCs consolidate directional air flow and high efficiency particulate air (HEPA) filters. To prevent the contaminants entering the laboratory, air enters the cabinet through the face (where the user sits) and the air released from the cabinet first passes through a HEPA filter, evacuating 99.97% of particles with an aerodynamic diameter of 0.3 microns; smaller or larger particles are removed with more prominent productivity. BSCs should be used for all open manipulation of organisms requiring BSL-3 containment and activities with a BSL-2 organism having potential for splashes or aerosol generation.

7.4.1.1. Class I BSC

Room air enters at face, circulates within the work space, and exits through the HEPA filter after passing through the rear plenum. These type of cabinets protect the user and the environment, but they do not protect research materials from environmental contamination.

7.4.1.2. Class II, type A1 BSC

Room air draws through the supply grille at the front of the work area and entering the rear plenum, passes through a fan. Portions of air stream pass through an exhaust filter or supply filter. Only HEPA-filtered air contacts the work area, providing protection from environmental contamination of research materials.

Please note that, Class I and Class II biosafety cabinets exhaust filtered air back into the laboratory. Gases or vapors, volatile, toxic chemicals are not captured by HEPA filters so they must not be used in these BSCs. Limited quantities of these materials may be used in Class II, type B cabinets, which discharge into building exhaust systems.

7.4.1.3. Class III BSC

Often referred to as "glove boxes", these are totally enclosed, gas-tight cabinets designed for work with the highest risk pathogens. Before being discharged through ventilation systems, exhaust from Class III cabinets is filtered.

Some laboratories have clean air benches which can be confused with BSCs because of their physical similarities. They are not safety devices and should never be used for handling infectious materials. Clean air benches draw air through a filter and direct a filtered airstream. They are designed for handling sterile materials or when a dust-free environment is needed.

7.4.1.4. Procedures for effective use of BSCs

Appropriate user protection and contamination prevention provided by a BSC is directly related to the activities of the operator.

Cabinets must be certified under the following conditions:

- Annually
- Following relocation (including within-room). BSC on castors may be moved carefully without subsequent recertification.
- Following HEPA filter change
- Following service that may have affected containment ability.

- Semi-annual certification is recommended when cabinets are used for work with airborne-transmitted organisms or other high risk agents, e.g. M. tuberculosis.
- If the airflow, indicated by magnehelic gauges fall out of an established range.

To maintain proper directional airflow, do not block the front air intake or the rear exhaust grille and minimize the amount of material kept inside the cabinet.

- HEPA filters may be harmed and the protective airflow pattern may be disrupted by heat from a Bunsen burner. The utilization of disposable immunizing supplies joined with the sterile climate of the BSC, should eliminate the need for heat decontamination throughout the procedure.
- There should be 10-15 cm working distance from the front of the cabinet. Working should be done over the tray and not over the grille. Rapid arm movements that can disrupt airflow should be avoided.
- In order to minimize arm movement in and out of the cabinet, all needed materials should be placed in BSC at the start of procedures and arranged so that 'dirty' items do not pass over 'clean' ones. Clean cultures (left) can be inoculated (center); contaminated pipettes can be discarded in the shallow pan and other contaminated materials
- Cabinet fan should be allowed to run 5 minutes prior to and at the completion of work and the interior should be wiped with 70% ethanol before and after work.
- BSCs should be located in low-traffic areas away from air supply grilles and doorways; drafts may disrupt protective air flow.
- Many BSCs are equipped with UV lights. UV lights should be turned off when the cabinet is in use and wiped with an alcohol-moistened cloth weekly; a dust covered bulb is ineffective. Bulbs must be disposed via hazardous waste protocol.
- When working in a BSC, the door should be closed, particularly if it is close to a laboratory door.
- Most BSCs have a removable work surface tray and front grille, and the space beneath it requires regular cleaning to avoid contamination problems. A schedule for regular removal of the work surface tray and disinfection of the space beneath with 10% bleach followed by 70% ethanol is recommended.

7.4.2. Vacuum Line HEPA Filters

Vacuum lines require periodic maintenance and it is crucial to ensure that exposures to research materials are prevented. All vacuum lines, both inside BSCs and on benchtops must be protected with a HEPA filter and a disinfectant-filled collection flask.

7.4.3. Sharps Containers and Safe Needle Devices

7.4.3.1. Sharps containers

Needles, razor and scalpel blades and similar items are discarded through Contaminated Waste procedure, and must be kept in sharps containers.

Improperly disposed sharp items or sharps that were left “lying around” may cause cuts; so a sharps container should be kept as close as possible to where these items are used, if possible within arm's reach.

- Glass items (pipettes, test tubes) should be substituted whenever possible by plastic ones. The use of sharp objects should be limited if there is an alternative way.
- Blunt needles, pipettes, or canulas should be used to aspirate fluids instead of hypodermic needles; and if possible plastic should be substituted for glass.
- Needle-locking units or units should be used only in which the needle is an integral part of the syringe.
- All needles should properly be disposed in a "sharps" container immediately after use.
- Unused needles should be disposed in sharps containers.
- Needles should never be recapped, sheared, broken, or bended under any circumstances. Air and bubbles should be expelled into a disinfectant-moistened pad.

7.4.3.2. Safe needle devices

Safe needle devices include 'needleless systems' and sharps which have automatic protection features. These devices eliminate the exposure to and minimize the risk of cuts. They are generally applicable to clinical settings but must be incorporated whenever there is the risk of exposure to materials containing recombinant DNA, human blood, body fluids, cells, unfixed tissue or any other material covered by Bloodborne Pathogens Standard.

7.4.4. Centrifuge Safety

Centrifuge accidents may release large volumes of infectious, aerosolized material.

- Rotor usage logs and decommission rotors as per manufacturers' recommendations must be corporated.
- Rotors, particularly the chambers must be inspected for corrosion and pitting.
- "Safety cups" or covers (gasketted containers into which tubes are placed during centrifugation) must be used. If a tube breaks, the material will be contained. These safety devices can be obtained from the manufacturer.
- If a safety cup is unavailable, the rotor cover or chamber lid must tightly be closed and an uncovered rotor may never be used.
- Tubes must be filled and rotors or safety cups inside a BSC must be loaded/unloaded for infectious materials or materials containing recombinant DNA.
- In case of a tube breakage during centrifugation:
  - Aerosols must be allowed to settle for 15 minutes before opening the chamber.
  - Personal protective equipment must be used as described in Spill Procedures.
  - A squeeze bottle must be used to carefully apply disinfectant solution to contaminated surface.
  - 20 minutes contact time must be allowed, buckets and rotors must be removed to nearest BSC, aspirate residual disinfectant must be aspirated, and all the surfaces must be wiped with clean water.
  - Debris must be placed in sharps containers or red bags.
  - Manufacturers' instruction must be followed for selection of disinfectants for use on rotors and buckets. These items are usually corrosion-sensitive.

7.4.5. Water Baths

In case of water bath contamination by organisms incubated in them or through amplification of water/airborne organisms, it is recommended to use iodine-based or phenolic disinfectants for intermediate temperature baths. It is also effective to use 1/1,000 diluted household bleach. However, it may corrode water bath components. Also placing a few pennies (copper) in the bath will inhibit microbial growth. Sodium azide must never be used; it is highly toxic, and may result in the formation of explosive metal azides. For the recommended disinfectant, the manufacturer should be consulted. Water baths should not be left overnight or when they will be unattended for an extended period of time.

7.4.6. Cryostats

Cryostat decontamination must be regularly done with a proper tuberculocidal hospital disinfectant (see in 7.5. Decontamination). Tissue sections and trimmings should be treated as highly infectious. Never clear debris from a blade with your hand; always use a proper brush or other mechanical means to prevent contact with the blade. When replacing blades use protective gloves and forceps or tongs to handle the blades. Pre-soak blades in a disinfectant solution before cleaning (removal of debris). This will decrease the population of viable microorganisms.

7.4.7. Mixers, Sonicators, and Blenders

Mixers, sonicators, and blenders are source of vast amount of aerosols. There are suitable models available to contain aerosols. Afore mentioned devices must be run within a BSC with a disinfectant-moistened towel placed over the top. Let the aerosols settle, then open the device. Avoid using glass bowls. Sonication can be securely accomplished by placing a firmly capped specimen tube in a beaker of water and putting the probe in the water, not in the tube.

7.4.8. Lyophilizers

A dry solid which is very easily dispersed is produced by lyophilizers. Fitting with a HEPA filter or venting to a BSC is advised when it used for drying suspensions of infectious substances. Lyophilized solids must be opened only in a BSC; put a disinfectant-moistened pad over the scored line, then open the ampoule. Hence, disinfect chamber area and any material collected in the vapor trap.

7.5. DECONTAMINATION

An activity that decreases the microbial load to a level deemed proper to avoid contamination or infection is decontamination. The suitability of a decontamination procedure depends on occasions. For example, surgical instruments must be sterile. However, this level of microbial disinfection is pointless for environmental areas, such as walls and floors.

The application of a chemical to living tissue to prevent infection refers as antisepsis. Example substances are iodine compounds and hand washing antimicrobial soaps.

7.5.1. Sterilization

Sterilization refers to the disinfection of all microbial life, including bacterial endospores.

7.5.2. Autoclaves

The most efficient and reliable method of sterilization in laboratory is offered by autoclaves. Critical process factors are exposure, temperature, time. Also ensuring that materials are packaged to allow the steam to penetrate throughout the load is another crucial parameter. Size of the load and the packing density of the chamber affects the sterilization time. Usual laboratory autoclaves function at 121 °C and 15 psi. All users must review the operating manual periodically. Instructions should be prominently posted. When removing processed material, heat resistant gloves and face protection must be used. Slowly crack the door and wait a few minutes before fully opening it.

For dry loads, addition of 250-500 mL of water to the load pan in order to aid steam generation is necessary. Do not tightly cap bottles and test tubes. Autoclave bags must be closed loosely to allow steam to penetrate.

Autoclave tape is not a fail-safe indicator of sterilization; it blackens after only brief exposure to a temperature of 121 °C.

Some autoclave tapes contain lead which makes it necessary to dispose of these tapes as Hazardous Waste. For properly eliminating this hazardous waste stream, laboratories must use lead-free autoclave tape.

7.5.3. Dry Heat

Dry heat is used for materials (some glassware, instruments, and anhydrous materials) that are sensitive to moisture or the corrosion it may cause. Consult the manufacturers of such items for recommendations for appropriate sterilization procedures. Dry heat requires higher temperatures and a longer exposure times than autoclaving. Dry heat for 2-4 hours at 160 °C is needed to sterilize a load requiring 30 minutes at 121 °C in an autoclave. This method may also be validated by using spore vials; see Autoclave section (above).

7.5.4. Chemical Sterilization

Chemical sterilization is mainly used for heat-sensitive patient-care instruments which enter body cavities or normally sterile areas. This process necessitates prolonged contact times with relatively high concentrated solutions. As a result, prior to dilution, these toxic products must be treated as hazardous chemicals. Cautiously follow manufacturers' directions regarding dilution, contact time and personal protective equipment. Some sterilants require specific ventilation systems in order to remove hazardous gases and vapors.

7.5.5. Disinfection

Elimination of virtually all pathogenic microorganisms on inanimate objects with the exception of large numbers of bacterial endospores is called disinfection.

Disinfection should be established if hazardous organisms are destroyed. Microorganisms can be grouped according to decreasing resistance to disinfectants as follows: bacterial endospores (*B. subtilis, clostridium spp*); Mycobacteria; nonlipid or small viruses (poliovirus, rhinovirus); fungi; vegetative bacteria; and lipid or medium sized virus (herpes simplex, HIV, HBV).

Table 7.2. offers a framework for the selection of the proper disinfectant.

When using any disinfectant:

- Label instructions must be followed for dilution and time needed for desired level of disinfection must be contacted.

- Disinfectants that require pre-use dilution must be treated as hazardous chemicals while mixing.
- Wear a proper lab coat, the correct type of chemical-resistant glove, and fit goggles (not glasses).
- Clean contaminated surfaces that may have become contaminated at the end of the task.
- Choose the disinfectant with the lowest possible toxicity.

Considerations for selecting and using disinfectants:

- Rough surfaces require a longer contact time than smooth ones.
- Surface compatibility-bleach will corrode many metals, after use rinse it with water. Based on their composition, instruments vary in their ability to withstand disinfectants.
- Organic compounds will inactivate some disinfectants; a second treatment may be necessary once visible contamination (and hence, most organic debris) has been removed. The removal of visible 'soil' is the most critical factor in assuring effective decontamination.
- Resistance of microorganisms, e.g. bacterial endospore vs. vegetative bacteria.
- Number of microorganisms present, overnight culture vs. a recently inoculated one.

The Bloodborne Pathogens Standard requires that products labelled "tuberculocidal hospital disinfectant" be used on surfaces and equipment when the Standard is in force. Household bleach, usually at a 1/10 dilution, also satisfies this requirement and may be used in these cases. Bleach solutions lose potency over time and should be prepared fresh daily. Table 7.2 summarizes the disinfectant activities:

Table 7.2 Summary of disinfectant activities

Disinfectant	Disinfection Level	1*	2*	3*	4*	5*	Comments
Alcohols (ethyl and isopropyl) 60-85%	intermediate	+	+	-	+/-	+	Not sporicidal; evaporates quickly so that adequate contact time may not be achieved, high concentrations of organic matter diminish effectiveness; flammable.
Phenolics (0.4%-5%)	intermediate	+	+	+/-	+	+	Not sporicidal; phenol penetrates latex gloves; eye/skin irritant; remains active upon contact with organic soil; may leave residue.
Glutaraldehyde (2-5%)	High	+	+	+	+	+	Used to sterilize surgical instruments that cannot be autoclaved; strong odor; sensitizer; use with adequate ventilation. Not for use on environmental surfaces.
Quaternary Ammonium (0.5-1.5%)	Low	+	+	-	-	+/-	May be ineffective against Pseudomonas and other gram – bacteria; recommendation limited to environmental sanitation (floors, walls). Low odor, irritation.
Iodophors (30-1,000 ppm iodine)	intermediate	+	+	+	+/-	+/-	Inactivated by organic matter.
Chlorine (100-1,000 ppm)	intermediate	+	+	+	+/-	+	Not sporicidal; inactivated by organic matter; fresh solutions of hypochlorite should be prepared daily; corrosive; irritating to eyes and skin.

** 1. Bacteria; 2. Lipophilic Viruses; 3. Hydrophilic Viruses; 4. Mycobacterium Tuberculosis; 5. Fungi*
Adopted from Columbia University, Medical Center.

7.5.6. *Using Bleach as a Disinfectant*

As a strong oxidizing agent, the sodium hypochlorite in household bleach is an effective disinfectant for the known and potential infectious materials. However, as sodium hypochlorite breaks down into salt and water, it is recommended that the solution is made fresh daily. When bleach and water are mixed together, 1:10, to create a cleaning or disinfecting solution, the solution rapidly begins to lose needed disinfecting properties.

Bleach stock must be stored in an opaque plastic bottle at room temperature. Initial hypochlorite concentration is affected by the rate of degradation, the volume remaining and the ambient temperature. A good practice is to mark the bottle with the receive date, and replace bleach that was received more than 6 months prior. Colorimetric test strips for hypochlorite concentration offers an useful monitoring means.

All bleach brands are not manufactured to the same potency. Depending on manufacturer, the potency of commercial bleach is between 3.25 and 6.15% hypochlorite.

Proper gloves must be worn while handling bleach, because it can be corrosive on some surfaces, including steel. Bleach residue on non-porous surfaces must be wiped off with 70% ethanol or water. As ammonia and bleach can react to produce a highly toxic product, bleach should not be used in conjunction with other household cleaning products that contain ammonia. Pre-filled spray bottles that contain a 1:10 mixture are appropriate for using in the lab. Aspiration of tissue culture media into a collection flask, under vacuum, is one of the most commonly performed laboratory procedures. SU Policy requires that such media may be decontaminated prior to disposal in the municipal sewer system (Waste Management). Following these instructions guaranties effective decontamination.

Bleach must be added before aspiration, and undiluted bleach must be added to fill 10% of the final volume of the collection flask. Bleach is an active decontaminant. Also, its strong oxidizing properties will turn the phenol red indicator in tissue culture media from pink to yellow/clear. Aspiration flasks containing pink liquid is a sign of insufficient bleach concentration. So they should be topped off with fresh bleach until a yellow/clear colour is obtained. The collection flasks must be emptied when they are 3/4 full.

7.6. GEL ROOM, DARK ROOM, RADIOISOTOPE ROOM AND COLD ROOM SAFETY

7.6.1. *Gel Room Safety*

Electrophoresis is a commonly used laboratory technique which uses electrical energy to separate molecules such as proteins or nucleic acids by their size, structure, and electrical charge. Electrophoresis work poses potential electrical, chemical and thermal safety hazards.

Electrophoresis equipment can pose significant electrical hazards in the laboratory. Typical electrophoresis units operating at 100 Volts can provide a lethal shock of 25 milliamps. Take the following precautions when working with electrophoresis equipment:

Power Supplies:

- Ensure all switches and indicators are in proper working condition and that power cords and leads are undamaged and properly insulated.
- Label equipment with the warning: “Danger Electrical Hazard.”
- Connect equipment to outlets with ground fault circuit interrupters (GFCIs).
- Use power supplies with safety features that detect issues with the electrical circuit (e.g., no-load, overload, sudden load changes, short circuits, etc.).

Connecting Leads:

- Turn off main power supply before connecting or disconnecting electrical leads.
- With dry gloved hands, connect one lead at a time using one hand only.
- Be sure that leads/banana plugs are fully seated.

Using Equipment:

- Don’t run equipment unattended.
- Keep equipment clear of unintentional grounding points and conductors (e.g., sinks or other water sources, metal plates, jewellery, aluminium foil, pipes or other electrical/metal equipment).
- Gel chamber must have a lid or cover with safety interlocks to prevent accidental contact with energized electrodes or buffer solutions.
- Gel chamber exterior must be dry with no spilled solutions. Check the chamber for leaks.

- Switch off all power supplies and unplug the leads before opening the gel chamber lid or reaching inside the gel chamber. Do not rely on safety interlocks.

Users may be exposed to thermal hazards when heating agarose solutions.

Ultraviolet (UV) light boxes and handheld lamps are often used in visualizing ethidium bromide gels and pose potential exposures to UV radiation.

Hazardous chemicals commonly used in conjunction with electrophoresis work include:

- Ethidium bromide – mutagen, irritant
- Acrylamide – carcinogen, neurotoxin, irritant
- Phenol – corrosive, toxic
- Chloroform – suspect carcinogen, toxic

General Work Practice:

- Read and follow manufacturer's instructions for electrophoresis equipment.
- Instructions should include operating procedures written by the manufacturer and laboratory, as well as the associated hazards, the correct personal protective equipment (e.g., lab coats, gloves, and eye protection), and applicable emergency procedures.
- Use double gloves while working in the gel room, remove the contaminated gloves safely and dispose of before leaving the room.
- Locations where ethidium bromide is used or stored must be identified with "Mutagenic" marked stickers. Do not remove the hazard out of room.
- Only trained and qualified users are permitted to operate gel electrophoresis equipment. Responsible Faculty Member or LS are responsible for ensuring that all users are trained to use the equipment in a safe manner. Training should include special hazards and safety precautions.
- Measure, mix, and handle hazardous powdered chemicals or gel prep mixtures with hazardous components (e.g., acrylamide monomer, phenol, ammonium persulfate, and formaldehyde) in the fume hood.
- Purchase pre-made gels or pre-mixed acrylamide and ethidium bromide solutions instead of making your own.
- Consider using ethidium bromide substitutes.
- Exercise caution when using a microwave to melt agarose solutions; don't use sealed containers, and beware of superheated liquids that may suddenly and unexpectedly boil. Let hot agarose solutions cool to 50-60 °C before adding ethidium bromide or pouring into trays. Wear insulated gloves and point the flask opening away from you.
- During normal use, small spills may occur and residues may build up on equipment and other laboratory surfaces. A solution of soap and water is recommended for cleaning small spills and removing residues on equipment and laboratory surfaces. For more information see Emergency Procedures.

Ethidium Bromide waste in concentrated or solid form is collected as hazardous waste and should not be flushed down the drain or disposed of in the trash. Gels containing ethidium bromide can be easily de-stained in the laboratory by simply placing the gels in a DI-water bath for 15 minutes and gently agitating or 15 min treatment under UV light. This eliminates the need to collect the gels as a hazardous waste. For information on disposal of other hazardous materials please see Waste Management section.

7.6.2. Dark Room and Radioisotope Room

Radioactive labelling is conducted in SU and is restricted to Radioisotope room which is interconnected with the Dark room (Room FENS 2078). All potential hazards must be taken into account while conducting experiments in this facility and access is only granted upon corresponding training.

The following describes general guidelines associated with work in the facility, for further information please see Radiation Safety section.

7.6.2.1. Dark room

It is of high importance to keep the dark room clean at all times. All chemicals shall be stored and labelled appropriately. Secondary containers should be placed under all chemicals in storage.

The darkroom is a low light and even no light working environment. Be sure that:

- There are no obstacles left around that could be tripped over.
- Check the labels of the chemicals before turning off the main white lights.
- Make sure equipment that you need is at hand.

Use necessary PPE:

- Splash proof safety goggles and appropriate gloves are to be used at all times.
- Dispose of the contaminated gloves prior to leaving the work area.
- As in any chemical area, clothing in the darkroom should offer protection from splashes and spills. Clothing should be easily removable in case of accident.

Dispose of all chemicals through hazardous waste procedure. Take care of any spills immediately (see Emergency Procedures section)

Under no circumstance block the radioisotope room entrance.

7.6.2.2. Radioisotope room

Radioactive material at SU, is mainly used for biomedical research in the radioisotope room and in the Physics programme. Such research could be interrupted or stopped completely without the use of radioactive materials.

SU is devoted to ensure that the use of radioactive materials is carried out in a safe manner for employees, students, the public and the environment.

In Turkey, the possession and the use of radioactive materials is governed by the Radiation Safety Rules and Regulations administered by the Turkish Atomic Energy Agency (TAEK). SU holds a consolidated license covering the possession use, storage, import and export of radioactive materials, and a waste license covering the disposal of radioactive materials.

General Safety Practices

In the use of radioactive materials for teaching or research, consideration must also be given to other physical, chemical and biological hazards which may arise during the procedure. Care should be taken to ensure that the safety requirements necessary for radioisotope use do not compromise the safety requirements for the use of other hazardous agents.

Work Area Safety

- All radioisotopes must be kept locked. Only authorized people can work with them.
- Work must be limited to an area in laboratory with minimal traffic.
- All radioisotope usage areas must be labelled properly with radiation warning labels.
- Radioactive waste keeping should not be performed without adequate shielding and containment, since the users working in this area may be exposed to radiation.
- Disposable absorbent materials must be used to cover work area, and in the case of a spillage this area must immediately be evacuated.
- Radioisotope work areas must be obstacle free. For example, laboratory records and books should be kept away from possible contamination.
- If there is a possibility of volatilization of the radioactive material, working under fume hood is a necessity. A dry-box or transfer-hood must be used working with dusty radioactive materials. In addition, gloves, safety glasses and, if necessary, face masks or respirators, must be worn.
- Fume hoods must not be used for storage of materials which may disrupt the air flow.
- A radiation dosimeter (whole body) must be worn at all times according to specified radioisotope permit. Also wearing an extremity dosimeter (ring badge) in case of a specific radioisotope is a necessity.
- Within seven days of the usage of radioisotopes, monitoring and contamination control checks must be carried out.
- Eating, drinking, use of cosmetics or other material in contact with the skin is strictly forbidden in the laboratory. Food containers must not be stored in a radioisotope laboratory or in a refrigerator used to store radioisotopes.
- Before working with radioactive material, any wound in the skin should be properly protected by a waterproof covering.
- All equipment used during a radioisotope procedure must be labelled with appropriate radiation warning labels. If possible, this equipment must be kept separate from general laboratory area. If an item is decontaminated, remove the warning labels.

- Radioactive solutions must be labelled with radiation warning tape including relevant information such as the activity and its radioisotope. All containers contaminated with radioactive materials must be labelled, covered and stored properly.
- Designate proper glassware for radioisotope work. Wash them separately with a detergent explicitly designed for radioisotope work. Store these glassware in a separate marked area. Decontamination of these exposed glasswares must be done properly before being returned to general use.
- Use only one sink for cleaning of contaminated glassware and equipment. Label this sink with proper radiation warning signs.
- In order to prevent the spread of radioactive spills, cover it with absorbent materials. The spill area must be marked to warn others. In this case, initiate the decontamination of the area as soon as possible.
- Usually, equipment may be washed with a proper laboratory detergent. Use chelating agent or ultrasonic cleaning if necessary. Unsatisfactorily decontaminated equipment must be stored separately until the radiation has decayed sufficiently or it must be discarded as radioactive waste.
- To encourage laboratory users to remove contaminated clothing before leaving the laboratory, coat hooks must be installed near the exit door.
- Before starting maintenance in radioisotope laboratory, locally decontaminate the working area.
- All users must wash their hands after using radioisotope laboratory.

7.6.3. Cold Room Safety

The intention of cold rooms is to properly store certain agents and to conduct certain tests at a controlled temperature.

The supplied air in cold rooms is intended to prevent the buildup of carbon dioxide generated from users in the room as well as other contaminants that might be released in the room. Nevertheless, this small volume of supplied air creates moisture problems contributing to mold growth, especially when trace contaminants are present on surfaces.

A number of health and safety problems can occur in cold rooms. These problems range from inhalation exposure of mold, to unsafe use/storage of chemicals resulting in inhalation exposures, and storage of food and drinks in cold rooms resulting in potential ingestion exposures to molds.

To that extent, these guidelines are recommended to minimize mold growth, recommend correct chemical and biological use and storage, and list some activities that are prohibited. Users can experience inhalation exposures to mold and a buildup of carbon dioxide when they are in cold rooms.

Guidelines

Minimizing Potential Mold Growth

In many cold rooms various molds are available. A cold room contamination with mold can happen quickly if an improper procedure occurs. It results to potential health problems from breathing of the mold spores and contamination of used materials.

The storage of cellulose containing materials leads to mold growth. Also, mold growth can lead to contamination of research substances. Mold growth in cold rooms can be prevented by controlling condensation/moisture and removing materials. The following procedures can be considered:

- Clean up spilled liquids (e.g., buffers, media). Mold growth can initiate on an organic medium.
- Inform water leaks to LS/LSS.
- Keep door shut to prevent condensation. Left open doors can increase the relative humidity in the working area which supports mold growth.
- Damaged door gaskets can provide a cold surface resulting in condensation problems. Be aware of condensation on other sections as well. Sometimes condensation is an sign of decontamination. Inform LS for an assessment of the problem.
- Eliminate all wood. Wood can absorb moisture and, since it is composed of cellulose, it is a perfect ground for mold growth. Wood shelves must be replaced with stainless steel shelves that allow air flow throughout the storage area.
- Eliminate all products which contain cellulose, such as cardboard and paper. These surfaces act like wood and promote mold growth. If paper products are required, store them in an

enclosed plastic container between uses. If visible mold found on a paper product, throw away the item immediately.
- Keep surfaces clean. Do not use bleach on metal surfaces, because bleach on metal surfaces can result in pitting. Wet clean-up activities are recommended. For example, dusting, sweeping or brushing will spread mold into the air and can cause breathing exposures and spread potential contamination.
- If you need minor cleaning, use following wet clean up method. For example, dampen cloth with a non-ammoniated soap or detergent (do not combine ammonia and bleach; produced fumes are highly toxic).
- If mold reappears soon after cleaning, use any hospital approved disinfectant, drying surfaces after cleaning to ensure moisture has been removed.
- Users will be held responsible for cleaning mold growth if LS/LSS inspections note improper actions that could contribute to mold growth.

Proper Chemical Use and Storage

Cold rooms can recirculate the air contained within. Vapor of chemicals in the air can accumulate and pose a breathing exposure or an explosion hazard to laboratory users. Therefore:

- Flammable solvents can spread sufficient vapors to form an explosive atmosphere. Fans and electrical laboratory equipment in these rooms are potential ignition sources. Do not store large quantities (>1 liter) of flammable solvents in cold rooms. A standard refrigerator must never be used for the storage of flammable materials. Instead, use flammable storage refrigerators.
- Cold rooms have a contained atmosphere, some hazardous chemicals such as chloroform, formaldehyde which are not flammable may vaporize and cause exposures to users. All users should consider the risk when applying experiment procedures and evaluate those procedures where vapors are released in a chemical fume hood. Quantities need to be limited to less than 250 mL (note: chemicals such as chloroform vaporize very quickly. Such chemicals should NOT be placed in squeeze dispenser bottles.
- In cold rooms, prompt removal of the spilled materials is essential.

Prohibited activities

To provide the safety of all users, the following activities are forbidden in cold rooms:

- Storage of food and beverage: Storage of any beverages or food is explicitly prohibited.
- Usage of compressed gas: Gases released from incubators in a cold room can cause a lowering of the oxygen level, resulting in possible asphyxiation. Gases must be used outside of a cold room. In case of a gas usage in a cold room, an oxygen sensor which is equipped with a local alarm, must be installed in the cold room in order to warn other users if a low oxygen level occurs.
- Never store dry ice in a walk-in cooler. Dry ice can create an oxygen deficient atmosphere when it sublimes and releases gaseous carbon dioxide.
- A single individual may create problems affecting all users since most cold rooms are shared between multiple groups. If there is a problem, the Responsible Faculty Member or LS, and furthermore all users, must take the appropriate action to resolve the issue.

LS will notify users of cold rooms of improper use issues.

7.7. EMERGENCIES, EXPOSURES AND SPILLS

7.7.1. Emergency Types

There are three types of emergencies:

- Disasters due to fires, floods and earthquakes
- Biohazardous spills
- Spills which involve multiple hazards

General Emergency Procedures

- Alert others
- Confine the problem (if possible without undue risk)
- Turn off ignition sources
- Leave ventilation on
- Evacuate, if necessary
- Close doors
- Call from a secure area

- Give name, phone number, location, type of emergency
- Remain near phone to assist responders

For more information please see Emergency Procedures.

7.7.2. Exposures and Injuries

The procedures, activities, personnel attitudes, and equipment that create conditions favorable for occupational laboratory infections are similar to those that lead to the occurrence of industrial type accidents.

The extra ingredient is the presence of biohazardous agents capable of causing human infections.

Laboratory events that might create hazards, exposures, or accidents requiring reporting could be classified in two categories:

- Events occurring during work with biohazardous materials or in a biohazardous area that could result in physical injury, cuts, burns, abrasions, or fractures.
- Events occurring during the handling of biohazardous agents, infected specimens, or animals that could allow release of the agent to the environment or its undesired transfer to employees, animals or cultures.

In the first category the injury site could be contaminated with the biohazardous agent in use. In the second category illness or unwanted cross contamination could occur without physical injury.

Mechanisms of infection typical of the second category are ingestion of contaminated fluids, exposure to aerosols, and penetration of agents through the unbroken skin.

Therefore, for the purpose of controlling biohazards, all accidents, known exposures, and potential hazards must be identified and reported.

7.7.2.1. Skin and eye contact

By direct contact with the skin or eyes, chemicals can easily enter the body resulting a local reaction, such as a burn or rash, or absorption into the bloodstream. If there is an absorption into the bloodstream, the chemical may cause toxic effects on other parts of the body. The SDS usually includes information regarding if skin absorption is an important way of exposure.

Health of the skin and the properties of the chemical influence the chemical absorption through the skin. The resistance of a skin, which is dry or cracked, is low. Organic solvents can easily penetrate skin which changes the resistance of the skin to other materials.

Gloves and other protective clothing should be worn to reduce skin exposure. Skin exposure shows symptoms like dry, whitened skin, redness and swelling, rashes or blisters, and itching. If there is chemical contact on skin, the clothes should be removed and the affected area hould be rinsed with water. If symptoms continue, medical care should be taken.

If the eyes are exposed to chemicals, painful injury or loss of sight may be seen. Safety goggles or a face shield should always be worn to reduce the risk of eye contact. Eyes that have been in contact with chemicals should be rinsed immediately with Diphoterine or water continuously for at least 15 minutes and the contact lenses should be removed while rinsing. If symptoms continue, medical care should be taken.

7.7.2.2. Inhalation

Gases, vapors, particles, and aerosols (smoke, mists and and fumes) can easily penetrate into the respiratory system and may be transported into the lungs or be absorbed into the bloodstream. The vapor pressure of the material, solubility, particle size, its concentration in the inhaled air, and the chemical properties of the material influence the absorption of these materials into the respiratory system. If the vapor pressure is high, this means a substance can quickly evaporate into the air and the concentration in air can increase. Higher concentrations in air cause greater exposure in the lungs and greater absorption in the bloodstream. As most of the chemicals have an odor, there is no relationship between odor and toxicity. There is considerable individual variability in the perception of odor. The odor may seem to disappear as fatigue may occur when the lab user is exposed to high concentrations of chemicals; but the danger of over-exposure remains. Headaches, increased mucus production, and eye, nose and throat irritation are included in the symptoms of over-exposure. In addition, many solvents may induce narcotic effects, including confusion, dizziness, drowsiness, or collapse. containers should be closed and the ventilation should be increased in the event of exposure. If symptoms continue, medical care should be taken.

To reduce the exposure capacity, volatile hazardous materials should be used in a well-ventilated area, rather a fume hood. Respirators should also be used in the case of inadequate ventilation and bad working fume hoods. The use of a respirator is subject to prior review by LS/LSS according to SU Policy. See Personal Protective Equipment for more information.

7.7.2.3. *Ingestion*

Toxic substances can also penetrate from the gastrointestinal tract. Chemicals direct ingestion may not be possible, but the lab user may be exposed to the chemicals by ingesting contaminated food or beverages, touching the mouth with contaminated fingers, or swallowing inhaled particles. Therefore, to reduce the possibility of this kind of exposure, users should not eat, drink, smoke or store food in the working area and hands should always be washed after working with chemicals, even when gloves were worn.

In the event of accidental ingestion, immediately go to Health Center or contact LSS for instructions. Do not vomit unless directed to do so by a health care provider.

7.7.2.4. *Injection*

Injection is the final possible way of exposure to chemicals. Syringe needles, handling animals, or accidents with pipettes, broken glassware or other sharp objects that have been contaminated with toxic substances may cause injection. Direct access to the bloodstream, thus, to internal organ systems is provided by injection.

In the incident of injection, the area should be washed with soap and water and if possible, Health Center should be called from 7666. Cautious use of any sharp object is always important. For supplying protection from the injection, cannulas should be substituted for syringes and gloves should be worn.

7.7.3. *Spills of Biological Material*

The consequences of any spill of biological material can be minimized by performing all work on plastic-backed absorbent liner to absorb spills.

A well designed spill kit is highly recommended. It can save injury, time, and resources. For a Biohazard Spill Kit, the following items are highly necessary:

- A chemical decontaminant; generally a 10% household bleach solution is appropriate, the following fact should be kept in mind: Bleach will corrode stainless steel if left in contact with it for 30 minutes or more. For human blood and body fluids, iodophors or 70% alcohol is appropriate.
- Absorbant materials for liquids after decontamination; paper towels, absorbent lab pads, or special materials designed to absorb large volumes of liquid are appropriate.
- Appropriate personal protective equipment; gloves and a long-sleeved laboratory coat or gowns, also facial protection are necessary during the clean-up procedure. Additional personal protective equipment is necessary when working with Class 3 agents.
- A mechanical means for handling broken glass; tongs, forceps, small disposable scoops and sponges, autoclavable dust pans, or any other method that prevents direct contact with the broken glass are necessary.
- Biohazard bags, autoclavable bags sharps containers, and/or other containers to place the material in for further treatment and disposal.

7.7.3.1. *Bio safety level 1 organism spill*

Risk Group 1 infectious agents are biological agents that are unlikely to cause disease in healthy workers or animals (low individual and community risk).

- Wear disposable gloves.
- Soak paper towels in disinfectant and place over the spill.
- Place towels in a plastic bag for disposal.
- Clean up spill area with fresh towels soaked in disinfectant.

7.7.3.2. *Bio safety level 2 organism spill (moderate risk agents)*

Risk Group 2 infectious agents are pathogens that can cause human or animal disease but, under normal circumstances, are unlikely to be a serious hazard to laboratory users, the community, livestock, or the environment (moderate individual risk, limited community risk). Laboratory exposures rarely cause infection leading to serious disease; effective treatment and preventive measures are available and the risk of spread is limited.

- Alert people in the immediate area of the spill.
- Put on protective equipment. This may include a laboratory coat with long sleeves, back-fastening gown or jumpsuit, disposable gloves, disposable shoe covers, safety goggles, mask or full-face shield.
- Cover the spill with paper towels or other absorbent materials.
- Carefully pour a freshly prepared 1 to 10 dilution of household bleach around the edges of the spill and then into the spill. Avoid splashing.
- Allow a 20-minute contact period.
- After the spill has been absorbed, clean up the spill area with fresh towels soaked in disinfectant.
- Place towels in a plastic bag and decontaminate in an autoclave.

7.7.3.3. Bio safety level 3 organism spill

Risk Group 3 infectious agents are pathogens that usually cause serious human or animal disease, or which can result in serious economic consequences, but do not ordinarily spread by casual contact from one individual to another (high individual risk, low community risk), or that can be treated by antimicrobial or antiparasitic agents.

- Do not breathe; leave the room immediately and close the door.
- Notify others in the room to evacuate immediately, and assist others if necessary.
- Remove personal protective equipment in the airlock or access zone, turn potentially contaminated clothing outward, remove gloves last, and wash any exposed skin areas with antiseptic soap and warm water.
- Warn others not to enter the contaminated area. Place an appropriate sign on the door.
- Wait at least 30 minutes to allow dissipation of aerosols created by the spill.
- Put on a long sleeved gown, gloves, appropriate respirator, and rubber boots, if required, before re-entering the room.
- Cover the spilled area with paper towels or disinfectant soaked paper towels.
- Slowly pour appropriate decontaminant solution around the spill and allow to flow into the spill. Avoid splashing or the creation of aerosols during this step.
- Let stand at least 15 - 20 minutes to allow adequate contact time.
- Using an autoclavable dust pan and squeegee, transfer all contaminated materials (paper towels, glass, liquid, gloves, etc.) into a deep autoclave pan, and autoclave promptly.
- Repeat the decontamination procedures.
- The dust pan and squeegee should be placed in an autoclave bag and autoclaved as well.

7.7.3.4. Spill Involving human blood and body fluids

- Alert people in immediate area of spill.
- Any employee exposed to human blood and body fluids must cleanse the affected areas as soon as possible:
  Skin contact/cuts/puncture wounds: wash with soap and water, then pour 3% hydrogen peroxide over the cut/lesion or wash with either chlorhexidine or iodophor.
  Eyes: flush with water
  Mouth: rinse well with 3% hydrogen peroxide and then water.
- Inform the LS or Responsible Faculty Member in case of exposure.
- A properly trained employee must proceed with the cleanup and decontamination of the spill area.
- Put on protective equipment (full face shield or mask and safety glasses/goggles, latex gloves, lab coat).
- Pick out any sharps using tongs or other mechanical means and cover spill absorbent material such as paper towels.
- Carefully pour a freshly prepared 1/10 dilution of household bleach around the edges of the spill and then into the spill. Avoid splashing.
- Allow a 20 minute contact period.
- Use paper towels to wipe up the spill, working from the edges into the center.
- Clean spill area with fresh paper towels soaked in bleach solution.
- Place towels in a red bag for disposal.
- Remove protective equipment and wash hands thoroughly.

7.7.3.5. Spills within a biological safety cabinet

- Leave the ventilation on.
- All items within the cabinet should be disinfected (Walls and surfaces wiped down, equipment wiped down and/or autoclaved).
- Cover the spill area with paper towels or absorbent material.

- Soak the spill area with an appropriate disinfectant (i.e. 10% bleach). Pour the disinfectant from the outside surface of the absorbent material towards the inside.
- Leave on for 20 to 30 minutes.
- Pick up with absorbent material.
- All waste should be autoclaved.
- Ventilation should run for 10-15 minutes.
- If the spill overflows onto the interior of the BSC contact LS or the technical service as a more extensive decontamination may be required.

7.7.3.6. Spills inside a centrifuge

- Leave lid closed and allow aerosols to settle for at least 1 hour (ensure centrifuge is off).
- Notify others in the lab not to use the centrifuge (include signage) and inform the lab supervisor.
- If possible move the centrifuge or at least the rotors and buckets to a BSC.
- Disinfect the centrifuge or rotors and buckets in an appropriate disinfectant, allow at least 20 to 30 minutes of contact time.
- Carefully retrieve any broken glass from inside the centrifuge using forceps and place in a sharps container.
- Drain the disinfectant.
- Thoroughly wipe down the inside of centrifuge and all parts including the lid with paper towels soaked in disinfectant.
- Rinse both the rotors and the inside of the centrifuge with water if bleach was used.
- All waste should be autoclaved.

7.7.3.7. Spills outside of a biological cabinet, in a laboratory

Biological spills outside biological safety cabinets will generate aerosols that can be dispersed in the air throughout the laboratory. These spills are very serious if they involve microorganisms that require Biosafety Level (BSL) 3 containment, since most of these agents have the potential for transmitting disease by infectious aerosols.

- Notify others.
- If an aerosol is generated (or the risk exists), hold your breath and quickly leave the lab. Close the door and post a warning sign. Evacuate the area for at least 30 minutes to allow aerosols to settle.
- Remove any contaminated clothing. For more hazardous substances place the contaminated clothing in an appropriate bag for autoclaving.
- Thoroughly wash exposed skin with soap and water.
- Assemble cleaning supplies and PPE.
- Cover the spill area with paper towels or absorbent material.
- Using an appropriate concentrated disinfectant cover the spill area. Pour disinfectant from the outside, towards the inside of the spill.
- Pick up any broken glass with forceps and place in a sharps container.
- Cover with absorbent material. For more hazardous substances, allow the disinfectant to act for 20 minutes.
- All adjacent areas should also be disinfected or wiped down.
- All waste should be autoclaved.

7.7.3.8. Spills outside the laboratory (during transport)

If a biohazardous agent is spilled during transport outside the laboratory, the main difference from the first procedure is to initiate the clean-up immediately. Otherwise, use those procedures.

Because it would already be too late to prevent aerosolization in this case, it is better to place extra emphasis on prevention of spills during transport:

- Develop a procedure for the removal of biohazardous materials for incubation, refrigeration, or for any other reason from the laboratory, and enforce adherence to it.
- Place all such materials in an unbreakable container that would prevent the escape of liquid or aerosol if it were dropped. 2 – 4 liter paint pails are good examples of acceptable containers.
- Label the container with the biohazard symbol to ensure no mistake is made as to the contents
- Viable organisms should only leave the laboratory in a well-sealed primary (inner) and secondary (outer) container with a closable top. A test-tube rack inside a tray is not acceptable.
- The exterior of the secondary container should be wiped down with disinfectant prior to leaving the laboratory so that it can be transported without wearing gloves.

- Carry paper towels and if a spill occurs use the towels to cover the spill but do not attempt a clean-up without appropriate disinfectant and personal protective equipment.
- Notify people in the immediate area and collect clean-up material and proceed with clean-up.

7.8. PERSONAL PROTECTIVE EQUIPMENT

To reduce the exposure to potentially infectious materials, personal protective equipment (PPE) should be properly used. When engineering controls and work practices do not supply enough protection, PPE is to be considered as the “last line of defence”. Here, necessary biosafety PPE is summarized.

7.8.1. Gloves

Working with infectious materials requires wearing gloves. Due to the fact that users may be allergic to latex gloves, nitrile or vinyl gloves should be used instead of latex. Those who prefer latex should use only powder-free gloves.

Corrosives and organic solvents may penetrate gloves or reduce their protective ability; so different types of gloves should be stockpiled in the laboratory.

When using any glove:

- Check for visible tears and other defects.
- Remove rings and other jewellery if they are able to rip gloves.
- Change gloves regularly or as soon as possible if they are obviously contaminated.
- Wash hands immediately after removing gloves.
- Remove gloves when leaving the laboratory; even if they are "clean".

7.8.2. Eye Protection

Following should be done for providing eye protection.

- Safety glasses with side shields are necessary which provide minimum level of protection for handling any hazardous material.
- When doing activities with a small splash hazard or working with organisms transmissible through mucous membrane exposure, goggles are necessary, which fit firmly all around the eyes.
- Face shields should be used with goggles when there is an elevated risk of large quantity splashes or if the user is working with highly toxic, corrosive, or infectious materials. Face shields must also be used for protection against UV radiation (be sure that the face shield carries the manufacturer’s validation of UV protection) and when handling liquid nitrogen.

7.8.3. Lab Coats

Lab coats that are resistant to liquid penetration for activities with splash potential should be worn or a plasticized apron should be utilized. Lab coats must not be worn outside of the laboratory if they were used during work with infectious materials. For high risk activities, a rear-fastening lab coat should be worn. Provision, laundering, and replacement of lab coats is the responsibility of the LS; lab users should not wash contaminated lab coats at their home.

7.8.4. Surgical Masks

Masks will help prevent ingestion and protect the mucous membranes of the nose and mouth. They do not provide sufficient protection against infection from organisms transmitted by inhalation, e.g., M. tuberculosis.

7.8.5. Respirators

Respirators are used when there is the risk of airborne exposure to organisms transmitted by inhalation and containment devices are unavailable or unable to provide sufficient protection. Respirator use must be preceded by medical clearance and training.

7.9. TRANSPORTATION AND SHIPMENT OF BIOLOGICAL MATERIALS

The transportation and shipment of biological materials is subjected to strict regulatory controls. Individuals involved in the transportation and shipment of infectious substances must receive training on the applicable regulations and requirements before shipping such materials.

Biological materials transported by laboratory users within a laboratory or between buildings must be contained in such a way as to prevent release to the environment in case of an accident by following the procedure below:

- Biological samples must be placed in a primary container or vessel that is a securely closed, leak-proof (or O-ring) tube, vial or ampoule, which is then placed in an unbreakable, lidded, watertight, secondary container.
- If the outside of the primary container or vessel is suspected of being contaminated, decontaminate prior to placing in secondary container using 10% bleach solution or a disinfectant appropriate for the biological material in use.
- All biohazards must be labelled with the international biohazard symbol on the outside of the secondary container.
- When transporting liquids in glass vials/containers, place enough absorbent material, such as paper towels, in the space at the top, bottom, and sides between the primary and secondary containers to absorb the entire contents of the primary container(s) in case of breakage or leakage.
- The outside of the secondary container must be free of any biohazardous material so that the package can be carried safely between buildings without wearing gloves or lab coats outside.
- The package must be taken directly to its intended location.
- If a spill occurs during transport, do not attempt to clean it up without appropriate spill response material and PPE. Keep other people clear of the spill.

7.9.1. Packaging Unregulated Biological Materials

All biological materials must be packaged according to a triple packaging system. The three components of a triple packaging system are:

- Primary receptacle
- Leak-proof secondary container
- Rigid outer container

The primary receptacle holds the biological material and must be leak-proof, watertight. It is packed in the secondary container in such a way that, under normal conditions of transport, they will not break, be punctured, or leak their contents into the secondary container. If the primary receptacle is fragile, it must be individually wrapped or separated to prevent contact between multiple primary receptacles.

The secondary container is a durable, watertight, leak-proof container that encloses and protects the primary receptacle(s). Several cushioned primary receptacles may be placed in one secondary container. If the primary receptacle contains any liquid, the secondary container must contain enough absorbent material to absorb all of the fluid from the primary receptacle(s) in case of breakage.

The outer container is a rigid and durable container with one side that is at least 10 cm x 10 cm that houses the secondary container. The outer package should be properly marked and labelled. It should be able to withstand outside influences such as physical damage while in transit. An itemized list of package contents must be included between the outer and secondary container.

7.9.2. Shipping of Biological Materials

Biological materials are classified as infectious substances (including “biological substances, category B” and “patient specimens”), biological products, genetically modified organisms, or medical/clinical waste for the purposes of shipping. The shipment of certain genetically modified organisms is also regulated.

Infectious substances - Substances which are known or are reasonably expected to contain pathogens. Pathogens are defined as micro-organisms (including bacteria, viruses, rickettsiae, parasites, fungi) and other agents such as prions, which can cause disease in humans or animals. Infectious substances are separated into the following categories:

Category A - An infectious substance which is transported in a form that, when exposure occurs, is capable of causing permanent disability, life-threatening or fatal disease to humans or animals.

Infectious substances meeting these criteria which cause disease in humans or both in humans and animals must be assigned to UN2814. Those which cause disease in only animals must be assigned to UN2900.

Assignment to UN2814 or UN2900 must be based on the known medical history and symptoms of the source human or animal, endemic local conditions, or professional judgment concerning individual circumstances of the source human or animal.

The proper shipping name for UN2814 is Infectious Substance, affecting humans. The proper shipping name for UN2900 is Infectious Substance, affecting animals.

Infectious Substances (Category A) Shipping Requirements

- Triple layer packaging (materials used for transport must be tested to ensure sample won't leak)
- Absorbent material
- Itemized contents list
- Outer package must bear Class 6.2 Infectious Substance diamond label
- Additional labelling and marking requirements
- Shipper's Declaration required

Category B - An infectious substance which does not meet the criteria for inclusion in Category A. Infectious substances in Category B must be assigned to UN3373

When transported, infectious substances (both Category A & B) are classified as dangerous goods and must be shipped in accordance with international (IATA) regulations.

Infectious Substance, Category B Requirements

- Triple layer packaging
- Materials used for transport must be tested to ensure sample won't leak
- Outer package must bear UN3373 diamond label
- Outer package and air waybill must bear "Biological Substance, Category B" statement
- No Shipper's Declaration required; only airway bill

Patient Specimens - Exempt specimens are those collected directly from humans or animals, for which there is a minimal likelihood that pathogens are present. Professional judgment should be used to determine if a substance is exempt. Examples include blood or urine tests for cholesterol levels, blood glucose levels, hormone levels, or prostate specific antigens (PSA); tests required to monitor organ function such as heart, liver or kidney function for humans or animals with non-infectious diseases, or therapeutic drug monitoring; tests conducted for insurance or employment purposes and are intended to determine the presence of drugs or alcohol; pregnancy tests; biopsies to detect cancer; and antibody detection in humans or animals.

Biological products - products derived from living organisms that are known not to produce viruses, toxins, etc. and are manufactured and distributed in accordance with requirements of national government authorities. These include, but are not limited to, finished or unfinished products such as vaccines. Biological products are not currently regulated for the purposes of shipping.

Dry Ice - In addition to the classifications and rules for potentially infectious materials, shipment of solid carbon dioxide, or dry ice, is regulated as a dangerous good regardless of the hazard classification of any other materials in the package. Dry ice may cause burns, and if packaged improperly, can result in dangerously high pressure build-up inside of a sealed contained. For these reasons, there are specific training, labelling, and packaging requirements for shipments containing dry ice.

Infectious Substance Shipments with Dry Ice Requirements:

- Never place dry ice in a sealed container
- Outer package must be approved to hold dry ice, otherwise use an over pack
- UN 1845 Dry Ice label, including estimated weight of dry ice
- Class 9 Miscellaneous Dangerous Goods label

For specific information please see material SDS using ChemWatch.

References

- Cornell University Environmental Health & Safety, Biological Safety (2015, March). Retrieved from https://sp.ehs.cornell.edu/lab-research-safety/bios/Pages/default.aspx
- Stanford University Environmental Health & Safety Lab Safety Sheets (2015, March). Retrieved from

http://web.stanford.edu/dept/EHS/prod/researchlab/lab/lab_safety_sheets.html

- University of Nebraska Lincoln, Electrophoresis Safety (2015, March). Retrieved from http://ehs.unl.edu/sop/s-electrophoresis_safety.pdf
- University of Toronto Environmental Health & Safety (2015, March). Retrieved from http://ehs.utoronto.ca/our-services/radiation-safety/
- University of Waterloo Safety Office (2015, March). Retrieved from https://uwaterloo.ca/safety-office/programs-and-procedures/laboratory-safety/radiation
- University of Rochester Environmental Health & Safety Cold Room Guidelines (2015, March). Retrieved from https://www.safety.rochester.edu/ih/guidelines/coldrooms.html
- US Department of Health and Human Services (2009). *Biosafety in Microbiological and Biomedical Laboratories*. (5th ed.). United States of America: HHS Publication.
- European Agency for Safety and Health at Work, Directive 2000/54/EC – biological agents at work (2000). Retrieved from https://osha.europa.eu/en/legislation/directives/exposure-to-biological-agents/77
- Mevzuatı Geliştirme ve Yayın Genel Müdürlüğü Mevzuat Bilgi Sistemi, Biyolojik etkenlere maruziyet risklerinin önlenmesi hakkında yönetmelik (2015, March). Retrieved from http://www.mevzuat.gov.tr/Metin.Aspx?MevzuatKod=7.5.18485&MevzuatIliski=0&sourceXmlSearch=

8. CHEMICAL SAFETY

8.1. SAFETY DATA SHEET

Safety data sheet (SDS) contains important data about physical and chemical properties of a particular substance along with health and safety measures. It provides lab users and emergency personnel with procedures for safe handling and working with chemicals particularly on storage, disposal, necessary protective equipment, spill handling and include relevant information on physical data such as melting point, boiling point, flash point along with health measures including toxicity, health effects, first aid, reactivity. A safety data sheet may not always be the sole source in selecting appropriate safety precautions in the laboratory. Therefore, if you have questions about handling, or protecting yourself from, a particular chemical after you review the SDS, contact your supervisor or LS/LSS.

8.1.1. What is a Safety Data Sheet?

The globally harmonized system of classification and labelling of chemicals (GHS) is an international system created by the United Nations that defines and classifies the chemicals with respect to their hazards and puts labelling and classification standards to be consistent used internationally. As a part of GHS, SDS is a written document produced by the chemical manufacturer or importer that includes communication of the hazards and precautionary information including:

- Identification of substance/mixture and company/distributor
- Identification of hazard
- Information on composition/ingredients
- First aid measures
- Fire-fighting measures
- Accidental release measures
- Storage and handling
- Exposure controls/ personal protection
- Physical and chemical properties
- Stability and reactivity
- Toxicological information
- Ecological information
- Disposal information
- Transport information
- Regulatory information
- Others

8.1.2. Which Substances Do Not Require an SDS?

Following items or chemicals does not require SDS:

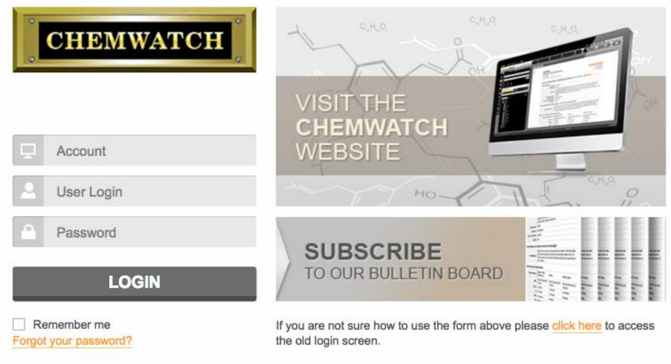
- Chemicals that are not considered as “hazardous” by OSHA
- Pesticides
- Laboratory chemicals defined in “Occupational Exposure to Hazardous Chemicals in Laboratories”. (Note: if you work in a laboratory and receive an SDS when a chemical is shipped to you, you are required to retain the SDS and make it available to lab users.)
- Nuisance particulates that do not pose any physical or health hazard
- Ionizing and non ionizing radiation
- Biological hazards
- Drugs in solid, final form for direct administration to the patient (For example, tablets, pills, and capsules.)
- Drugs which are packaged by the chemical manufacturer for sale to consumers in retail establishments or those for personal consumption such as included in first aid cabinets

8.1.3. ChemWatch

Our university provides ChemWatch Gold FFX chemical management system software to access SDS datasheets. ChemWatch is one of the largest supplier system of individual SDS and all related chemical data. It provides a fully managed service to control, assess chemicals and cover risks within laboratory by developing offline and online application software, which uses a global database. Gold FFX application is used in managing hazardous substances and dangerous goods by using a web based database system by means to providing access to SDS, create manifests and conduct task based risk assessments. This application draws from the library of Chemwatch global database system that contains more than 13 million SDS. ChemWatch is available online at:

http://jr.chemwatch.net/chemwatch.web

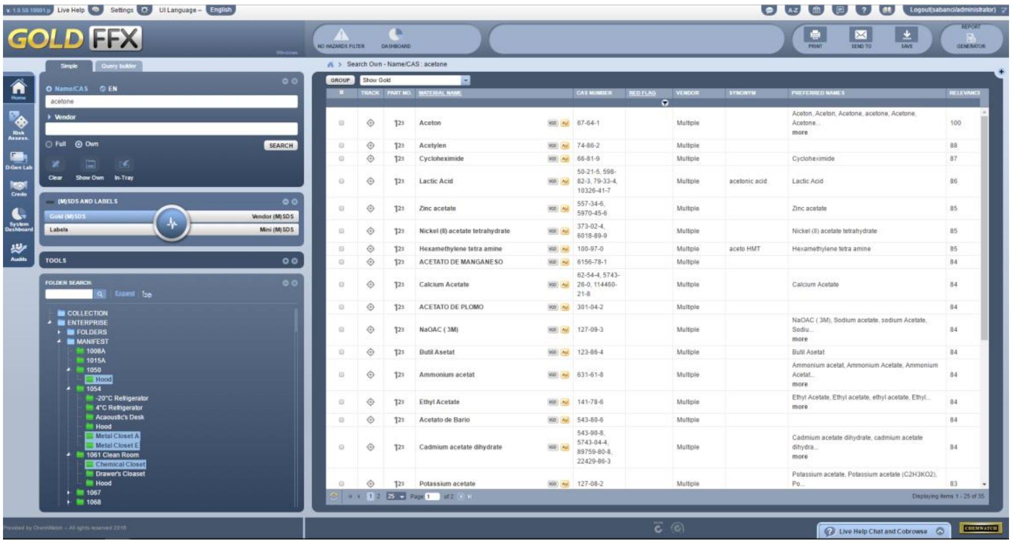
You must login to the system using your account (Figure 8.1) and password provided by Sabancı University during lab safety training sessions/Chemwatch training.



If you are not sure how to use the form above please click here to access the old login screen.

Figure 8.1 Gold FFX ChemWatch login page

Once you login, you can search different types of SDS, such as miniSDS, VendorSDS, and Gold SDS (Figure 8.2). The system also allows you to find the places of chemicals you search for.



Name/CAS: acetone

Search Own - Name/CAS : acetone

☐	TRACK	PART NO	MATERIAL NAME	CAS NUMBER	RED FLAG	VENDOR	SYNONYM	PREFERRED NAMES	RELEVANCE
☐			Aceton	67-64-1		Multiple		Aceton, Aceton, Acetone, acetone, Acetone, Acetone... more	100
☐			Acetylen	74-86-2		Multiple			88
☐			Cycloheximide	66-81-9		Multiple		Cycloheximide	87
☐			Lactic Acid	50-21-5, 598-82-3, 79-33-4, 10326-41-7		Multiple	acetonic acid	Lactic Acid	86
☐			Zinc acetate	557-34-6, 5970-45-6		Multiple		Zinc acetate	85
☐			Nickel (II) acetate tetrahydrate	373-02-4, 6018-89-9		Multiple		Nickel (II) acetate tetrahydrate	85
☐			Hexamethylene tetra amine	100-97-0		Multiple	aceto HMT	Hexamethylene tetra amine	85
☐			ACETATO DE MANGANESO	6156-78-1		Multiple			84
☐			Calcium Acetate	62-54-4, 5743-26-0, 114460-21-8		Multiple		Calcium Acetate	84
☐			ACETATO DE PLOMO	301-04-2		Multiple			84
☐			NaOAC (3M)	127-09-3		Multiple		NaOAC (3M), Sodium acetate, sodium Acetate, Sodiu... more	84
☐			Butil Asetat	123-86-4		Multiple		Butil Asetat	84
☐			Ammonium acetat	631-61-8		Multiple		Ammonium acetat, Ammonium Acetate, Ammonium Acetat... more	84
☐			Ethyl Acetate	141-78-6		Multiple		Ethyl Acetate, Ethyl acetate, ethyl acetate, Ethyl... more	84
☐			Acetato de Bario	543-80-6		Multiple			84
☐			Cadmium acetate dihydrate	543-90-8, 5743-04-4, 89759-80-8, 22429-86-3		Multiple		Cadmium acetate dihydrate, cadmium acetate dihydra... more	84
☐			Potassium acetate	127-08-2		Multiple		Potassium acetate, Potassium acetate (C2H3KO2), Po...	83

Page 1 of 2

Displaying items 1 - 25 of 35

Figure 8.2 Chemwatch search interface

A detailed training on ChemWatch usage is provided by LSS at the beginning of each semester. For further information regarding Chemwatch please navigate to trainings section/ChemWatch and/or contact LSS. It is highly recommended that you should obtain a copy of the SDS for your chemicals.

8.1.4. Safe Work Practices

8.1.4.1. General Regulations

- Never eat, drink, or smoke while working in the laboratory.
- Clothing: When handling dangerous substances, wear gloves, laboratory coats, and safety shield or glasses. Shorts and sandals should not be worn in the lab at any time. Steel-toe-shoes are required when working in the machine shops.
- Use the personal protective equipment (e.g. gloves, goggles, dust mask, etc.) as recommended in the SDS.
- Ensure that the SDS for the materials you work with are readily accessible and up-to-date.
- Lab users must receive training in the safe use, handling, disposal and clean-up of hazardous chemicals and products.
- Practice good housekeeping, personal cleanliness and equipment maintenance.

8.1.4.2. Chemical Storage

- Store chemicals and products in a designated area.
- When storing chemicals side by side make sure they are compatible and will not react to produce a hazardous chemical reaction.
- Ensure that portable containers are properly labelled with a workplace label when a controlled product is decanted from the supplier's original container.
- Replace defaced or accidently removed supplier or workplace labels.
- Close caps and lids tightly before storing any container.
- Store only the products you require and quantities you need.
- Limit access to storage areas and the janitorial closet.

8.1.4.3. Chemical Handling

- Handle containers safely to avoid damaging them.
- Do not mix chemicals and cleaning products unless you have consulted the SDS and are sure that it is safe (e.g. mixing ammonia and bleach will produce a highly toxic gas).
- Do not use the contents of unlabelled containers.
- Do not leave open containers of flammable products such as paintbrush cleaner, varnish, etc.
- Do not dispose of flammable materials in the trash.
- Do not smoke, eat or drink while using chemicals.
- Do not reuse empty containers; the residue may be hazardous.
- Do not open a container that appears to be swollen.
- Out-dated controlled products should be disposed of in a timely and appropriate manner.

8.1.4.4. Emergency

- Know how to handle emergencies (e.g. fire, spill, personal injury, etc) and the appropriate first aid measures (i.e. for eye contact, skin contact, ingestion, inhalation, etc.).
- Know where the closest eye/face wash station and/or emergence shower are located, and how to use them. Emergency equipment should be inspected and tested on a regular basis.
- Be aware of the potential hazards (e.g. fire/explosion, health, chemical reactivity, etc.) for the materials you work with.
- Report all incidents/accidents and chemical spills to your supervisor, LS/LSS.
- Follow the recommended clean-up procedures in case of a spill.

8.2. GENERAL CHEMICAL PROCEDURES

This section covers frequently used highly hazardous chemicals and provides detailed information on their handling, storage and disposal.

8.2.1. Aluminum Chloride (anhydrous)

8.2.1.1. Overview

Anhydrous aluminum chloride (aluminum trichloride, $AlCl_3$) is an odourless, white or yellow crystalline solid. Reaction of $AlCl_3$ with water violently liberates hydrogen chloride (HCl) gas. $AlCl_3$ readily sublimes to yield $HCl_{(g)}$ at 178 ^oC. Both solid and gas byproducts are highly corrosive to eyes, skin and mucous membranes. $AlCl_3$ is considered as incombustible; however, it is strongly advised not to use ABC or BC type fire extinguishers.

8.2.1.2. Handling

Working with $AlCl_3$, wear safety glasses, impervious gloves and a fire-retardant laboratory coat. Keep ignition sources under control and try to avoid dust formation. Avoid contact with water or moisture. Always keep dry sand available in the working area and make sure that there is a Class D extinguisher available nearby. When large quantities of $AlCl_3$ are to be used, make sure to work on a dry bench, preferably in a fume hood or glove box. Avoid contact with water and moisture.

$AlCl_3$ is incompatible with strong oxidizers and caustics, hydrated reagents, alcohols, sodium oxide, ethylene oxide, nitromethane and a wide variety of other materials. $AlCl_3$ corrodes transition metals.

Always heat $AlCl_3$ in a proper containment for generated $HCl_{(g)}$. Treatment of $AlCl_3$ with water or heat yields an exothermic reaction where hydrogen chloride gas is released.

8.2.1.3. Storage

Tightly seal $AlCl_3$ storage containers and keep in a cool dry place separated from other combustible materials. Storage containers may pressurize upon water contamination.

8.2.1.4. Disposal

Store wastes in tightly sealed containers. Dispose as hazardous waste.

8.2.2. Aqua Regia

8.2.2.1. Overview

Aqua regia (Latin for "Royal Water") is nitrated hydrochloric acid solution. It is prepared by mixing hydrochloric acid and nitric acid in a ratio of 3:1, respectively. It is generally employed to remove metals such as gold, platinum and palladium from substrates; therefore it is widely used in microfabrication and microelectronics labs. It also helps to remove trace amount organic compounds from glass. Aqua regia solutions are extremely corrosive and may result in explosion or skin burns if not handled with extreme caution.

8.2.2.2. Handling

- Aqua regia melts plastics and corrodes most metals. Always use glass (preferably Pyrex) containers.
- Do not store aqua regia solutions. Mix up only the amount you need, then dispose right after use.
- Prepare the solution in hood and lower the sash as much as possible. Wear PPE such as chemical splash goggles, face shield, lab coat and appropriate gloves.
- Always add the nitric acid to the hydrochloric acid slowly.
- While working with aqua regia, always use a fume hood since dissolving metals in aqua regia result in toxic gases release.
- Aqua regia solution is highly energetic and possesses explosion risk. It is very likely to become more than 100 ^{o}C. Be careful while handling.
- An exothermic reaction takes place upon adding acids or bases to aqua regia, or spraying water on it.
- Leave the hot aqua regia solution cooling in an open container and do not remove/replace until it is cooled.
- Do not store aqua regia in a closed container since it oxidizes over time to form toxic gases such as nitrosyl chloride, nitrogen dioxide and chlorine. Therefore, the container gets pressurized, likely causing an explosion.
- Be aware of the risk that mixing aqua regia with organic compounds may cause an energetic reaction, *i.e.* explosion.

8.2.2.3. Storage

Do not store aqua regia since its reactive components readily oxidize and lose effectiveness. Prepare a fresh solution prior to each use. Neutralize excess solution with sodium bicarbonate and then drain-dispose by flushing with large amount of water.

8.2.2.4. Disposal

Aqua regia is disposed via drain by flushing with copious amounts of water once the material has cooled and neutralized with sodium bicarbonate. On the other hand, if there’s heavy metal contamination (i.e. silver, chromium) in aqua regia then the neutralized solution should be collected as hazardous waste.

8.2.3. Hydrofluoric Acid

Hydrofluoric acid is an aqueous inorganic acid solution commonly used in research and industry due to its etching property of silicon compounds. It is a fundamental tool in semiconductor and electronic fabrication, mineral processing and glass etching. Besides these useful properties, hydrofluoric acid poses serious health risks upon exposure. Therefore, safe handling and usage practices should be reviewed prior to use and continuously applied while working with this material.

The Technical Info:

Hydrofluoric acid (CAS#7664-39-3) is the aqueous form of hydrogen fluoride gas with a molecular weight of 20.01 g/mole and both versions are referred to as HF in general use. It is miscible with water and is usually found in concentrations of 48-52% in water. 0.1 M aqueous solution of HF has a pH at approximately 1.0. Hydrofluoric acid is so corrosive that unlike other mineral acids, it attacks glass, concrete, rubber, quartz and alloys containing silica.

If you have to use hydrofluoric acid, please contact and inform LS/LSS beforehand.

Why So Dangerous?

There is a risk of surface burns due to exposure of mineral acids including hydrochloric, phosphoric, nitric and sulfuric acid. This may result in local tissue corrosion caused by acid's hydrogen cation activation. Effect of exposure to these acids is usually local focused on the area affected by acid.

On the other hand, hydrofluoric acid does not only cause local injuries but it also does not stop there. The skin rapidly absorbs free fluoride anion and the damage propagates inside, penetrates into non-surface body tissues, resulting in systemic injury.

In addition, the affinity of fluoride anion against essential minerals of body health; calcium and magnesium. Fluoride readily binds to calcium in blood, consuming body reserves of this mineral. It also attacks bone structure and forms calcium fluoride salt. A condition called hypocalcaemia, *i.e.* organ failure takes place due to depletion of serum calcium levels. Thus, heart functions become disordered and the heart eventually fails, resulting in death.

Another notable peculiarity of hydrofluoric acid is that the local dermal burns caused by hydrogen cation may not be as painful as the other acids, making the exposure harder to feel from warning properties. One may not feel any symptoms for 1 to 8 hours following skin contact with a concentration range of 20% to 50% hydrofluoric acid. This latency period will elongate to 24 hours as the concentration drops to less than 20%. Without medical care, a skin contact of 10 % of total body with 1-2% hydrofluoric acid results in death, but dermal burns are not likely to be immediate.

Hydrofluoric acid in moderate concentrations tends to fume releasing HF gas. When exposed to air, this gas produces additional health risks by inhalation.

Signs and Symptoms of Exposure

Skin Exposure – High HF concentrations, particularly anhydrous HF causes severe burns and an immediate pain and a visible white color occurs around the contact area, which eventually forms blisters. Dilute solutions of HF bring redness, swelling and blistering symptoms followed by acute throbbing pain.

Eye Contact – HF causes severe burns in eyes resulting in opacification, even destruction of the cornea. This may lead to blindness if not treated.

Inhalation – HF inhalation may cause several acute symptoms including coughing, choking, chest tightness, chills, fever and cyanosis (blue lips and skin). In case if you suspect of having exposed to HF by inhalation, seek medical attention as soon as possible and get further pulmonary effects observed by physicians. This is also valid for people exposed with HF around head, neck or chest areas. Significant inhalation exposure is not likely if there's no upper respiratory system irritation is observed.

Ingestion – Ingestion of even a very small amount of dilute HF results in death by severe burns in mouth, esophagus and stomach.

What to Do if You Are Exposed to HF

Time is of the essence as exposure to HF is a life-threatening emergency. Delay in first aid or medical treatment will result in greater damage or possibly death.

Skin Contact

- It is of primary importance to wash the acid off quickly and thoroughly. Even before taking contaminated clothes off, immediately start washing under a safety shower.
- The affected area should be flushed off for 5 minutes with plenty of water.

Begin the following procedure right after rinsing:

- Apply 2.5% calcium gluconate topical gel on affected skin area and massage. It should be noted that, the person applying calcium gluconate gel shuld wear gloves to prevent secondary HF exposure.
- **Apply iced 0.13%Benzalkonium chloride (Zephiran®)** solution soaks or compresses.
- Ask professional medical care right after first aid.

Eye Contact

- Wash the eyes with plenty amount of lightly flowing water and apply hexafluorine.
- Apply ice water compress during transportation to hospital.

Inhalation

Immediately move victim to fresh air and call health center (7666).

Ingestion

- Drink large amounts of water as quickly as possible to dilute the acid. Do not induce vomiting. Do not give emetics or baking soda. Never give anything by mouth to an unconscious person.
- Drink several glasses of milk or of milk of magnesia, Mylanta®, Maalox®, etc. or grind up and administer up to 30 Tums™, Caltrate™ or other antacid tablets with water.

Personal Protective Equipment

The best medicine in working with hazardous chemicals as hydrofluoric acid is prevention. When working with HF, following personal protective equipments should be worn in most (but not all) cases:

- Gloves – particularly Polyvinyl Chloride (PVC) or Neoprene gloves. A suitable size should be selected for each individual. In case of working with large amounts or if there's a risk of immersion of hands, Gauntlet style gloves are advised.
- Shoes – closed toe, preferably made up of leather or durable non-porous material. Rubber boots or over-boots should be worn when working with large amounts.
- Lab coat – preferably rubber or impermeable material, must be in a full-length and full arm construction. Please consult to LS/LSS to get the necessary PPE.
- Eyewear – Chemical splash goggles should be worn at all times.
- Ventilation – Fume hood use is obligatory.

Storage, Use, and Disposal

Hydrofluoric acid rapidly attacks silica-containing materials, including glass. It can best be stored in polyethylene containers. HF storage requires secure capped bottles and lids providing a gas-tight seal to prevent HF gas leaks. Hydrofluoric acid is never disposed of by drain even though it was neutralized. In case of neutralization, drain disposal is not advisable even if the resulting solution is at neutral pH (7.0). Since the neutralization of HF produces toxic metal fluoride salts, it should always be collected as hazardous waste and kept in plastic bottles. Universal adsorbent material, such as spill pillows, may be used to absorb small spills of hydrofluoric acid (<100 mL). For major spills of hydrofluoric acid (100 mL to 4 L) HF resistant spill materials must be used to soak up since spill pillows may degrade easily. Make sure that you are wearing the appropriate personal protective equipment and gear and have calcium gluconate around when you are cleaning an HF spill.

Along with the spill area, all equipment contaminated with hydrofluoric acid poses high risk and should be disposed of along with other hazardous waste. These equipment include research tools, empty containers previously containing HF, spill debris and personal protection equipment worn.

8.2.4. Lithium Aluminum Hydride

8.2.4.1. Overview

Lithium alumium hydride (LAH) is a chemical rapidly reacts with water, acids and oxygen-containing compounds. It is an odourless solid can ignite in moist air due to friction or static sparks. Conventional fire extinguishers of ABC and BC should never be used to fight an LAH fire since they may intensify the fire. LAH is corrosive and may cause complications in eyes, skin and mucous membrane.

8.2.4.2. Handling

Safety glasses, impervious gloves and fire-retardant laboratory coats should always be worn while handling LAH. Ignition sources should always be kept under control to prevent fire. Contact with water should also be avoided. It is advised to keep dry sand and a class D extinguisher immediately available while working with LAH.

An inert gas atmosphere, such as argon or nitrogen, should be ensured while working with large amount of LAH in powder form. As a personal safety measure, one should work with LAH under fume hood or glove box.

LAH is incompatible with several chemicals including alcohols, transition metal salts, oxidizing agents, and a wide variety of other materials. On the other hand, LAH reacts violently on contact with powerful oxidizers.

Never grind LAH nor heat it. LAH releases hydrogen gas via an exothermic reaction when in contact with water, acids or when heated.

8.2.4.3. Storage

LAH should be separated from combustible materials and be stored in tightly sealed containers.

8.2.4.4. Disposal

Waste LAH should be stored in sealed containers and be disposed as hazardous waste.

8.2.5. Phenol

8.2.5.1. Overview

The major hazard of phenol is its ability to penetrate the skin rapidly, causing severe burns. Toxic and even fatal amounts of phenol can be absorbed through relatively small areas of skin. Due to its local anesthetizing properties, skin burns may be painless. Phenol may be fatal if swallowed, inhaled or absorbed through the skin.

Since phenol easily penetrates leather, care should be taken not to walk in spill areas.

8.2.5.2. Handling

In case if there's a splash risk wear chemical splash goggles and/or a face shield. Wear personal protective equipment such as impervious clothing including close-toed shoes, lab coat or apron and butyl rubber or neoprene gloves. Since hot liquid phenol attacks aluminium, lead, zinc and magnesium, avoid heat sources, flame and ignition.

8.2.5.3. Storage

Phenol must be isolated from heat or ignition sources and be stored in a cool, dry and ventilated area. It must also be separated from combustible or reactive materials and kept safe from direct sunlight.

8.2.5.4. Disposal

All phenol and phenol-contaminated materials should be disposed of as hazardous waste.

8.2.6. Phosphorus

8.2.6.1. Overview

Amorphous (red) phosphorus is not considered as toxic in pure form. It is a reddish-violet powder and mostly stable under ordinary conditions. However, it may fire easily when exposed to excessive shock or friction.

Yellow phosphorus, considered as contaminant in red phosphorus, is a rather more hazardous form of the material. It is in fact an allotrope of phosphorus and is extremely toxic with an estimated human lethal dose of 50-100 mg. Yellow phosphorus is spontaneously combustible when exposed to air; therefore it must be stored under water.

It is strongly advised to take precautions against yellow phosphorus risks while handling or working with amorphous phosphorus.

8.2.6.2. Handling

Safety glasses, impermeable gloves and a fire-retardant laboratory coat should always be worn while working with phosphorus.

Safety glasses, impermeable gloves and a fire-retardant laboratory coat should be worn all the time. Ignition sources must be kept under control and dust formation be avoided, along with heat, shock and friction. It is advised to keep dry sand and a class A water/wet foam extinguisher immediately available while working.

In case if large amount of phosphorus will be used, it is strongly advised to work in an inert atmosphere, particularly glove box.

The two allotropes of phosphorus form toxic phosphine gas upon exposure to alkalis. They are incompatible with halogens, halides, sulphur and oxidizing materials as well.

8.2.6.3. Storage

Keep red phosphorus separated from incompatible materials mentioned above and store in a cool dry place in tightly sealed containers. Yellow phosphorus, along with contaminated red phosphorus, must be kept under water and sealed to avoid exposure to air.

8.2.6.4. Disposal

Store wastes (under a layer of water) in tightly sealed containers. Dispose as hazardous waste.

8.2.7. Phosphorus Trichloride

8.2.7.1. Overview

Phosphorus trichloride (phosphorus chloride, PCl_3) is a colorless fuming liquid easily react with most of the organic compounds. It also rapidly react with water and yield phosphoric acid and hydrogen chloride (HCl) gas. It is a strong oxidizer and highly corrosive to eyes, skin and mucous membrane along with its by-product.

8.2.7.2. Handling

PCl_3 gives an exothermic reaction with water, releasing acid gases. Personal protective equipment involving safety glasses, impervious gloves and a fire-retardant laboratory coat should be worn while working/handling. Ignition sources must be kept under control and water contact must be avoided. It is strongly advised to keep a dry sand supply and a class D extinguisher available around the working area.

Dry surroundings, preferably glove box must be used while working with large amounts of PCl_3. Water-containing or humid environments must be avoided. PCl_3 makes most of the transition metal corroded especially in humid environment. Incompatibility list of PCl_3 includes most of the organics, fluorine, and lead oxide along with many other substances.

PCl_3 should not be heated without a proper container dedicated to and durable of acids, particularly hydrochloric and phosphoric acid. It may release gaseous phosphine and diphosphine in thermal decomposition.

8.2.7.3. Storage

Keep PCl_3 separated from combustibles and store in a cool dry place in tightly sealed containers. It is advised to use pressurized containers in case of water contamination.

8.2.7.4. Disposal

Store wastes in tightly sealed containers. Dispose as hazardous waste.

8.2.8. Piranha Solutions

8.2.8.1. Overview

Piranha solutions are widely used in microfabrication labs for cleaning purposes to remove organic residues. It is prepared by mixing 3:1 of sulphuric acid and hydrogen peroxide (30%), respectively. Mixing may be carried out either beforehand or during the application to the material. In that case, sulphuric acid should be applied before peroxide.

Piranha solutions are energetic materials may easily cause explosion. It is also quite probable to cause thermal burns if not handled safely. When exposed to its vapor, respiratory system may be irritated.

8.2.8.2. Handling

- Glass containers, preferably Pyrex®, should be used all the time since plastic containers may be degraded when in contact with piranha solutions.
- Label all piranha solution containers properly.
- Prepare piranha solution in a fume hood by keeping the sash between you and solution as low as possible. Appropriate PPE, such as acid resistant lab coat and/or apron with sleeve covers, gloves (butyl) and chemical splash goggles should be worn at all times.
- Hydrogen peroxide should be added to sulphuric acid by gentle stirring. Never add sulphuric acid before hydrogen peroxide.
- It is advised to keep the peroxide concentration under 30%. Do not exceed 50%.
- While preparing, piranha solution becomes extremely hot, exceeding 100 °C. To avoid thermal injuries, do mind the personal protective measures.

- Piranha solutions should never be mixed with organic compounds, as it is incompatible with them. Do not mix with bases either, including photoresist. It may cause to an explosion to mix piranha solution with incompatible materials.
- Piranha solutions are intended to clean residual compounds, therefore make sure that the containers are all washed, rinsed and dried beforehand.
- When in contact with equipment to be cleaned, it takes time to stabilize the solution. Thus, immerse equipment one by one, slowly and carefully.
- Do not store fresh piranha solution in closed containers, not even partially closed.
- Allow piranha solution react with equipment overnight. Label the container and leave open in a fume hood until disposal.

8.2.8.3. Storage

As it is quite reactive, piranha solution cannot be stored before use. Prepare fresh solutions every time as needed. Excess or used piranha solutions should be disposed following the procedures below.

8.2.8.4. Disposal

Piranha solution is sent to disposal only if it was fully reacted, the cooled and all the gases were allowed to release.

Small amounts of piranha solution (>100 mL) should be neutralized. Note that, this process releases energy and must be cooled in an ice bath to control the temperature and prevent heating. Neutralization can only be done with acid resistant lab coat and/or apron with sleeve covers, gloves (rubber or butyl) and chemical splash goggles and only under hood. The solution should be diluted to less than 10% prior to neutralization. Once diluted, bases such as sodium hydroxide or sodium carbonate should be added very slowly with effective stirring. This process is done until the pH reaches to a range between 4 to 10. After this point, resulting solution may be disposed of via drain. Using carbonates as neutralizing agent may cause to bubbling and foaming and this may create some additional risks of splash and spill.

If the amount to be disposed is higher than 100 mL, used piranha solutions are collected as waste in an acid bottle (empty sulphuric acid bottle, for example). Doing this, a small amount of waste piranha solution should be added to bottle in order to check if there's any residual materials left in the container. If no reaction takes place, then the rest of the solution may be slowly transferred to bottle. Waste piranha solution containers must be labelled. Waste piranha solutions should not be combined with any other waste.

8.2.9. Potassium

8.2.9.1. Overview

Potassium is a silver-colored metal that is odourless and highly corrosive to eyes, skin and mucous membranes. Highly unstable peroxides may form if potassium is stored for a long time. It rapidly reacts with water, acids and oxygenated compounds and may ignite in moist air or due to friction or static spark. Water and conventional ABC fire extinguishers should never be used since they may intensify the fire.

8.2.9.2. Handling

Safety glasses, impervious gloves and a fire-retardant laboratory coat should be worn all the time while working with potassium. Any contact with water or moist must be avoided. It is strongly advised to keep a dry sand and class D type fire extinguisher available around when you work with potassium.

An inert atmosphere such as argon or nitrogen must be maintained when large amounts of potassium are to be used.

Note that potassium is incompatible with alcohols, oxidizing agents, hydrated salts, acids and many other chemicals, therefore it must be stored separately from these chemicals. It is also oxidized rapidly.

Potassium should not be grinded or heated. Any contact with water and incompatible chemicals results in an exothermic reaction where hydrogen gas is released that is highly flammable. In addition, oxidized potassium poses a risk of explosion upon handling.

8.2.9.3. Storage

Potassium should be kept in dry toluene, kerosene and/or under an inert atmosphere of nitrogen or argon. Storage requires tightly sealed containers and a cool and dry environment, rather well separated from combustibles. Unused potassium should not be stored more than one year in any condition.

8.2.9.4. Disposal

Waste potassium should be stored in toluene or kerosene by tightly sealing the container. It should be disposed of as hazardous waste. Superoxide or peroxide derivatives should never be handled. A white precipitate identifies contamination of those materials.

8.2.10. Sodium

8.2.10.1. Overview

Sodium is a silver-white-colored metal that is highly corrosive to eyes, skin and mucous membranes. It rapidly reacts with water, acids and oxygenated compounds and may easily ignite in moist or dry air above 115 °C. Water and conventional ABC fire extinguishers should never be used since they may intensify the fire.

8.2.10.2. Handling

Safety glasses, impervious gloves and a fire-retardant laboratory coat should be worn all the time while working with sodium. Ignition sources must be kept under control and dust formation should be avoided. Any contact with water or moist must be avoided. It is strongly advised to keep a dry sand and class D type fire extinguisher available around when you work with sodium.

An inert atmosphere such as argon or nitrogen must be maintained in a fume hood when large amounts of sodium are to be used.

Note that sodium is incompatible with oxygen, carbon dioxide, halogens and halogenated solvents, alcohols, oxidizing agents, hydrated salts, acids and many other chemicals, therefore it must be stored separately from these chemicals. It is also oxidized rapidly upon contact with oxidizers and/or water.

Sodium should not be grinded or heated. Any contact with water acids or alcohols results in an exothermic reaction where hydrogen gas is released that is highly flammable. Hydrogen gas is also released in the presence of dry air above 115 °C.

8.2.10.3. Storage

Potassium should be kept in dry toluene, kerosene and/or under an inert atmosphere of nitrogen or argon. Storage requires tightly sealed containers and a cool and dry environment, rather well separated from combustibles.

8.2.10.4. Disposal

Sodium waste should be stored in tightly sealed containers under toluene or kerosene. Dispose as hazardous waste.

8.2.11. Sodium Amide

8.2.11.1. Overview

Sodium amide ($NaNH_2$) is a greyish-white powder that is highly corrosive to eyes, skin and mucous membranes. It has a slight odor of ammonia. It rapidly reacts with water, acids and halogenated compounds and may easily ignite in moist or dry air above 450 °C. Water and conventional ABC fire extinguishers should never be used since they may intensify the fire.

Sodium amide forms peroxides that are sensitive to shock. These peroxides poses a high risk of explosion upon contact with air, heat or if stored for a long time. Residual sodium amide should be immediately disposed.

8.2.11.2. Handling

Safety glasses, impervious gloves and a fire-retardant laboratory coat should be worn all the time while working with sodium. Ignition sources must be kept under control and dust formation should be avoided. Any contact with water or moist must be avoided. It is strongly advised to keep a dry sand and class D type fire extinguisher available around when you work with sodium amide.

An inert atmosphere such as argon or nitrogen must be maintained in a fume hood or glove box when large amounts of sodium amide are to be used.

Note that sodium amide is incompatible with oxygen, carbon dioxide, halogens and halogenated solvents, alcohols, oxidizing agents, hydrated salts, acids and many other chemicals, therefore it must be stored separately from these chemicals. It is also oxidized rapidly upon contact with oxidizers and/or water.

Sodium amide should not be grinded or heated. Any contact with water acids or alcohols results in an exothermic reaction where hydrogen gas is released that is highly flammable. Peroxide derivatives can easily explode upon handling.

8.2.11.3. Storage

Potassium should be kept under an inert atmosphere of nitrogen or argon. Storage requires tightly sealed containers and a cool and dry environment, rather well separated from combustibles. Unused sodium amide should not be stored for more than one year.

8.2.11.4. Disposal

Sodium amide waste should be stored in tightly sealed containers under dry inert atmosphere. Deactivation of used material can be carried out under well controlled environment. Dispose as hazardous waste. Containers of peroxide derivatives should never be handled. Yellow or brown solids identify a contamination of these materials.

8.2.12. Explosives

8.2.12.1. Overview

An explosive is defined as a chemical that undergoes a rapid chemical transformation when subjected to heat, impact, friction, detonation, or other suitable initiation, evolving large amount of gases as a result and significantly exerting the pressure of surroundings. It can either be found in a form of chemical compound or a mechanical mixture. The term explosive also applies to materials that either detonate or deflagrate.

8.2.12.2. Handling

Great care must be taken upon handling explosives, particularly peroxide formers. Container bottles should be visually inspected for any residual peroxide crystals.

- The scale of work is critical. Explosives should be used/worked with at the smallest scale possible (e.g., mmole) and scale-up should only be taken care with the authorization of the supervisor.
- Eliminate the confinement sources in case if you work with materials that easily deflagrate.
- There must be no additional chemicals around the working area while working with explosives.
- Static discharge sources should be eliminated since they may initiate certain type of explosives. Note that low humid air enhances the risk of static discharge. Nonstatic wipes and brushes must be used. If not, appropriate wet methods should be selected cleaning.
- All transfer operations should be conducted using compatible equipment. Note that certain explosives may form more sensitive compounds when in contact with metals.
- Working area, along with all the equipment and tools used should always be kept clear. Explosives should not be scraped from any surface.
- Never crush or grind and explosive, nor apply pressure.

8.2.12.3. Storage

Explosives should be stored in designated cabinets. Flammables should be stored in designated cabinets or refrigerators approved for flammable storage.

Newly arrived containers of explosives should be labelled with receipt date. Reactive materials cannot be used past their expiration date.

8.2.12.4. Disposal

Explosive waste should be collected as hazardous waste. Explosive compounds are more stable when diluted. Therefore, they are diluted using a safe solvent if possible. Explosive waste must be separated from other wastes.

8.2.13. Flammables

8.2.13.1. Overview

- Flammable liquids are defined as liquids having a flash point below 38 ^{o}C.
- Combustible liquids are defined as liquids having a flash point at or above 38 ^{o}C and no greater than 93 ^{o}C.
- Flash point is the minimum temperature at which vapors are formed on the surface of a substance in sufficient quantity to ignite when exposed to an ignition source.
- Fire point is the minimum temperature at which self-sustained combustion of a substance will occur upon or after exposure to an ignition source.

- Boiling point is the temperature at which the vapor pressure of a liquid equals the atmospheric pressure and the liquid transforms into a vapor.
- Auto-ignition temperature is defined as the minimum temperature at which self-sustained combustion will occur in the absence of an ignition source.
- Lower explosive limit (LEL) stands for the lowest concentration (percentage) of a gas or a vapor in air capable of producing a flash of fire in presence of an ignition source (arc, flame, heat).
- Upper explosive limit (UEL) stands for highest concentration (percentage) of a gas or a vapor in air capable of producing a flash of fire in presence of an ignition source (arc, flame, and heat).

8.2.13.2. Handling

- Flammable liquids must be stored in a designated area such as a flammable storage cabinet.
- Large amounts of flammable liquid (more than 37 liters) are not permitted to be stored outside a flammable cabinet.
- Flammables should not be over-purchased; one should only purchase them amount that can be safely stored regarding the facility capacity.
- Any contact with skin, eyes, and inhalation should be avoided.
- Flammables must be kept away from ignition sources.
- Containers must be kept tightly closed. Storage requires a cool, dry, and well-ventilated area away from incompatible substances such as oxidizers.
- Follow LS/LSS' instructions for PPE, which may differ depending on the type and/or quantity of flammable/combustible liquid being used.
- They should be used in the smallest quantities possible for the experiment being performed.
- Work must be conducted in a chemical fume hood if air concentrations above 10% of the LEL could be created, if the chemical is irritating to the eyes or respiratory system, and/or is toxic by inhalation.
- When not in use, containers should always remain closed. This is the main precaution to prevent release of flammable vapor and/or unintended ignition.
- Containers should be labelled properly.
- If not used, they must be stored in designated flammable storage cabinets.
- Containers of flammables must be compatible with the material stored inside.
- Using ignition sources (flame burners or any open flame source, hot plates, electrical equipment with frayed or cracked wiring, etc.) and/or creating static electricity around the flammable/combustible chemicals should be avoided.
- Containers must be grounded and bonded upon transfer of large amounts (more than 4 liters) of flammable/combustible liquids.
- All flammable/combustible liquids should be transported in secondary containment, such as polyethylene or other non-reactive acid/solvent bottle carrier.
- Flammable/combustible liquids must be segregated from incompatible materials such as oxidizers (e.g., hydrogen peroxide, nitric acid).
- In case if flammable liquids are to be stored in refrigerators or freezers, these should be specially modified or designated “flammable-safe” refrigerators and freezers which does not pose a risk of ignition due to the internal light or thermostat circuit.

8.2.14. Water-Reactives

8.2.14.1. Overview

Water reactive materials can react violently with water or atmospheric moisture to produce gas and heat. The risks associated with a specific chemical depend on its reactivity and the nature of the gaseous product (flammable, toxic, or both). The mutual production of flammable gas and heat can lead to spontaneous ignition or explosion. Typical gases produced are: H_2, CH_4, H_2S, NH_3, PH_3, HCN, HF, HCl, HF, HI, SO_2, and SO_3. Prior to working with any water reactive chemicals you must identify which gas may be formed in case of exposure to water and learn the risks associated with this gas.

The reaction rate of solid material (and therefore heat and gas generation) depends on the material's surface area. Therefore smaller particle size increases the hazards associated with these materials.

8.2.14.2. Handling

- Unless it is known otherwise, assume the material is pyrophoric.
- To be handled always in a glove box or under inert atmosphere.
- Design a quenching scheme for residual materials prior to using water reactive materials.
- Never use water to quench the material itself or a reaction where a water-reactive reagent is used.

- Begin quenching with a low reactivity quenching agent and slowly add more reactive quenching agents. For example, first quench residual sodium metal with isopropanol and then add ethanol to the mixture.
- Design your experiment to use the least amount of material possible to achieve the desired result.
- It is better to do multiple transfers of small volumes than attempt to handle larger quantities. Before transferring, make sure that the material is at room temperature.
- Avoid formation of dusts and aerosols.
- Provide appropriate exhaust ventilation at places where dust is formed.
- Take measures to prevent the build-up of electrostatic charge.
- Keep away from sources of ignition – open flames (e.g. Bunsen Burner).
- Eliminate or substitute a less hazardous material when possible.
- Verify your experimental set-up and procedure prior to use.
- Inform colleagues that this material will be used and where. Label the work area with a sign saying “Water Reactives Use Area”.
- Only use if the area is properly equipped with a certified eye wash/safety shower within ten seconds of travel.
- Never use water to extinguish fires caused by water reactive materials.

8.2.14.3. Storage

- Never allow contact with water.
- Always handle inside a glove box.
- Over time, pressure may increase causing containers to burst. Keep container tightly closed in a cool, dry, well-ventilated place and protected from sunlight.
- Store and handle under inert gas (Inert gases such as nitrogen, argon etc.)
- Keep in a dry place (such as a desiccator or a dry box or glove box) free of moisture/humidity.
- Store away from heat sources and in a flameproof area.
- Do not leave the container near a lab sink, emergency eyewash or safety shower.
- Store in a location, separated from acids, oxidizing and other incompatible materials.
- Use/purchase only amount that is needed in a reasonable amount of time. Use small quantities whenever possible.
- Store in a separate secondary container and label the material clearly.
- Minimize dust generation and accumulation.
- Hazard communication label on the container must read “*Water Reactive*”.
- Never allow product to get in contact with water or water-based compounds during storage.
- Do not leave the container on the benchtop - even momentarily.
- Follow any substance-specific storage guidance provided in safety data sheet documentation.
- Monitor your inventory closely to assure that you have tight control over your material.
- Wash hands and arms with soap and water after handling.
- Minimize dust generation and accumulation.
- At the end of each project, thoroughly inspect the area for residual reactive material.

8.2.15. Oxidizers

8.2.15.1. Overview

Oxidizing chemicals are materials that spontaneously evolve oxygen at room temperature or with slight heating or promote combustion. This class of chemicals includes peroxides, chlorates, perchlorates, nitrates, and permanganates. Strong oxidizers are capable of forming explosive mixtures when mixed with combustible, organic or easily oxidized materials.

8.2.15.2. Handling

- Do not store with incompatible material.
- Do not store with flammables or combustibles.
- Review SDS for specific storage conditions.
- Chemicals shall not be drain-disposed unless prior approval is given by LSS/LS.
- Excess oxidizers and all waste material containing oxidizers must be placed in a container labelled with the following “Hazardous Waste Oxidizers”, and the full chemical name.

8.2.15.3. Storage

Oxidizers should be stored in a cool and dry location. Keep oxidizers segregated from all other chemicals in the laboratory. Minimize the quantities of strong oxidizers stored in the laboratory. Never return excess chemicals to the original container. Small amounts of impurities may be introduced into the container, which may cause a fire or explosion.

8.2.15.4. Disposal

All materials contaminated with oxidizing chemicals pose a fire hazard and should be disposed of as hazardous waste. Do not let contaminated wastes remain in the laboratory overnight unless proper containers are provided.

8.2.16. Peroxide Forming Compounds

8.2.16.1. Overview

Organic peroxides are a special class of compounds that have unusual stability problems, making them among the most hazardous substances normally handled in laboratories. In addition, certain laboratory chemicals can react with the oxygen in air to form peroxides. Some may continue to build peroxides to potentially dangerous levels, while others accumulate a relatively low equilibrium concentration of peroxides, which becomes dangerous only after being concentrated by evaporation or distillation. The peroxide becomes concentrated because it is less volatile than the parent chemical. Stabilizers or inhibitors are sometimes added to the liquid to extend its storage life, but distillation will remove the inhibitor.

8.2.16.2. Handling

- Avoid friction, grinding, and all forms of impact near peroxides, especially solid peroxides. Do not use glass containers with screw caps or glass stoppers. Polyethylene containers with screw tops may be used.
- Store peroxides at the lowest possible temperature consistent with their solubility or freezing point to minimize the rate of decomposition. Do not store them at or lower than the temperature at which the peroxide freezes or precipitates because peroxides in these forms are extremely sensitive to shock and heat.
- Store all peroxidizable compounds in tightly closed, air-impermeable, light-resistant containers, away from light, heat, direct sunlight, sources of ignition, oxidizers, and oxidizing agents. Storage under nitrogen may be advisable in some cases.
- Do not use metal spatulas to handle peroxides because metal contamination can lead to explosive decomposition. Magnetic stirring bars can unintentionally introduce iron, which can initiate an explosive reaction of peroxides. Teflon, ceramic or wooden spatulas and stirring blades may be used if it is known that the material is not shock sensitive.
- Do not allow these compounds to evaporate to near dryness unless absence of peroxides has been shown.
- Purchase peroxide formers with inhibitors added by the manufacturer when possible.
- For peroxide forming compounds, mark the receipt and opening date on the container and discard within the time frame listed in the table above (or by the manufacturer’s expiration date, if listed on the container).

8.2.16.3. Disposal

Organic peroxides or peroxide forming compounds must be collected as hazardous waste.

8.2.17. Pyrophoric Compounds

8.2.17.1. Overview

Pyrophoric compounds are chemicals that, even in small quantities, are prone to ignition within five minutes after coming into contact with air.

8.2.17.2. Storage

Pyrophoric chemicals should be stored under an atmosphere of inert gas or under kerosene as appropriate. Do not store pyrophoric chemicals with flammable materials or in a flammable-liquids storage cabinet. Store these materials away from sources of ignition. Minimize the quantities of pyrophoric chemicals stored in the laboratory.

Never return excess chemicals to the original container. Small amounts of impurities may be introduced into the container, which may cause a fire or explosion.

8.2.17.3. Disposal

Never return excess chemicals to the original container. Small amounts of impurities may be introduced into the container, which may cause a fire or explosion. A container with any residual material must never be opened to the atmosphere. Attempt to use the entire reagent in your chemical reaction. If there is unused and unwanted material left over, place the bottle in a secondary container (preferably the original provided by manufacturer) in the satellite accumulation area for disposal by a licensed contractor and notify LSS for disposal.

8.3. CHEMICAL EXPOSURE MONITORING

Laboratory users may use various potentially hazardous materials on a daily basis. Proper laboratory health and safety measures and engineering controls should be applied for the sake of safe use of such materials. In some cases verification of the effectiveness of work practices and engineering controls in limiting hazardous chemicals exposure is required.

Exposure monitoring is the determination of the airborne concentration of a hazardous material in the work environment. Exposure monitoring data is compared to existing international standards exposure guidelines and is often used to make recommendations concerning engineering controls, work practices, and PPE.

Occupational exposure limits for several chemicals that have been determined by Turkish Government is shown in Table 8.1. For further information please see the Regulations on Health and Safety Measures for Working with Chemicals (References, 8.19).

8.4. CHEMICAL SPILLS

Every laboratory should have access to spill control materials for the chemicals used in their lab. General use chemical spill kits equipped with spill pads, waste bags, loose absorbents and personal protective equipment can be found in the chemical spill kits.

If your lab uses hydrofluoric acid (HF), keep a supply of spill control materials specifically designed for HF.

If your lab uses mercury or mercury-containing equipment, keep some mercury absorbing powders or sponges or similar materials on hand. Consider replacing mercury-containing equipment with non-mercury alternatives.

Prevention

The following practices can help prevent spills or minimize the spread of a spill:

- Place containers of hazardous chemicals in secondary containment (Figure 8.3.a), such as a tray, bucket, basin or plastic tub.
- Line benchtops with absorbent paper.
- Move chemicals through the building on carts with lips to prevent the container from sliding off.
- Use chemical carriers (Figure 8.3.b) when carrying chemicals through hallways.

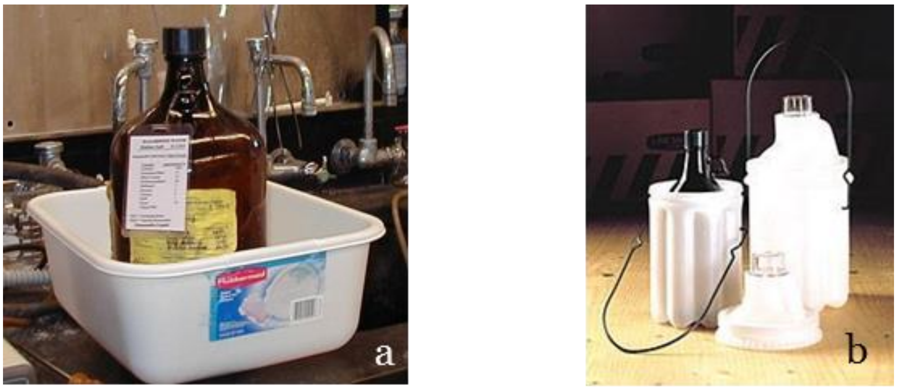


Figure 8.3 Secondary containment (a) and chemical carrier (b)

Table 8.1 Occupational exposure limits for several chemicals have been determined by Turkish Government

EINECS	CAS	Sample name	Limiting values				Sign (3)
			TWA (4) (8 hours)		STEL (5)(15 min.)		
			mg/m³ (6)	ppm (7)	mg/m³	ppm	
200-467-2	60-29-7	Diethylether	308	100	616	200	-
200-662-2	67-64-1	Acetone	1210	500	-	-	-
200-663-8	67-66-3	Chloroform	10	2	-	-	Skin
200-756-3	71-55-6	1,1,1-Trichloroethane	555	100	1110	200	-
200-834-7	75-04-7	Ethylamine	9,4	5	-	-	-
200-863-5	75-34-3	1,1-Dichloroethane	412	100	-	-	Skin
200-870-3	75-44-5	Phosgene	0.08	0,02	0.4	0.1	-
200-871-9	75-45-6	Chlorodifluoromethane	3600	1000	-	-	-
201-159-0	78-93-3	Butanone	600	200	900	300	-
201-176-3	79-09-4	Propionic acid	31	10	62	20	-
202-422-2	95-47-6	o-Xylene	221	50	442	100	Skin
202-425-9	95-50-1	1,2-Dichlorobenzene	122	20	306	50	Skin
202-436-9	95-63-6	1,2,4-Trimethylbenzene	100	20	-	-	-
202-704-5	98-82-8	Cumene	100	20	250	50	Skin
202-705-0	98-83-9	2-Phenylpropene	246	50	492	100	-
202-849-4	100-41-4	Ethylbenzene	442	100	884	200	Skin
203-313-2	105-60-2	e-Kaprolactam (dust or its vapor)	10	-	40	-	-
203-388-1	106-35-4	Heptan-3-one	95	20	-	-	-
203-396-5	106-42-3	p-Xylene	221	50	442	100	Skin
203-400-5	106-46-7	1,4-Dichlorobenzene	122	20	306	50	-
203-470-7	107-18-6	Allyl alcohol	4.8	2	12.1	5	Skin
203-473-3	107-21-1	Ethylene glycol	52	20	104	40	Skin
203-539-1	107-98-2	1-Methoxypropanol-2	375	100	568	150	Skin
203-550-1	108-10-1	4-Methylpentane-2-on	83	20	208	50	-
203-576-3	108-38-3	m-Xylene	221	50	442	100	Skin
203-603-9	108-65-6	2-Methoxy-1-methylethylacetate	275	50	550	100	Skin
203-604-4	108-67-8	Mesitylene (Trimethylbenzenes)	100	20	-	-	-
203-631-1	108-94-1	Cyclohexanone	40.8	10	81.6	20	Skin
203-632-7	108-95-2	Phenol	7,8	2	-	-	Skin
203-726-8	109-99-9	Tetrahydrofurane	150	50	300	100	Skin
203-737-8	110-12-3	5-Methylhexan-2-one	95	20	-	-	-
203-767-1	110-43-0	Heptan-2-one	238	50	475	100	Skin
203-808-3	110-85-0	Piperazine	0.1	-	0.3	-	-
203-905-0	111-76-2	2-Butoxyethanol	98	20	246	50	Skin
203-933-3	112-07-2	2-Butoxyethyl acetate	133	20	333	50	Skin
204-065-8	115-10-6	Dimethylether	1920	1000	-	-	-
204-428-0	120-82-1	1,2,4-Trichlorobenzene	15.1	2	37.8	5	Skin
204-469-4	121-44-8	Triethylamine	8.4	2	12.6	3	Skin
204-662-3	123-92-2	Isopentylacetate	270	50	540	100	-
204-697-4	124-40-3	Dimethylamine	3.8	2	9.4	5	-
204-826-4	127-19-5	N,N-Dimethylacetamide	36	10	72	20	Skin
205-480-7	141-32-2	n-Butylacrylate	11	2	53	10	-
205-563-8	142-82-5	n-Heptane	2085	500	-	-	-
208-394-8	526-73-8	1,2,3-Trimethylbenzene	100	20	-	-	-
208-793-7	541-85-5	5-Methylheptan-3-one	53	10	107	20	-
210-946-8	626-38-0	1-Methylbutylacetate	270	50	540	100	-
211-047-3	628-63-7	Pentylacetate	270	50	540	100	-
	620-11-1	3-Pentylacetate	270	50	540	100	-
	625-16-1	Amylacetate, tert	270	50	540	100	-
215-535-7	1330-20-7	Xylene, (mixture isomers, pure)	221	50	442	100	Skin
222-995-2	3689-24-5	Sulfotep	0.1	-	-	-	Skin
231-634-8	7664-39-3	Hydrogen fluoride	1.5	1.8	2.5	3	-
231-131-3	7440-22-4	Silver (Metallic)	0.1	-	-	-	-
231-595-7	7647-01-0	Hydrogen chloride	8	5	15	10	-
231-633-2	7664-38-2	Orthophosphoric acid	1	-	2	-	-
231-635-3	7664-41-7	Ammonia (anhydrous)	14	20	36	50	-
231-954-8	7782-41-4	Fluoride	1.58	1	3.16	2	-
231-978-9	7783-07-5	Dihydrogen selenide	0.07	0.02	0.17	0.05	-
233-113-0	10035-10-6	Hydrogen bromide	-	-	6.7	2	-
247-852-1	26628-22-8	Sodium azide	0.1	-	0.3	-	Skin
252-104-2	34590-94-8	(2-Methoxymethyletoxy)-propanol	308	50	-	-	Skin
		Fluorides, inorganic	2.5	-	-	-	-

(1) EINECS: European inventory of chemicals.

(2) CAS: Chemical abstracts service number.

(3) Skin: “indicates that the chemical can be significantly absorbed by skin

(4) TWA: Weighted average that was measured or calculated in 8 hours reference

(5) STEL: Unless stated otherwise, exposure maximum that should not be exceeded in

(6) mg/m³: Amount of substance in milligrams present in 1 m³ of air at 760 mmHg (101.3 KPa in 20 ⁰C).

(7) ppm: Amount of substance in milliliters present in 1 m³ of air (ml/m³).

Adopted from Turkish Ministry of Labour and Social Security, Regulations on Occupational Health and Safety Measures of Working with Chemicals (Reference 8, 19).

8.4.1. Spill Clean up Procedures

Spill Response and Clean-up Procedures

In the event of a chemical spill, the individual(s) who caused the spill is responsible for prompt and proper clean up. It is also their responsibility to have spill control and personal protective equipment appropriate for the chemicals being handled readily available.

The following are general guidelines to be followed for a chemical spill.

- Immediately alert area occupants and supervisor, and evacuate the area, if necessary.
- If there is a fire or medical attention is needed, contact LS.
- Attend to any people who may be contaminated. Contaminated clothing must be removed immediately and the skin flushed with water for no less than fifteen minutes. Clothing must be laundered before reuse.
- If a volatile, flammable material is spilled, immediately warn everyone, control sources of ignition and ventilate the area.
- Use personal protective equipment, as appropriate to the hazards. Refer to the SDS or other references for information.
- Consider the need for respiratory protection. The use of a respirator or self-contained breathing apparatus requires specialized training and medical surveillance. Never enter a contaminated atmosphere without protection or use a respirator without training. If respiratory protection is needed and no trained personnel are available, call LS. If respiratory protection is used, be sure there is another person outside the spill area in communication, in case of an emergency. If no one is available, contact LSS.
- Using the chart below, determine the extent and type of spill. If the spill is large, if there has been a release to the environment or if there is no one knowledgeable about spill clean-up available, contact LS.
- Protect floor drains or other means for environmental release. Spill socks and absorbents may be placed around drains, as needed.
- Contain and clean up the spill according to the Table 8.2 below. Loose spill control materials should be distributed over the entire spill area, working from the outside, circling to the inside. This reduces the chance of splash or spread of the spilled chemical. Bulk absorbents and many spill pillows do not work with hydrofluoric acid. Many neutralizers for acids or bases have a color change indicator to show when neutralization is complete.
- When spilled materials have been absorbed, use brush and scoop to place materials in an appropriate container. Polyethylene bags may be used for small spills. 20 L pails or 75 L drums with polyethylene liners may be appropriate for larger quantities.
- Complete a hazardous waste sticker, identifying the material and affix onto the container. Spill control materials will probably need to be disposed of as hazardous waste. Contact LS for advice on storage and packaging for disposal.
- Decontaminate the surface where the spill occurred using a mild detergent and water, when appropriate.
- Report all spills to your supervisor and LSS.

Table 8.2 Spill containment and clean-up*

Category	Size	Response	Treatment Materials
Small	up to 300 mL	chemical treatment / absorption	neutralization or absorption spill kit
Medium	300 mL – 2.5 liters	absorption	absorption spill kit
Large	more than 2.5 liters	call 7444	outside help

Adopted from Princeton University emergency guidelines for the campus community web page.

* This table serves only as a general directive. Spills of highly hazardous or unknown materials must be conducted only by trained users, SDS directives must be followed. For further information please see the flow chart (Figure C.2. Chemical Spills section) summarizing the educated decision-making process during handling of the spill.

8.4.2. Developing a Spill Response Plan

An effective spill response procedure should consider all of the items listed below. The complexity and detail of the plan will, of course, depend upon the physical characteristics and volume of materials being handled, their potential toxicity, and the potential for releases to the environment.

- Review SDSs or other references for recommended spill clean up methods and materials, and the need for personal protective equipment (e.g., respirator, gloves, protective clothing, etc.)
- Acquire sufficient quantities and types of appropriate spill control materials to contain any spills that can be reasonably anticipated. The need for equipment to disperse, collect and contain spill control materials (e.g., brushes, scoops, sealable containers, etc.) should also be reviewed.
- Acquire recommended personal protective equipment and training in its proper use.
- Place spill control materials and protective equipment in a readily accessible location within or immediately adjacent to the laboratory.

Develop a spill response plan that includes:

- Names and telephone numbers of individuals to be contacted in the event of a spill.
- Evacuation plans for the room or building, as appropriate.
- Instructions for containing the spilled material, including potential releases to the environment (e.g., protect floor drains).
- Inventory of spill control materials and personal protective equipment.
- Means for proper disposal of clean up materials (in most cases, as hazardous waste) including contaminated tools and clothing.
- Decontamination of the area following the clean up.
- Discuss the spill response plans with all employees in the area.

8.5. COMPRESSED GAS SAFETY

8.5.1. *Compressed Gases*

Compressed gases can be toxic, flammable, oxidizing, corrosive, and inert or they may possess combinations of these hazards. Besides their chemical hazards, compressed gases are rather pressurized. The amount of energy in a compressed gas cylinder makes it a potential rocket. It is of essential importance to handle and use compressed gas cylinders appropriately.

8.5.2. *Hazards*

Following risks of hazards should be kept in mind while handling, working with storing compressed gases:

- Asphyxiation: This is the most important hazard associated with inert gases. These gases may easily leak into atmosphere and rapidly reduce the oxygen amount below minimum oxygen concentration for human breathing. Since they are colorless and odourless, it is hard to detect the leak. An equipment to monitor oxygen level should always be carried while working with inert gases in enclosed areas.
- Fire and Explosion: This is the most important hazard associated with flammable gases such as oxygen and oxidizers. Static electric or a heat source such as flame or a hot object can ignite flammable gases. Although oxygen or oxidizing agent does not burn, they start a combustion reaction with organic materials. The rate of this combustion reaction enhances as the amount of oxidizers in the reaction medium increase. In addition, non-flammable materials may also burn in an oxygen-enriched medium.
- Chemical Burns: Corrosive gases can chemically attack various materials, including fire-resistant clothing. They may rapidly destruct skin and eye tissue. Some gaseous substances that are normally non-corrosive may become extremely dangerous in the presence of moisture, even in a very small amount.
- Chemical Poisoning: This is the most important hazard associated with toxic gases. A short-time exposure to these gases may result in severe injuries of poisoning, even in very small concentrations. Symptoms of exposure may not be acute, delayed symptoms are more likely to be observed.
- High Pressure: Since the containers/cylinders of compressed gases are in high levels of pressure, they are potentially hazardous. A sudden release of pressurized gas, by means of propelling a cylinder or whipping a line, may cause several injuries.
- Cylinder Weight: A full size cylinder may weigh more than 58 kg. Manual movement of a cylinder, including dropping and dragging may cause injuries concerning back, spinal cord or muscles.

8.5.3. *Handling Precautions*

- Do not drop, drag or slide cylinders. Even for short distances a suitable hand truck or a chain-equipped-cart should be used and cylinders must be belted to secure the cylinder to the cart.

- Do not permit cylinders to strike each other violently. Cylinders are not intended to use as rollers to move other materials or equipment.
- Cylinder caps protect the valve on top of the cylinder from damage, therefore they should be kept on cylinder until it has been secured and the regulator has installed. Securing may be done against a wall or bench or by placing in a cylinder stand.
- Do not tamper with pressure relief devices in valves or cylinders.
- Only the wrenches or tools provided by the cylinder supplier should be used to remove a cylinder cap or to open a valve. Do not use a screwdriver or pliers.
- If the cylinder is not in use, keep the cylinder valve closed all the time.
- Place cylinders in a position that the cylinder valve is accessed easily.
- Compressed gases should only be used in well-ventilated areas. Toxic, flammable and corrosive gases should be kept in a hood or gas cabinet and be handled carefully. Containment systems should be proper to use and there should be only necessary amount of these products kept in the working area.
- A trap or a suitable check valve should be used upon discharging gas into a liquid to prevent liquid from escaping back into the cylinder or regulator.
- Label gas lines if more than one type of gas is in use. This is particularly important when the gas supply is not in the same room or area as the operation using the gases.
- Do not use the cylinder valve itself to control flow by adjusting the pressure.

8.5.4. Storage of Compressed Gas Cylinders

- Secure all cylinders against to a wall, bench or fixed support via a chain or strap placed 2/3 of the way up. As an alternative to straps, cylinder stands can be used.
- Keep the cylinders strapped individually.
- Full and empty cylinders should not be stored together.
- Store oxidizers and flammable gases in areas separately at least 6 m. by a non-combustible wall.
- Do not store cylinders close to heat sources including radiators. Protect cylinders from weather differences if you store cylinders outdoor and damp ground to prevent corrosion.
- Cylinders should not be subjected to temperatures higher than 51 °C. Never permit a flame to come in contact with any part of a compressed gas cylinder.
- Cylinders should not be placed where they may become part of an electric circuit.
- Minimum number of cylinders should be kept in a laboratory in order to reduce the risk of fire and toxicity hazards.
- Cylinder should be properly and prominently labelled as to its contents.
- NEVER place acetylene cylinders on their side.

8.5.5. Using Compressed Gas Cylinders

SDSs, along with label information, of the gas being used should be carefully read prior to use. The cylinder valve outlet connections are intended to prevent incompatible gases from mixing. The outlet threads vary in diameter *i.e.,* some are internal and some are external while some are right-handed and some are left-handed. Right-handed threads are generally used for fuel gases. Follow the steps below to set up and use the cylinder:

- Closed regulators should be attached to cylinders. Unless the regulator is completely closed, do not open a cylinder valve. Note that regulators are gas-specific; therefore they are easily attached to appropriate gas cylinders. Do not force the threads to attach a regulator to a cylinder. Do not force a regulator to attach if the inlet of it does not fit the outlet of cylinder. If the fit is poor, it indicates that the regulator is not intended for the gas cylinder being attached.
- Turning the delivery pressure by adjusting screw counter-clockwise until it turns freely prevents unintended gas flow into the regulator.
- Open the cylinder slowly until the inlet gauge on the regulator registers the cylinder pressure. The cylinder valve may be leaking if the pressure read is lower than expected.
- Turn the delivery pressure adjusting screw clockwise until the required delivery pressure is reached while the flow control valve at the regulator outlet is closed.
- Use a *Snoop* or soap solution to detect a leak. Instead of soap, a mixture of glycerine and water, such as *Snoop*, should be used to check the leaks at/below freezing temperature. Do not use an open flame to check the leak.
- Close the cylinder valve and release regulator pressure when you’re done with compressed gas containers.

8.5.6. Assembly of Equipment and Piping

- Threads should never be forced if they do not fit exactly.

- A Teflon tape or thread lubricant should be used for assembly. Use Teflon tape only for tapered pipe thread, they are not intended to use for straight lines or metal-to-metal contacts.
- Since copper hardens and cracks with repeated bending, do not bend copper tubing sharply.
- Inspect tubing frequently and replace when necessary.
- Since Tygon and plastic tubing may easily fail under pressure or thermal stress, they are not appropriate for most pressure work.
- Brands and types of tube fittings should be the same. Construction parts are usually not interchangeable; therefore do not mix different brands and types.
- Never use oil or lubricants on equipment used with oxygen.
- Never use copper piping for acetylene.
- Never use cast iron piping for chlorine.

8.5.7. Leaking Cylinders

Leaking usually takes place at the valve attached to cylinder and may usually arise from failed valve threads, valve stem, valve outlet, or pressure relief devices. Call LS/LSS in case if there's a necessity to repair a leaking cylinder.

Following action can be taken if there's no risk of serious exposure to lab users:

- Move the cylinder to an isolated, well-ventilated area (away from combustible materials especially if the cylinder contains a flammable or oxidizing gas).
- Contact LS/LSS.
- Evacuate the area and immediately contact security if there's a large or uncontrollable leak takes place.

8.5.8. Empty Cylinders

- When the cylinder is emptied, regulator should be removed and the cylinder cap must be replaced.
- Empty cylinder should be labelled and stored in an area designated to return to the supplier.
- Full and empty cylinders should not be stored together.
- A reverse flow may take place when an empty cylinder is connected to a pressurized system. Therefore, full and empty cylinders should not be connected to the same manifold.
- Empty cylinders should not be filled. Only the cylinder supplier is in charge to refill gases.
- Compressed gas cylinders should never be emptied to a pressure below 25 psi (172 KPa). The remaining contents may become contaminated with air.
- Lecture bottles should always be returned to the distributor or manufacturer promptly when no longer needed. Do not purchase lecture bottles that cannot be returned.

8.5.9. Flammable Gases

- Any possible source of ignition should be kept away from the cylinders.
- Store oxidizers and flammable gases in areas separately at least 6 meters by a non-combustible wall.
- All cylinders, lines and equipment used with flammable compressed gases should be bonded and grounded.

8.5.10. Highly Toxic Gases

Highly toxic gases possess serious hazard and risk of health in case of a leak. Following additional precautions must be taken upon working with or handling the highly toxic gases:

- Highly toxic gases should be stored and used only in well-ventilated gas cabinet or in a fume hood.
- Use coaxial (double-walled) tubing with nitrogen between the walls for feed lines operating above atmospheric pressure.
- To avoid sudden loss of pressure in the supply line, regulators should be equipped with an automatic shut-off to turn off gas supply.
- For a routine check for leaks, an alarm system with proper warning properties should be installed and the alarm level should be set to a level lower than or equal to permissible exposure limits of the gas.
- To install or change highly toxic gases, a self-contained breathing apparatus (SCBA) may be necessary.
- Label the storage and use area as "*Designated area for highly toxic gases*".

8.5.11. Gases Requiring Special Handling

The following gases present special hazards either due to their toxicity or physical properties.

8.5.11.1. Acetylene

Overview

Pressurized acetylene is highly flammable and may undergo spontaneous combustion upon contact with air at pressure levels higher than 15 psig. If released to air in a confined area, acetylene may cause asphyxiation. Acetylene cylinders contain acetone, because acetylene is shock-sensitive and rapidly explode above 30 psi. Since acetone and binders may be dislodged, acetylene cylinders should never be placed on their sides. This may result in a polymerization reaction inside and acetone may also be released into regulator.

Emergency Procedures

In case of skin contact: Skin effects are not likely to occur. An irritation may take place when in contact with liquid acetylene upon repeated exposures. Affected area(s) should be washed with soap and warm water. One should seek medical attention if irritation develops.

In case of eye contact: Since acetylene is gaseous at room temperature, this effect is not a likely route of exposure. Contact of liquid acetylene with the eyes may cause temporary irritation. In this case, eyes should be flushed with water for at least 15 minutes. Medical attention may be asked if needed.

In case of inhalation: Acetylene causes asphyxiation and at high concentrations it may cause anaesthetic effects. Victims should be assisted to an uncontaminated area with fresh air.

In case of ingestion: Since acetylene is gaseous at room temperature, this effect is not a likely route of exposure.

Handling

Shipment of acetylene is carried out in a cylinder packed with a porous material and a solvent such as acetone. When the valve of a charged acetylene cylinder is opened, the acetylene comes out of solution and passes out in the gaseous form. Inspection of fuse plugs in the top and bottom of an acetylene cylinder to detect the solvent loss is of utmost importance whenever handled. Any ignition source should be kept away from storage area. Move the cylinder to an open space and keep away from risk sources if leaking takes place due to incorrect handling or other occurrences. In this case, the cylinder should also be labelled as “Leaking Flammable Gas”.

Storage

Acetylene cylinders should never be placed on their side. Place the cylinder upright carefully if acetylene cylinder has tipped over was stored on its side and do not use until the liquid has settled to bottom. The rule of thumb is not to use the cylinder for as many minutes as the cylinder was horizontally placed, up to 24 hours.

Disposal

Acetylene cylinders should be returned to the compressed gas distributor when emptied or no longer used.

8.5.11.2. Oxygen

Overview

Oxygen is a strong oxidizer and rapidly accelerates spontaneous combustion of many organics. Since there’s a risk of dangerous explosion upon contact high-pressure oxygen with oil, oxygen cylinders should be handled very carefully. Oil or grease should never be used on connections to an oxygen cylinder or gas line carrying oxygen. Oxygen should be stored separately from all flammable materials because it is incompatible with them.

Emergency Procedures

Oxygen gas intended for laboratory use is non-toxic. On the other hand, liquid oxygen is cryogenic and may cause tissue damage when exposed with skin.

Handling

Oil, greases and other readily combustible substances should never be allowed to come in contact with any part of oxygen containers; cylinders, valves, regulators, and fittings. Since pneumatic equipment usually contains flammable lubricants, oxygen should not be used as a substitute for compressed air in pneumatic equipment. There’s a risk of explosion upon contact of liquid oxygen with many organic substances.

Storage

A distance of 6 meters or a non-combustible wall with a fire endurance of at least 1 hour must be maintained between an oxygen cylinder and flammable gases or any combustible material.

Disposal

When emptied or are no longer in use, oxygen cylinders should be returned to the compressed gas distributor.

8.6. CARCINOGENIC, REPRODUCTIVE AND HIGHLY TOXIC CHEMICALS

8.6.1. Reproductive Toxins and Highly Toxic Chemicals

Carcinogens are defined as reproductive toxins and substances that possess high acute toxicity as particularly hazardous substances (PHS). Lab users handling and working with carcinogens need to take additional precautions besides handling toxic substances. Note that carcinogenic chemicals are highly toxic, therefore strong attention is required to be paid while working with these chemicals, particularly if the threshold limits for human health has not been determined. Carcinogens vary in dose requirements to produce a tumour in laboratory animals. In addition, there's a limited standard to compare the carcinogenic effect between human and animal. Yet, any chemical that has lead to a malignant tumour in laboratory animals must be regarded as potential hazard to human health and be handled accordingly. All lab users who are in contact with these type of chemicals should be aware of the risks in a full extent. These chemicals often do not have an acute effect but long term, and the threshold limits are usually uncertain. Seek safer alternatives if possible.

The World Health Organisations International Agency for Research on Cancer (WHO-IARC) has classified carcinogens into three groups as follows:

Category 1 Established human carcinogens. There is sufficient evidence to establish a causal relationship between human exposure to these agents and the development of tumours.

Category 2 Probable human carcinogens. Evidence, usually related to long-term animal studies, suggests that human exposure may result in the development of tumours.

Category 3 Substances suspected of having a carcinogenic potential in humans. In these cases there is limited evidence from animal and epidemiological studies to suggest a hazard.

Exposure to carcinogenic chemicals can result from the following:

- Carcinogens may be absorbed through respiratory system via inhalation of dust or vapor, or both.
- Carcinogens may be absorbed through skin contact with spills or splashes, or through contact with contaminated clothing, benches, apparatus and floors.
- Carcinogens may be absorbed by ingestion for contaminated food. Never pipet by mouth.
- Carcinogens may be absorbed through eye membranes upon contact with dust, vapor or splashes.

There must be a designated area in the laboratory to work with carcinogenic materials. Hands must be thoroughly washed before and after use. In these designated area, several additional precautions need to be taken:

- Always work under a fume hood. The airflow of this fume hood must be at least 0.60 m/s. The exhaust of fume hood should not be fed back into laboratory. Exhaust should also be discharged separately from others since it may create additional hazard risks.
- The surface of working bench for carcinogenic materials should be non-adsorbent so that any spill can be easily cleaned.

Always wear full protective clothing including;

- Rubber, P.V.C. or polythene disposable gloves.
- Buttoned laboratory coats or preferably wrap around gowns, which tie at the back.
- Laboratory safety glasses, or a full-face safety shield if the possibility of a splash exists.
- An approved respirator with a suitable particulate vapour cartridge.

8.6.2. Treatment

In case of an eye or skin contact with a carcinogenic chemical, the affected body part should be immediately washed with cold water for 15 minutes, at least. Hot water accelerates absorption, and water vapor may cause chemical particle to be inhaled through respiratory system. Washing should be continued until all the visible evidence of the chemical has been removed. Safety shower should be used if the area of containment is large, and all the clothing needs to be changed and washed separately from other laboratory apparatus.

Carcinogenic materials should be appropriately labelled and stored in closed screw cap containers. They should be separated from other chemicals. A logbook to record their use is strongly advised.

8.6.3. Destruction and Disposal of Carcinogenic Waste

A solution of sodium dichromate in strong sulphuric acid (*i.e.* chromic acid solution) destroys organic compounds. It takes one or two days to clean all residual organic compounds from materials if the solution is freshly prepared. Residual chromic acid can be disposed of via drain by flushing large amount of water.

A solution of potassium permanganate in acetone is added to carcinogens that readily oxidize to deactivate them. As an alternative, concentrated or 50% aqueous sodium hypochlorite can be used.

Nucleophiles such as water, hydroxyl ions, ammonia, thiols and thiosulphate deactivate alkylating, arylating or acylating agents can be destroyed. This nuclepohillic substitution reaction is easier if it takes place in ethanol.

Aflotoxins should be dissolved in acetone and added to a hypochlorite solution to destroy any 2,3-dichloroaflotoxin B1, which may have been formed.

A solution of potassium hydroxide in methanol deactivates Cyclophosphamide.

Polycyclic aromatic hydrocarbons can be easily oxidized in sodium dichromate-sulphuric acid mixture.

8.7. CHEMICAL STORAGE GUIDELINES

- Ensure all containers of hazardous chemicals are properly labelled with the identity of the hazardous chemical(s) and appropriate hazard warnings.
- Segregate all incompatible chemicals for proper storage of chemicals by hazard class. In other words, store like chemicals together and away from other groups of chemicals that might cause reactions if mixed.
- Do not store chemicals alphabetically except within a grouping of compatible chemicals.
- Flammable materials should be stored in an approved, dedicated flammable materials storage cabinet or storage room if the volume exceeds ten gallons. Keep cabinet doors closed.
- Chemicals should be stored no higher than eye level and never on the top shelf of a storage unit. Do not overcrowd shelves. Each shelf should have an anti-roll lip.
- Avoid storing chemicals on the floor (even temporarily) or extending into traffic aisles.
- Liquids should be stored (Figure 8.5) in unbreakable or double-contained packaging, or the storage cabinet should have the capacity to hold the contents if the container breaks.
- Store acids in a dedicated acid cabinet. Nitric acid may be stored there also but only if it is kept isolated from all other acids.
- Store highly toxic or controlled materials in a locked, dedicated poison cabinet.
- Volatile or highly odorous chemical shall be stored in a ventilated cabinet. Chemical fume hoods shall not be used for storage as containers block proper airflow in the hood and reduce available work space.
- All chemicals should be labelled and dated upon receipt in the lab and on opening. This is especially important for peroxide-forming chemicals such as ethers, dioxane, isopropanol, and tetrahydrofuran. Solutions should be labelled and dated when prepared.
- Look for unusual conditions in chemical storage areas, such as:
  - Leaking or deteriorating containers
  - Improper storage of chemicals
  - Spilled chemicals
  - Temperature extremes (too hot or cold in storage area)
  - Lack of or low lighting levels
  - Blocked exits or aisles
  - Doors blocked or open, lack of security
  - Trash accumulation
  - Open lights or matches
  - Fire equipment blocked, broken or missing
  - Lack of information or warning signs ("Flammable liquids", "Acids", "Corrosives", "Poisons", etc.)

- First aid supplies, emergency phone numbers, eyewash and emergency shower equipment, fire extinguishers, spill clean up supplies and personal protective equipment should be readily available and personnel trained in their use.
- Chemicals stored in explosion-proof refrigerators or cold rooms shall be sealed and labelled with the name of the person who stored the material in addition to all other required hazard warnings.
- Only compressed gas cylinders that are in use and secured in place shall be kept in the laboratory. All others, including empties, shall be sent to the compressed gas cylinder storage area for the particular facility.
- Keep all stored chemicals, especially flammable liquids, away from heat and direct sunlight.

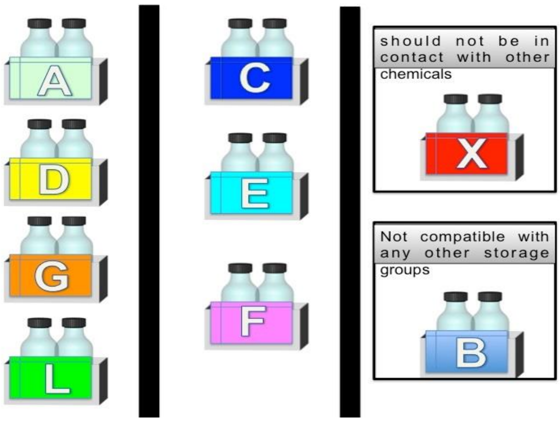


Figure 8.4 Storage groups

A. Compatible organic bases
B. Compatible pyrophoric & water reactive materials
C. Compatible Inorganic bases
D. Compatible organic acids
E. Compatible oxidizers including peroxides
F. Compatible Inorganic Acids excluding oxidizers or combustibles
G. Not intrinsically reactive or flammable or combustible
J*. Poisonous compressed gas
K*. Compatible explosives or other highly unstable materials
L. Non reactive, combustible and flammable, including solvents
X*. Incompatible with all other storage groups

Groups J, K and X requires specific storage. For further information consult to product SDS and LSS.

Along with purchased chemicals, samples prepared by lab users for research purpose should also be stored according to chemical storage guidelines mentioned here.

References

- United Nations Globally Harmonized System of Classification and Labelling of Chemicals (GHS) (2015, March). Retrieved from http://www.unece.org/trans/danger/publi/ghs/ghs_rev04/04files_e.html
- Health and Safety Executive, Chemical Classification (2015, March). Retrieved from http://www.hse.gov.uk/chemical-classification/index.htm
- Duke Occupational Health & Safety Office Hazard Communication (2015, March). Retrieved from http://www.safety.duke.edu/OHS/HazComFAQ.htm
- Zararli Maddeler ve Karışımlara İlişkin Güvenlik Bilgi Formları Hakkında Yönetmelik (2015, March). Retrieved from http://www.resmigazete.gov.tr/eskiler/2014/12/20141213-1.htm)
- US Environmental Protection Agency, Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (2015, March). Retrieved from http://www.epa.gov/agriculture/lfra.html
- US Department of Labour Occupational Safety & Health Administration Hazard Communication (2015, March). Retrieved from
- https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106
- Chemwatch GoldFFX User Guide, Version GFX1.0_2014, 2014 (March 2015). Retrieved from http://jr.chemwatch.net/8uehfjnkzdf8r/
- Eastern School District, Chemical Safety (WHMIS) Safe Work Practices and Procedures (2015, March). Retrieved from

http://www.esdnl.ca/staff/ohs/pdf/oh&sprogram/Safe%20Work%20Practices%20and%20Procedures/Chemical%20Safety%20(WHMIS)%20SWPP.pdf

- Princeton University Environmental Health & Safety, Chemical Specific Protocols (2015, March). Retrieved from https://ehs.princeton.edu/emergencies-and-incidents/emergency-action-plans/emergency-coordinator-program
- Yale University standard operating procedures, potentially explosive and explosive compounds (2015, March). Retrieved from http://ehs.yale.edu/sites/default/files/Chemical_SOP_Explosives.pdf
- Purdue University standard operating procedures, flammable and combustible liquids (2015, March). Retrieved from https://www.purdue.edu/ehps/rem/home/sop.htm
- Berkeley University standard operating procedures settlement class: Water-reactive chemicals (2015, March). Retrieved from http://ehs.berkeley.edu/standard-operating-procedures
- San Diego State University Environmental Health & Safety Department, standard operating procedure for oxidizing chemicals (2015, March). Retrieved from http://bfa.sdsu.edu/ehs/pdf/SOPOxidizing.pdf
- Wake Forest University, Standard Operating Procedure, Oxidizers (2015, March). Retrieved from http://ehs.wfu.edu/files/2014/08/ehs-oxidizers-wfu-sop.pdf
- Yale University, Standard Operating Procedure, Organic peroxides and peroxide forming compounds (2015, March). Retrieved from http://ehs.yale.edu/sites/default/files/Chemical_SOP_Peroxides_PeroxideFormers.pdf
- Tufts University Environmental Health and Safety, Standard operating procedures (SOP) for pyrophoric chemicals (2015, March). Retreived from http://publicsafety.tufts.edu/ehs/files/PyrophoricSOP.pdf
- Cornell University Laboratory Manual and Chemical Hygiene Plan, Chapter 7.6: Safe chemical use; chemical exposure measurement (2015, March). Retrieved from http://sp.ehs.cornell.edu/lab-research-safety/laboratory-safety-manual/Pages/ch7.aspx
- T. C. Resmi Gazete No: 28733, Kimyasal maddelerle çalışmada sağlık ve güvenlik önlemlerinin alınması (2013, August)
- Environment, Health and Safety Online, Chemical Storage Guidelines from the CDC (2015, March). Retrieved from http://www.ehso.com/ChemicalStorageGuidelines.htm

9. CRYOGENIC SAFETY

This section provides safety information and precautions regarding cryogenic fluids and defines the hazards associated with their use.

9.1. DEFINITIONS

A cryogenic liquid is defined as a liquid with a normal boiling point below -150 °C.

Cryogenic liquids escape from their storage containers via evaporation as a part of their normal operation. Properties of cryogenic liquids are shown in Table 9.1. A 160 L tank loses a gas amount equivalent to 2 L of liquid per day, depending on the type of Dewar material used. To minimize the heat loss, cryogenic liquid containers are usually in vacuum-jacketed design. Excessive venting and/or a partial ice accumulation on vessel walls are a sign of an integrity problem in the vessel or in process line. A leaking container should not be used and be transported to a well-ventilated area.

Table 9.1 Properties of cryogenic liquids

Gas	Boiling Point (°C)	Boiling Point (K)	Volume Expansion to Gas
Helium-3	-269.9	3.2	757 to 1
Helium-4	-268.9	4.2	757 to 1
Hydrogen	-252.7	20.4	851 to 1
Deuterium	-249.5	23.6	...
Tritium	-248.0	25.1	...
Neon	-245.9	27.2	1438 to 1
Nitrogen	-195.8	77.3	696 to 1
Carbon monoxide	-192.0	81.1	...
Fluorine	-187.0	86.0	888 to 1
Argon	-185.7	87.4	847 to 1
Oxygen	-183.0	90.1	860 to 1
Methane	-161.4	111.7	578 to 1
Krypton	-151.8	121.3	700 to 1
Tetrafluoromethane	-128	145	. . .
Ozone	-111.9	161.3	. . .
Xenon	-109.1	164.0	573 to 1
Ethylene	-103.8	169.3	. . .
Boron trifluoride	-100.3	172.7	. . .
Nitrous oxide	-89.5	183.6	666 to 1
Ethane	-88.3	184.8	...
Hydrogen chloride	-85.0	188.0	...
Acetylene	-84.0	189.1	...
Fluoroform	-84.0	189.1	...
1,1-Difluoroethylene	-83.0	190.0	...
Chlorotrifluoromethane	-81.4	191.6	. . .
Carbon dioxide	-78.5	194.6	553 to 1

Adopted from Canadian Centre for Occupational Health and Safety, OSH Answers Fact Sheets.

9.2. PRECAUTIONS

Due to the extreme low temperature and high rate of gas escape, a number of precaution and safety measures must be applied while working with cryogenic liquids.

9.2.1. Extreme Cold Hazard

All cryogenic liquids are extremely cold and, along with their vapors, they can rapidly freeze human tissue.

Brief exposures that would not affect skin on the face or hands can damage delicate tissues such as the eyes. Prolonged exposure of the skin or contact with cold surfaces can cause frostbite.

When a tissue freezes, one may not feel pain initially. An intense pain is felt upon thawing. If the skin is unprotected it can stick to metal containers of cryogenic liquids. It may then tear when pulled away. Even non-metallic materials are dangerous to touch at low temperature.

Breathing of extremely cold air for long periods of time may damage the lungs.

Due to low temperature, many common materials such as carbon steel, rubber and plastics may become brittle upon contact with cryogenic liquids and easily break under stress.

9.2.2. Asphyxiation Hazard

Normally, 21% of air is composed of oxygen. Symptoms of asphyxia develop when the oxygen percentage of air drops to 15-16%. At 12% oxygen, the individual will lose consciousness without warning and may be unaware of any danger. Cryogenic liquids produce a large amount of gas upon vaporization. One volume of liquid nitrogen vaporizes to yield 694 equal volumes of nitrogen gas at standard conditions. If the oxygen level is not regulated, asphyxiation may quickly lead to death. The gaseous product formed by cryogenic liquid evaporation is very cold and heavier than air. This gas does not disperse in air, but accumulate near the floor. Although this gas is non-toxic, it replaces the air. Thus, oxygen deficiency becomes a serious hazard risk closed spaces. Therefore, cryogenic liquids should only be used and stored in well-ventilated areas.

Symptoms of asphyxiation include giddiness, mental confusion, loss of judgement, loss of coordination, weakness, and nausea, fainting and lead to death. A few breaths of oxygen-deficient air are enough to reduce the dissolved oxygen level in blood. Once blood oxygen level is dropped, mental failure and coma follow very quickly. Asphyxiation symptoms may not always be observed, even though they do, loss of mental abilities and coordination may make it impossible for people to ask for help.

Gaseous products of most cryogens are odorless, colorless and tasteless. In addition, most cryogenic liquids are colorless, except oxygen (light-blue). The most significant warning property of extremely low liquids and their vapors is that they tend to form visible fog by condensing the moisture around. In other words, a fog cloud does not define the vapor cloud but it rather defines the area where vapor is still cold enough to condense the moisture in the air. Although fog cloud is an important clue to cryogenic gas leak, it is highly probable that the leak extends beyond the fog cloud. Therefore, fog cloud must never be used to define the leak area and should never be entered by anyone.

In summary, cryogenic vapors are undetectable to human sensory system. Therefore, one should not enter a possible oxygen-deflected area without wearing an external breathing air source and without carrying and atmospheric monitor. It is strongly advised to check the safe oxygen level prior to enter these areas.

9.2.3. Oxygen Enriched Air

Liquid oxygen in an enclosed area vaporizes to increase the amount of oxygen in air and saturate the combustibles, such as clothing. This may easily start a fire if an ignition source is present. Oxygen is not flammable, but it starts and accelerates combustion reactions.

Release of liquids below the boiling point of air may condense the surrounding air that leads to an oxygen-enriched local atmosphere. Moreover, extremely cold cryogens, such as helium, may even freeze the surrounding air.

9.2.4. Explosion Due to Rapid Expansion

If a cryogenic liquid vaporizes more than expected in a sealed container, it increases the internal pressure of container, which may lead to a rupture in the container. Therefore, pressurized cryogenic containers are designed in multiple protection devices to prevent over-pressure. A pressure relief device must be installed to prevent liquid trapping. Extra care must be taken while using pressurized containers. Please make sure that you have switched off the valve completely after use.

9.2.5. Special Helium Precautions

The most critical safety concern in dealing with liquid helium is its extremely low temperature. Helium is so cold that once it released it freezes all gases around. This includes not only water, but also nitrogen and oxygen; freezing of these gases inside a Dewar or a pipeline cause an “ice” plug which may lead to closing up the neck and create a bomb. Therefore, it is of utmost importance the set up a procedure for helium usage and to follow it strictly. This helps prevent other gases, including air, from entering the liquid helium delivery lines. If you suspect a blockage, remove the Dewar to a safe place and immediately contact the vendor. If helium is transferred by a piping system without vacuum jacket, air surrounding the pipe may liquefy. After condensation, nitrogen evaporates first, leaving an oxygen-enriched air around the pipe. This area, where the liquid is collected, should be insulated and oxygen-compatible.

9.3. GENERAL SAFETY PRACTICES

Storage and Use

All cryogenic liquids must be stored and used in a well-ventilated area.

- Dewars: Dewars should be selected as non-pressurized, vacuum-walled containers. They should be equipped with a loose-fitting cap or open top and should store only small amounts of liquid.
- Cryogenic Liquid Cylinders: These are sealed, vacuum-walled containers, which do contain pressure up to 350 psig. Cryogenic liquids can also be extracted from these containers.
- Cryogenic Storage Tanks: These tanks range in size from 1900 to 4.5 x 10^5 L and are always pad mounted. Liquid and gas can be extracted from these containers.

Personal Safety

Note that eyes are the most sensitive part of body against extreme cold liquid or vapors.

To handle cryogens, it is recommended to use personal protective equipment (PPE) including full-face shield over safety glasses, loose-fitting thermal insulated or leather gloves, long sleeved shirts and trousers without cuffs. To allow quick removal in case of a spill, gloves should be in loose fit. Note that cryogenic gloves does not allow you to immerse your hand inside a cryogenic liquid, they are only designed for and provide a short-term protection, particularly for accidental contacts. While transferring cryogenic liquids, you should not wear jewellery rings watches *etc*.

Safety Practices

Cryogenic liquids must be handled, stored and used only in containers or systems designed in applicable standards, procedures or proven safe practices.

- To withstand the extreme low temperatures, all the components including piping, valves etc. should be made up of appropriate materials that endure to low temperatures.
- To prevent over-pressure, pressure relief systems should be used in piping.
- Cryogenic containers or any part of these systems that could be valved off should be equipped with a pressure relief valve. These valves should be positioned to face forward.
- During transfer operations including opening cryogenic containers all required PPE should be worn. People must move slowly during transfer. Note that extra care must be taken not to contact non-insulated pipes and other components.
- Open transfers are allowed only in well-ventilated areas.
- Never use a funnel while transferring cryogenic liquids.
- Tongs or other similar devices should be used to immerse and remove objects from cryogenic liquids.
- Hazard reviews are required on all newly purchased, built or modified tools using cryogenic materials.

9.4. EMERGENCY PROCEDURES

- Note that there are no visible evidences of oxygen-deficient atmospheres. They don’t have warning properties.
- Always carry an air source while entering a suspected oxygen-deficient area. Carry air-monitoring devices to measure oxygen levels on site.
- When it is necessary to work in an oxygen-deficient area, supplied air must be provided.
- Should a Dewar of cryogenic liquid be venting continuously, call LS/LSS immediately.

For further information please see Emergency Procedures Section.

9.5. FIRST AID

Frostbite

In case of a skin contact with cryogenic liquid, all the clothing that may restrict the blood circulation should be removed from affected area. Frozen area should never be rubbed as it may result in tissue damage. If practical, affected area should be placed in a water bath with temperature not exceeding 40 °C. Dry heaters should never be used for frostbite. Call Health Center (7666) as soon as possible. Frozen tissue is usually pain-free. Symptoms of freezing are a waxy appearance and a possible yellow color. Once it is thawed, it is prone to swelling, pain and infection. If thawing has started, cover the affected area with a sterile dressing and seek medical attendance. If the exposure is massive, victim's clothes should be removed while showering with warm water. Call Health Center (7666) immediately. In case of eye exposure to cryogenics, warm the frostbite area immediately with water with temperature not exceeding 40 °C. Seek medical attention. Should the body temperature depressed, warm the victim slowly and gradually. Be aware of the shock risk upon hypothermia correction. Cardiac dysrhythmia may be associated with severe hypothermia.

Asphyxiation

Victims exposed to oxygen-deficient air should be immediately moved a normal atmosphere. Artificial respiration should be administrated if the victim does not inhale. If available, administer supplementary oxygen with respirator.

References

- Canadian Centre for Occupational Health and Safety, OSH Answers Fact Sheets. (2015, March). Retrieved from http://www.ccohs.ca/oshanswers/chemicals/cryogenic/cryogen1.html
- NC State University, Environmental Health and Safety Guidelines, Cryogenic Safety. (2015, March). Retrieved from http://www.ncsu.edu/ehs/www99/right/handsMan/worker/Cryogenic_Safety.htm
- United States Department of Labour Occupational Safety & Health Administration, Confined or Enclosed Spaces and Other Dangerous Atmospheres; Oxygen-Deficient or Oxygen-Enriched Atmospheres. (2015, March). Retrieved from https://www.osha.gov/SLTC/etools/shipyard/shiprepair/confinedspace/oxygendeficient.html
- Texas A&M University Office of Engineering Safety, Texas Engineering Experiment Station, Safe Handling &Use of Liquid Nitrogen and Other Cryogenic Gases. (2015, March). Retrieved from https://labsafety.tamu.edu/training/labsafety/PDF/12_LN2Cylinders-color.pdf

10. ELECTRICAL SAFETY

10.1. GENERAL SPECIFICATIONS

In laboratory areas; there are several electric-driven devices ranging from hot plates to lasers. Most of these devices are essential elements of many laboratories. Mishandling or lack of maintenance these devices give rise to insecure working condition or hazards to health of laboratory users.

In addition to this, many equipment work under different voltage, current or other characteristics. Electric energy storing elements like capacitors could pose lethal shock, even if they are disconnected.

10.1.1. Electrical Systems

Laboratories have relatively basic electrical requirement. The entire system must meet Turkish Standard and must be properly examined before being put into service. As far as the laboratory user is concerned, the details of the service to the building are relatively unimportant, but relevant circuits must have capability to provide enough outlets for all of the equipment in the laboratory.

Laboratory activities should not be assigned to spaces provided with standard electrical service until laboratory or industrial type electrical infrastructure is maintained.

All circuits, whether original equipment or added later, should consist of three wires: a hot or black wire, a neutral or white wire, and a ground or green wire. The ground connection should be a high-quality, low impedance ground (on the order of a few ohms), and all grounds on all outlets should be of comparable quality. Low-quality ground can result in a significant difference of potential between the grounds of two outlet receptacles. A further problem which can result from a poor ground is that leakage current through the high-impedance ground connection can develop a significant amount of localized resistance heating. This often can cause an electrical fire, rather than a short circuit or an overloaded circuit.

All connectors, switches, and wiring in a circuit must meet the expectations for the maximum voltage and current to be carried.

The female sockets must be protected with ground-fault interrupters as an additional measure of protection. In case the current is diverted through an electrical short or a person, they will break the circuit in a very few milliseconds, so as not to harm anyone.

The number of outlets should be above the number of equipment in a laboratory and also these outlets must be well distributed. Multiple outlet adapters or extension cords must not to be used. Even if they are used; they should not be placed under stress, and should be protected against pinching, cutting, or being walked upon. Where abuse may occur, they must be protected with a physical shield sufficient to protect them from reasonably anticipated sources of damage.

Circuits must be shielded by circuit breakers for the maximum current to be carried by the circuit. Normally, many breakers for a room or group of rooms are located together on a common breaker panel. All circuits should be described clearly, both within the facility and at the breaker panel, so that when required, the power supply to a given circuit may quickly and easily be cut off. This is especially important when it is necessary to disconnect power in an emergency. There should be no ambiguity about the breaker that needs to be thrown to kill the power to a given device laboratories with high voltage and/or high current sources should consider a readily accessible master disconnect button, which anyone can use to kill all of the circuits in the facility if someone becomes connected to an active circuit.

The location of electrical circuits and electrically operated equipment in a room should be such that they are unlikely to become wet and they should not be in an area susceptible to condensation or where a user might be in contact with moisture.

As unlikely as it may appear, instances have been observed where equipment has been located and electrical circuits have been installed where water from deluge showers would inundate them. For some equipment, such as refrigerators, freezers, dehumidifiers, and air conditioning units, moisture is likely to be present due to condensation, and these items of equipment must be well grounded.

10.1.2. High Voltage and Current

Repairs of high voltage or high current equipment should be performed only by trained electricians.

Laboratory users who are experienced in such tasks and would like to perform such work on their own laboratory equipment must first receive specialized electrical safety related work practices training by LS/LSS.

10.1.3. Altering Building Wiring and Utilities

Any modifications to existing electrical service in a laboratory or building must be completed or approved by Operation and Technical Services. All modifications must meet SU safety standards.

Any unapproved laboratory facilities modifications discovered during laboratory surveys or other activities are reviewed by LSS to determine whether they meet design specifications.

10.2. CARE AND USE OF ELECTRICAL SYSTEMS

10.2.1. Use of Extension Cords

In general, extension cords are not appropriate where a permanent wiring solution is available, regardless of convenience. Extension cords should be used only for temporary purposes. When extension cords are used, the following restrictions apply:

- Use only extension cords that are adequately rated for the intended use and environment. The rating must be denoted not only on the original package but printed on the extension cord insulating jacket. Review the capacity of the extension cord to ensure that you are staying within the cord’s power rating.
- Extension cords may not be run through doors, windows, walls, or ceilings and may not be attached to building surfaces (i.e. walls, ceilings) by staples or other means.
- Extension cords must be protected from damage and may not be placed in such a way that they create a tripping hazard. Do not run extension cords under carpets or any other flooring for protection that was not designed for this purpose.
- Extension cords may not be plugged end-to-**end or “daisy**-chained**”.** Extension cords must be inspected regularly for wear, as it is especially likely around the plug. Worn or frayed cords must be removed from service and replaced. Cracks in extension cords must not be repaired with electrical tape.

10.2.2. Use of Power Strips

Power strips permit more products to be plugged into the same outlet. While power strips may be convenient they may create safety hazards when used incorrectly. Power strips do not increase the amount of power available to a location, but rather more access to the same electrical source. A heavy reliance on power strips generally indicates that additional wall outlets are needed. Follow these procedures when using power strips:

- Select power strips that are properly rated for the application. For example, in a wet chemistry laboratory the power strip must be rated for corrosive and indoor wet locations.
- Read and understand the manufacturer’s instructions and limitations on the power strip. For example, the on/off switch on the power strip may not be designed to interrupt the power of the devices plugged into the strip during normal applications.
- Do not overload the circuit. Review the capacity of the circuit and the power requirements of all of the items plugged into it. This includes not only the items plugged into the power strip but also other devices plugged into wall outlets along the same circuit.

10.3. PREVENTING ELECTRICAL HAZARDS

10.3.1. Common Electrical Hazards and Preventable Steps

The major hazards associated with electricity are electrical shock and fire. Electrical shock occurs when the body becomes part of the electric circuit, either when an individual comes in contact with both wires of an electrical circuit, one wire of an energized circuit and the ground, or a metallic part that has become energized by contact with an electrical conductor.

The severity and effects of an electrical shock depend on a number of factors, such as the pathway through the body, the amount of current, the length of time of the exposure, and whether the skin is wet or dry. Water is a great conductor of electricity, allowing current to flow more easily in wet conditions and through wet skin. The effect of the shock may range from a slight tingle to severe burns to cardiac arrest. Table 10.1 shows the general relationship between the degree of injury and amount of current for a 60-cycle hand-to-foot path of one second's duration of shock. While reading this chart, keep in mind that most electrical circuits can provide, under normal conditions, up to 20,000 milliamperes of current flow.

Table 10.1 Body reactions under effect of electrical current

Current (Milliamperes)	Reaction
1	Perception level
5	Slight shock felt; not painful but disturbing
6-30	Painful shock; "let-go" range
50-150	Extreme pain, respiratory arrest, severe muscular contraction
1000-4,300	Ventricular fibrillation
10,000+	Cardiac arrest, severe burns and probable death

Adopted from Princeton University Environmental Health and Safety Handbook.

In addition to the electrical shock hazards, sparks from electrical equipment can serve as an ignition source for flammable or explosive vapors or combustible materials.

Loss of electrical power can create hazardous situations. Flammable or toxic vapors may be released as a chemical warms when a refrigerator or freezer fails. Fume hoods may cease to operate, allowing vapors to be released into the laboratory. If magnetic or mechanical stirrers fail to operate, safe mixing of reagents may be compromised.

10.3.1.1. Electric shock

Electric shock is another hazard common to many pieces of laboratory equipment. Any electrically powered item of laboratory equipment which is subject to spillage of chemicals or water, or exhibit signs of excessive wear should be used carefully.

Electrical shocks occur when the electrical circuit completed by the part of human body. One way this can occur is by contacting a metallic part of a piece of equipment that has become energized by contact with an electrical conductor. The severity of the electrical shock depends on the following:

- The amount of the current (given as a list above)
- The pathway through the body
- The duration of the exposure
- Whether the skin is wet or dry

A victim of electrical shock could be knocked unconscious. If the victim is still in contact with the live power source, turn off the live source or press the emergency power cut off button before administering aid. Do not touch anyone that is still in contact with a live power source, as you could be electrocuted as well.

After disconnecting power, administer first aid and/or call Health Center (7666).

10.3.1.2. Resistive heating

Even if an individual survives a shock episode, there may be immediate and long-term harm on tissue, nerves, and muscle due to heat generated by the current flowing through the body. The heat generated is basically resistive heating such as would be generated in heating coils in a small space heater.

The scope of the effects of external electrical burns is usually immediately apparent, but the total effect of internal burns may become manifest later on by losses of important body functions due to the destruction of critical internal organs, including portions of the nervous system, which is especially vulnerable.

If a victim has resistive heating burns; you should apply “Burn Kit”, then call Health Center (7666).

10.3.1.3. Spark ignition sources

Induction motors should be used in most laboratory applications instead of series-wound electric motors, which generate sparks from the contacts of the carbon brushes. It is vital to use non-sparking motors in pieces of equipment which result in considerable amounts of vapour, such as blenders, evaporators, or stirrers. Equivalent ordinary equipment or other items such as vacuum cleaners, drills, rotary saws, or other power equipment are not suitable for use in laboratories where solvents are in use. Blowers used in fume exhaust systems should at least have non-sparking fan blades, but in critical situations with easily ignitable vapors being exhausted, it may be worth the additional cost of a fully explosion-proof blower unit.

Any device in which an electrically live circuit makes and breaks, as in a thermostat, an on-off switch, or other control mechanism, is a potential source of ignition for flammable gases or vapors. Special care should be taken to eliminate such ignition sources in equipment in which the vapors may become confined, as already discussed for refrigerators and freezers. It is also possible in other equipment such as blenders, mixers, and ovens and the use of such devices should not be permitted with or in the vicinity of materials which emit potentially flammable vapors.

Spark ignition can cause electrical fire damage in the laboratory. In such cases; the laboratory must be evacuated and the Call Center must be called (9988).

10.3.2. Preventative Steps and Safe Work

10.3.2.1. Preventative steps

There are various ways of protecting people from the hazards caused by electricity, including insulation, guarding, grounding, and electrical protective devices. Laboratory users can significantly reduce electrical hazards by following some basic precautions:

- Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
- Use safe work practices every time electrical equipment is used.
- Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
- Limit the use of extension cords. Use only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.
- Multi-plug adapters must have circuit breakers or fuses.
- Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
- Minimize the potential for water or chemical spills on or near electrical equipment.

Insulation

- All electrical cords should have sufficient insulation to prevent direct contact with wires. In a laboratory, it is particularly important to check all cords before each use, since corrosive chemicals or solvents may erode the insulation.
- Damaged cords should be repaired or taken out of service immediately, especially in wet environments such as cold rooms and near water baths.

Any of the following circumstances requires that the user immediately take the equipment out of service:

- Experiencing shocks, even mild shocks, upon contact
- Abnormal heat generation
- Arcing, sparking, or smoking from the equipment

Laboratory users must label the equipment, “Do Not Use” and should arrange for equipment repair either through the equipment manufacturer or through their department support as appropriate.

Guarding

Live parts of electric equipment operating at 50 Volts or more (i.e., electrophoresis devices) must be guarded against accidental contact. Plexiglas shields may be used to protect against exposed live parts. Figure 10.1.a displays the safety fuse used in Sabancı University.

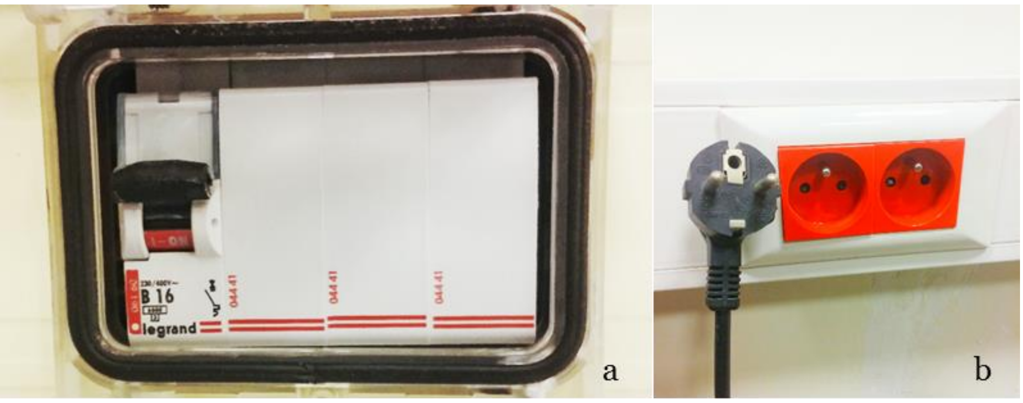


Figure 10.1 Safety fuse (a) and two-prong plug (b)

Grounding

Only equipment with two-prong plugs should be used in the laboratory. The two prong (Figure 10.1.b) provides a path to ground for internal electrical short circuits, thereby protecting the user from a potential electrical shock.

Circuit Protection Devices

Circuit protection devices are designed to automatically limit or shut off the flow of electricity in the event of a ground-fault, overload or short circuit in the wiring system. Fuses and circuit breakers prevent over-heating of wires and components that might otherwise create fire hazards. They disconnect the circuit when it becomes overloaded. This overload protection is very useful for equipment that is left on for extended periods of time, such as stirrers, vacuum pumps, drying ovens, Variacs and other electrical equipment.

The ground-fault circuit interrupter, or GFCI, is designed to shut-off electric power if a ground fault is detected, protecting the user from a potential electrical shock. The GFCI is particularly useful near sinks and wet locations. Since GFCIs can cause equipment to shut down unexpectedly, they may not be appropriate for certain apparatus. Portable GFCI adapters (available in most safety supply catalogs) may be used with a non-GFCI outlet.

Motors

In laboratories where volatile flammable materials are used, motor-driven electrical equipment should be equipped with non-sparking induction motors or air motors. These motors must meet Turkish Standard Electric Safety Code explosion resistance specifications. Many stirrers, variacs, outlet strips, ovens, heat tape, hot plates and heat guns do not conform to these code requirements.

Avoid series-wound motors, such as those generally found in some vacuum pumps, rotary evaporators and stirrers. Series-wound motors are also usually found in household appliances such as blenders, mixers, vacuum cleaners and power drills. These appliances should not be used unless flammable vapors are adequately controlled.

Although some newer items of equipment have spark-free induction motors, the on-off switches and speed controls may be able to produce a spark when they are adjusted because they have exposed contacts. One solution is to remove any switches located on the device and insert a switch on the cord near the plug end.

10.3.2.2. Safe work practices

The following practices may reduce risk of injury or fire when working with electrical equipment:

- Keep away from the energized or loaded circuits.
- Sources of electricity and exposed circuits must be guarded.
- Disconnect the device from the source in the period of service or maintenance of the device.
- Disconnect the power source before servicing or repairing electrical equipment.
- Handling the equipment that is plugged in, if it is necessary, hands or contacting parts must be dry and, wear non-conductive gloves and insulated-soles shoes.
- If it is safe to work with only one hand, keep the other hand away from all conductive material. This step reduces accidents that result in current passing through the chest cavity.
- Utilization of electrical equipment in cold rooms must be minimized due to condensation issues. If it is imperative to use such areas, the equipment must be fixed on a wall or vertical panel.

- If the device interacts with water or other liquid chemicals, equipment must be shut off power at the main switch or circuit breaker and unplugged.
- If an individual comes in contact with a live electric, do not touch the equipment, source, cord or individual. Disconnect the power source from the circuit breaker or pull out the plug using a leather belt.

References

- Furr, A. K. (2000). *CRC Handbook of Laboratory Safety*. Care and Use of Electrical Systems (5th ed.) (pp. 328-336). United States of America: CRC Press LLC.
- Occupational Safety & Health Administration (2012). *Occupational Safety & Health Administration Workplace Safety Awareness Council Train-the-Trainers Guide to Electrical Safety For General Industry* (March 2015.) Retrieved from https://www.osha.gov/dte/grant_materials/fy07/sh-16615-07/train-the-trainer_manual2.pdf
- Florida State University EH&S (2016). *FSU Safety Manual - Electrical Safety in the Laboratory* (March 2015.) Retrieved from http://pub.extranet.fsu.edu/sites/safety/safetywiki/Wiki Pages/Electrical Safety in the Laboratory.aspx
- SUNY College of Nanoscale Science and Engineering (October 15, 2013). *Procedure for Electrical Safety Program* (March, 2015) Retrieved from http://www.sunycnse.com/Libraries/Contractor_Documents/EHS-00054_R4_Electrical_Safety_Program.sflb.ashx
- Texas Tech University (2016). *Laboratory Safety Procedures* (March 2015). Retrieved from http://www.depts.ttu.edu/ece/docs/lab_safety.pdf

11. CLEANROOM SAFETY

11.1. CLEANROOM CONDITIONS

In general, the classifications of cleanrooms are done depending on the number and size of particles permitted per volume of air. Numbers like "class 100" or "class 1000" denote the number of particles of size 0.5 mm or larger permitted per cubic foot of air.

The classifications of cleanrooms are done with two standards; (1) US Federal Standard 209E and (2) the newer standard TC 209 from the International Standards Organization. The number of particles found in the laboratory's air is a basis for these two standards used in classification of cleanrooms. As an example; Sabancı University lab has been classified as a class 10 cleanroom because there are less than 10 particles per cubic foot. Table 11.1 relates FS to ISO classifications:

Table 11.1 ISO 14644-1 Cleanroom standards

Class	maximum particles/m^3						FED STD 209E equivalent
	>=0.1 µm	>=0.2 µm	>=0.3 µm	>=0.5 µm	>=1 µm	>=5 µm	
ISO 1	10	2					
ISO 2	100	24	10	4			
ISO 3	1,000	237	102	35	8		Class 1
ISO 4	10,000	2,370	1,020	352	83		Class 10
ISO 5	100,000	23,700	10,200	3,520	832	29	Class 100
ISO 6	1,000,000	237,000	102,000	35,200	8,320	293	Class 1,000
ISO 7				352,000	83,200	2,930	Class 10,000
ISO 8				3,520,000	832,000	29,300	Class 100,000
ISO 9				35,200,000	8,320,000	293,000	Room Air

Adopted from Brigham Young University, Department of Electrical and Computer Engineering, Cleanroom Classification.

In the K 10,000 two situations exist:

1. Mo - Fri, 07.00 a.m.. - 06.00 p.m. air extraction high
2. Mo - Fri, 06.00 p.m.. - 07.00 a.m., and on Saturday, Sunday and on holidays: air extraction low

Air extraction high: conditions meet safety and minimum contamination level requirements.

Air extraction low: conditions meet safety requirements; minimum contamination level not guaranteed.

11.2. ACCESS

As a general definition, lab usage is defined a privilege that can be suspended or revoked at any time if established procedures and practices are not followed. The aims of these procedures in place are particularly designed to protect the users of lab and their equipment, and therefore it is in the best interest of each user to follow them.

In Microelectronic Laboratory cleanroom (MEL), you must complete the following procedure in order to get an approved.

- Carefully read the information package which can be received from the LS.
- Make a proper arrangement with the MEL Lab Specialist to take a safety tour of MEL.
- MEL safety exam should be successfully passed by demonstrating the basic knowledge about safety and location of safety-related equipment in MEL. It is possible to take this test at your convenience any time after the safety tour.

In order to facilitate safe and efficient operation of the cleanroom, each user must be officially qualified before he/she will be allowed to enter the lab. Qualification requires the awareness of the health and physical/chemical hazards present in the lab, knowledge of safe practices, and adherence to cleanroom conduct guidelines (including gowning).

The next step after becoming an approved lab user is to be trained about the operation of equipment that is necessary for completion of your project. The training program has been offered by MEL in order to promote a safe and effective use of the cleanroom equipment. Please carefully review your need about process with the Responsible Faculty Member and LS to determine whether this training process meets for your fabrication needs or not. In a mutually convenient time of staff and trainee, the time of training sessions are to be scheduled; please recognize and respect the staff member's need to get other work done.

As a new operator, it is expected from you to learn the machine's routine operation and its hazards. This will involve primarily in-lab training and some out-of-lab reading. After training session, it is your responsibility to demonstrate the staff that you can operate the machine properly. After demonstration of necessary knowledge and skills about equipment and the staff member is sure that you are qualified to run the equipment, your name will be added to the "Approved Operators" list maintained by the LS.

Equipment in cleanroom is under MEL LS's responsibility. LS is responsible for training of new operators, performing routine and emergency maintenance tasks, and monitoring process data for quality control and reproducibility (e.g., deposition rate, sheet resistance, film thickness). All users are required to fill out process logbooks and make the process parameters of his/her experiments available to cleanroom staff. If there's a deviation from standard operation of a machine, LS should be communicated and informed as soon as possible. This system is designed to keep the machines in their best operating conditions and to track the process history.

11.3. CLOTHING

Proper gowning is an important part of cleanroom maintenance and serves to prevent, or at least minimize the contaminations and particle formation arising from human body and clothing. Human can be considered as the "dirtiest" object in a cleanroom and the main source of contamination. Recall that the airflow in a cleanroom is downwards *i.e.,* from ceiling to floor. Thus, floor is the dirtiest place and is where most particles are found. Thus, gowning steps (listed below) should be from top to bottom, while de-gowning is in reverse order:

- Remove your coat or jacket before entering the cleanroom. There's a coat rack available at the corner of cleanroom entrance. Personal items should not be carried into cleanroom. Also, if you are wearing woollen clothes you should remove them before entering the cleanroom in order to prevent electrostatic discharge (ESD) to your work.
- Once you enter cleanroom entry room, put on a pair of shoe covers. This is done by wearing one shoe cover and swinging the leg over the bench, then covering the other shoe and swinging that as well. You are not allowed to wear uncovered shoes beyond this point.
- Wear cleanroom hood. Your hair should be fully covered with hood.
- Wear the coverall, tuck in hood flaps and zip all the way.
- Put on boots over legs of coverall.
- Put on safety glasses or goggles. Since chemicals may permeate contact lenses and adsorbed on them, contact lenses are not recommended to use in cleanroom. Personal glasses including prescription lenses offer sufficient protection.
- Wear vinyl gloves. Care should be taken not to touch the outside of gloves with bare hands. Pull the gloves over sleeve of coverall.

Once you carry out all the steps in turn, you are ready to enter the cleanroom. Without gloves you shouldn't touch the door handle, or anything beyond it. The gloves, along with blue inner shoe cover are disposable and therefore should be disposed after use. The garment, on the other hand, can be worn several times. If your gloves are teared or dirty, you can replace them inside cleanroom.

As personal safety measures state, shorts, skirts and open-toed (or open-sided, open-heeled) shoes of any kind should not be worn in cleanroom. It is advised to keep another pair of lab shoes or pants available and worn prior to entering cleanroom. There are lockers available at the entrance of cleanroom. You may request a locker from LS.

In addition, visitors coming with you on an approved cleanroom tour should also follow all the clothing rules of cleanroom and are not allowed to enter cleanroom without wearing the clothes mentioned above. Registered cleanroom user is the main responsible to make sure that visitor is appropriately attired before entering. There will be no exceptions to this rule. Cooperation of all lab users is highly appreciated.

MEL LS should approve a cleanroom lab tour. Requests for cleanroom tour are made in advance. Size of the tour group should not exceed 3 users. For group tours with more than 3 person, please consult to LS.

11.4. WORKING ALONE

Working in the cleanroom is subject to certain limitations. It is restricted to use cleanroom between 06.00 pm - 07.00 a.m. from Monday through Friday and on Saturdays, Sundays and holidays. Depending on the situation and the equipment to be used the following categories are distinguished:

- Working alone is allowed
- Working alone is not allowed.

The second category should not be exposed to the same risk and should be well qualified to operate in case of emergency.

11.5. WORKING WITH WET CHEMICALS

- Wearing appropriate protective equipment (safety glasses, gloves, etc.) is mandatory.
- While working in the laminar flow of the clean benches, keep clear of exposure by inhalation of vapor. Do not put your head inside the fume cupboard.
- Once you pass the test, you are allowed to work with chemicals independently.
- When the air extraction is lower than usual (06.00 p.m. - 07.00 a.m.), it is not allowed to:
    - work with chemicals alone. There must be an experienced person working with you.
    - work with HF, bromine and peroxide solutions.
- When you finished your experiments, do not leave chemical residues. Everything, including the workspace, should be cleaned after use.
- Hands should be washed thoroughly with soap and water after you leave the cleanroom.
- Due to potential fire risk, organic solvent should not be placed anywhere close to hot plates. Organic solvents are only allowed to be heated in a water or oil bath.
- Recall that water should never be added on top of acids or bases.
- Since they are incompatible, organic liquids should be stored away from acids, peroxides and alkalines. They may give rise to an explosion.
- Always report the spills by calling the LS/LSS.
- When chemicals spilt on the body, then with:
    - HF: Immediately rinse with lage amounts of water. Alert the LS/LSS to apply first aid with the HF emergency kit.
    - Acids & alkalines: Immediately rinse with Diphoterine spray bottle; contact LS/LSS afterwards.
    - Organic liquids: Immediately rinse with Diphoterine spray bottle; contact LS/LSS afterwards.
- When chemicals spilt outside the workbench then with:
    - Strong acids: Call LS/LSS.
    - Organic liquids: Quickly absorb the liquid with tissues/absorbant mats.

Procedures to follow in the case of a calamity are explained in the "emergency procedures" section.

11.6. WORKING WITH EQUIPMENT

- Please schedule your runs in advance when possible. Do not sign up for more time than you think you may need.
- Comply with your schedule. If you do not log into the equipment within 15 minutes after your time begins, you will lose your time and other users may use the equipment.
- Remove tooling (boats, sample holders, etc.) from systems and clean-up particles from process chamber. Note any anomalies to the staff and next user.

NOTE: To establish a safe use of equipment, all approved MEL users are required in the cleanroom during the operation of equipment. Exceptions to this rule are furnace tubes because a deposition may take extended time periods.

11.7. CONTAMINATION CONTROL

- Necessary clothing should be worn properly. See Protective Clothing section.
- Gloves should be worn all the time including clean bench use, lithography experiments and loading/unloading reactors.
- There are designated cleanroom papers available to make notes. Normal paper is only allowed in cleanroom if it is sealed in plastic. It is strictly forbidden to use any kind of wood, cardboard or packing materials.
- Minimize the amount of items to take into cleanroom with you. Substrate boxes, syringes, ball pen or felt pen are allowed, but pencils are strictly forbidden.
- While working with benches, keep your head outside.
- Redundant clothes (jacket, jumper, etc.) and bags are not allowed in cleanroom. They should be kept in wardrobes at the entrance of cleanroom. Valuable items can also be stored in lockers.
- Avoid any turbulence: Do not hurry; use minimal working area on a clean bench, but stay in the centre of the down flow.

11.8. CLEANROOM EVACUATION PROCEDURE

Cleanroom evacuation reasons are listed below. If one of the conditions listed takes place while you are working in the cleanroom, you should warn other people in the cleanroom so that they can evacuate and help precede the protocols. Reasons to evacuate cleanroom include:

- Power loss: In this case, do not pull the fire alarm.
- Fire: You should pull the fire alarm and hazard gas shut-off button.
- Hazardous gas leak: In this case you should engage the hazard gas shut-off button.
- Major chemical spill outside a chemical hood, such as breaking a chemical bottle
- Unconscious lab user: You should notify other lab users.
- Non gaseous chemical exposure
- Physical injury
- Medical emergency
- Loss of fume hood exhaust

Please conduct the following procedure in case of an emergency event listed above:

- Immediately stop what you are doing, aborting your process.
- Quickly proceed to the closest emergency exit available. Do not run unless there is a life-threatening situation.
- Engage the hazardous gas shut-off button while evacuating cleanroom. Trigger the fire alarm in case of fire.
- Make sure that other people are evacuating cleanroom. If there are people not able to exit by her/his own, call security (7555) to help them. Do not lose time to remove cleanroom garments.
- Once you are out of cleanroom, proceed to the first floor exit of FENS building. Call LSS and report them about the incident.
- If they are not present in the event of evacuation, notify MEL LS.

It is not necessary to evacuate cleanroom in cases of:

- Small chemical spill inside a hood
- Inert gas leak

11.9. CLEANROOM CONDUCT

Next sections focus on approved and non-approved behaviour while using cleanroom. As a rule of thumb, if you are not sure whether or not you are allowed to do something, DON'T!

11.9.1. Cleanroom Conduct-General Behaviour

- If you see, hear or smell something unusual, use common sense and take necessary action.
- Adopt a "better safe than sorry" attitude.
- Report any violations of the rules to LS.
- Report equipment problem, malfunction, or breakage to appropriate LS.
- Hood, gown, booties with shoe covers, masks, gloves, and safety eyewear. Bouffant caps are required for long hair.
- Keep all hair and ears covered with hood or cap.
- Never open your gown in the cleanroom.

- No corrugated cardboard, styrofoam, foam rubber or non-cleanroom paper is permitted in the cleanroom.
- Be considerate by cleaning up your own mess, not messing up someone else's work.
- Let the LS know when new supplies are needed, etc.
- No pencil, erasers or retractable pens are permitted in the cleanroom.
- Only authorized users may enter the cleanroom unescorted.
- No eating and drinking is permitted in the lab.
- Smoking is not permitted in the lab.
- Ask for permission before bringing anything in or taking anything out of the cleanroom.
- Do not run in the lab.
- DO NOT modify equipment without the approval of the LS.
- Do not cover up any equipment problem or breakage. This will only make the situation worse.
- If you are not sure how a system works or anything else about it, ask the responsible person before you use it and in case something worse happens. Please do not be ashamed or hesitate to ask.

11.9.2. Cleanroom Conduct-Contamination Control

- Hair should always be inside the hood/mask.
- Tacky mats in the entrance of cleanroom help decrease the dirt.
- Gloves should be replaced if they are dirty.
- Only pens and paper provided by cleanroom staff should be used.
- Make sure that you leave your working space cleaner than you found.
- Any material brought to cleanroom should be cleaned with isopropanol (IPA) and cleanroom wipe prior to enter cleanroom. There is IPA available at the entry terminal. Note that LS should approve any item intended to brought to cleanroom beforehand. An exception to this rule is wafer boxes and holders.
- Gloves should be worn all the time. Do not touch anything without gloves.
- Once you wear your gloves do not contaminate them by touching your skin, face or hair.
- Do not bring paper or cardboard into the lab.
- Do not transfer quartz-ware or Teflon-ware between equipment, particularly the thin film furnaces.
- Do not deviate from your approved process sequence.

Teflon-ware can only be used in a designated hood. Teflon tanks or graduated cylinders cannot be transferred between hoods. Being aware of that the possibility of chemical contamination is low, LS attempts to minimize the risks arising from these kinds of occurrences. In addition, Teflon wafer boats for wet chemical processing should not be removed from their designated area. In other words, when you have successfully rinsed and dried following a chemical process, you should transfer the process wafers to your process box (usually a black process box) and then remove them from the fabrication medium.

11.9.3. Cleanroom Conduct-Wafer Handling And Storage

- Vacuum pens or wafer tweezers are used to handle wafers.
- If applicable, “dump” transfers are done from-cassette-to-cassette.
- “In process” wafers can be stored by sealing and labelling. Keep them either in storage bins or in a dry-box.
- Conduct appropriate labelling, *i.e.* your name, PI’s name, run name/number, date started, your phone number. Note that unlabelled wafers are subject to discard.
- Broken wafers in the container can be discarded. You may consult LS for disposal procedure. Wafers or any part of them are not discarded in common waste. Note that this **violates Sabancı University FENS standards and may result in injury** of you or others.
- Never touch wafers with hand or using tweezers.
- Never conduct your process with a broken or partially broken wafer*.
- Do not breathe on wafers.

* Permission of LS is required for processing partial wafers. Before starting a process with a partial wafer or with wafer different than the standard sizes (smaller or larger than 100 mm (4”)) you should ask and receive approval. Please be aware that resources of MEL are limited assisting such fabrications and processing.

11.9.4. Cleanroom Conduct-Chemical Handling and Storage

- Chemicals should be poured slowly and carefully. Note that acids are added to water upon mixing.
- Wear necessary personal protective equipment, including face shield, chemical-resistant gloves, sleeve guards, and an apron while pouring chemicals.
- Chemicals should be transported, stored and disposed of carefully.
- You should know the location of first aid kits, eyewashes and SDS's. Note that FENS provides an online SDS tracking software called as ChemWatch.
- Prior to disposal, you should rinse acid bottles at least 3 times in the hood where it is used. Empty acid bottles should be stored in boxes near acid cabinet. LS regularly sends these bottles to waste. Plastic bottles may be disposed of in the recyle bins.
- While lift-off processes, organic acids are allowed in metal etching. But they should not be used is acid/base metal etching is being carried out.
- Organics solvents, particularly acetone, and their designated area to use are separated metal etching area. Cleaning of glassware should be carried out at this designated area.
- All organic solvent bottles should be returned to solvent storage cabinet after use. In addition, organic solvents in squirt bottles should also be stored in solvent hood.
- Note that the primary sources of exposure to chemicals are:
  - Skin- Absorption
  - Lungs- Inhalation (the fastest route for chemicals to enter the bloodstream)
  - Mouth- Ingestion
- Chemical bottles should not be opened outside of a fume hood.
- You should not use chemicals you are not familiar with unless you review their SDS.
- Unlabelled chemicals should not be used.
- Solvents and acids should never be mixed or used in the same working area. Note that this mixture may lead to an explosion.
- Colorless drops may not be water. Do not assume they are water drops and act accordingly.
- Chemicals should not be disposed of via drain.
- Containers of chemicals should not be stored in hoods.

11.9.5. Cleanroom Conduct-Gas Handling and Storage

- Only approved carts should be used to transport gas cylinders.
- You should be aware of and take precautions regarding risks of hazards related to gases to be used.
- Gas cylinders should be secured all the time.
- You should be aware of the locations of emergency gas shut-off buttons, emergency exits and fire extinguishers. You should also know emergency evacuation procedures regarding gases.
- Odor is not a detection method for possible toxic gas leaks. Do not try to detect a gas leak by odor.
- Inert gases are hazardous. Do not assume otherwise.

11.10. LIST OF COMPRESSED GASES USED IN MEL CLEANROOM

The list of the compressed gases used in MEL cleanroom is shown in Table 11.2.

Table 11.2 List of compressed gases used in MEL cleanroom

Name	Formula	Hazard Statement
Argon	Ar	May cause drowsiness or dizziness
Nitrogen	N_2	May cause respiratory irritation, drowsiness or dizziness
Oxygen	O_2	May cause or intensify fire; oxidiser, may cause respiratory irritation
Sulfur Hexafluoride	SF_6	May cause drowsiness or dizziness
Tetrafluoromethane	CHF_4	May cause drowsiness or dizziness

Notes:

- Inert and non-flammable gases, although non-toxic, can cause asphyxiation (suffocation) by displacing oxygen.
- Pyrophoric means spontaneously combustible in contact with air.
- Any gas not labelled properly should be considered toxic.
- Loss of nitrogen to turbo-pumps or cryo-pumps may result in pump in the buildup of toxic waste. Under no circumstances should non-MEL staff attempt any repair or restorative action on vacuum pumps associated with MEL equipment.
- Safety data sheet (SDS) are available for review at any time. Please contact LSS for any safety information.

References

- Brigham Young University, Department of Electrical and Computer Engineering, Cleanroom Classification (2015, March). Retrieved from http://www.cleanroom.byu.edu/particlecount.phtml
- Clean Air Technology Inc., Cleanroom Planning Guide (2015, March). Retrieved from http://www.cleanairtechnology.com/cleanroom-classifications-class.php
- Delft University of Technology, Safety and Behavior Rules of the Kavli Nanolab cleanroom (2015, March). Retrieved from http://www.tnw.tudelft.nl/live/pagina.jsp?id=d32671fa-4621-4f9e-bb03-dda922a09cc3&lang=en

12. MECHANICAL SAFETY

Machine Shop facilities must be kept in properly working status and maintained in safe working and handling environment by every personnel. Self-discipline and good working manner is the key to success for laboratory and the workshop.

Any accident or mishap may damage equipment, cause injury or death.

There are general rules and guidelines for the people working with mechanical devices to follow. There are also operational manuals and specific rules for every item of mechanical equipment to be followed by users.
When you are operating a machine or a mechanical apparatus, you should always adopt a defensive attitude and be aware of the source of danger.

12.1. GENERAL SAFETY RULES

Following are the general safety rules for the people who work with mechanical devices.

- Most workshop machinery is fitted with a safety device and this must not be removed except under the direct supervision of the LS of the Workshop. Control of the safety equipment and its positions is under responsibility of the operators before using machinery. If equipment malfunctions during operation, the machine must be shut down and reported to the LS of the workshop.
- All workshops should be maintained in a sanitary condition and all workshop users should assist by returning tools and equipment immediately after use.
- Tools are not to be stored on machine beds while the machine is running. Nothing should be stored on the floor where a tripping hazard may be created and any spillages must be cleaned up immediately. Metal waste bins are provided for chip and scrap.
- All possible occupational hazards must be reported e.g. breakage on tools and machinery, faulty wiring, worn or defective equipment and unsatisfactory storage arrangements, accidents or potential accidents must be reported to the LS of the workshop.
- Personal protective equipment e.g. all eye, ear, breathing, clothing, gloves provided must be used when applicable.
- Proper racking facilities are provided for storage of sheet materials, rods, and bars. Vertical racking can be dangerous unless a safety chain or bar is used, and in horizontal racking the chance of accidental contact with the protruding end of rods and the sharp corners of sheet materials should be minimized.
- Portable electrical equipment (e.g. drills) must be regularly inspected visually, and electrically tested in accordance with electrical code of practice. The cables of the portable devices should not be loose on the floor as far as possible and certainly out of the circulation areas. Portable devices and heavy machinery must be switched off when not in use.
- Compressed air must never be used for blowing dust or swarf off clothing, skin or machinery. Incorrect utilization of compressed air may cause embolism, blindness or deafness to personnel and damage to nearby machinery.
- People who will use the machinery in mechanical laboratories must have training in machine tool operation.
- Appropriate eye protection (spectacles, goggles or a face mask) should be worn where there is a hazard of flying objects, small particles or dust arising out of the use of the machinery. Where cutting oils and similar liquids are in use, dermatitis presents a real hazard. Exposed skin should be protected by gloves, barrier creams and good hygiene practices, (following a suitable risk assessment). Hearing protection (ear plugs) should be readily available to shop users.

- Loose clothing, neckties, gloves, rings and other jewellery, long hair (unless tied back and/or covered up), fabric first-aid dressings and bandages and any other material likely to be entangled by the machinery should be avoided. Close fitting overalls with no external pockets should be worn.
- Many accidents can be avoided by the wearing of boots or shoes having built-in steel toecaps and reinforced, non-skid soles, especially in areas where oil is present or heavy equipment is being moved. Workshop users and plant operators should therefore be encouraged to use such approved safety footwear.
- No person should work alone. In certain situations people may establish a buddy system where people located in other parts of the building are responsible for checking to see that the shop user is safe at all times. A possible implementation might involve to call with cell phones. The “buddy” could then call the user every 15 minutes or so to check on his safety. If the “buddy” does not get a response, he/she would then immediately go to the shop area to check on the shop user.

12.2. SAFETY ISSUES WHEN USING MACHINE TOOLS

Machine tools located at Machine Shop are divided into two groups: manual (conventional) and CNCs. The manual machine tools are not covered fully with a protective case. CNC Machine tools on the other hand, are fully covered but can go up to very high spindle speeds and feed rates. Therefore, when using both types of machine tools, people should be very careful and be defensive when taking actions.

It is essential that people / students / machine operators receive quality and working instructions before attempting to use any CNC equipment.

The detailed cautions when using these meachine tolls are given below:

12.2.1. Drilling Machine Tool

- Drilling must be operated at the correct speed according to the diameter of drill bit and material.
- Sample must be clamped or attached to the drill table and controlled several times.
- Use a correctly drill for the material being drilled. Machine shop personnel can help select the correct drill type.
- Appropriate cutting fluid must be chosen for the material. Ask the machine shop personnel about the appropriate fluid for the material you are machining.
- Chips must be removed by brush, not by hand.
- Ease up on drilling pressure as the drill starts to break through the bottom of the material
- Don't use a worn or cracked drill. Inspect the drill before using.
- Material must be supported with backing board or on parallel when drilling through material.
- Always clean drill shank and/or drill sleeve, and, spindle hole before mounting.
- The drill must be loosen when the power is off.
- The drill spindle must be lowered close to the table when releasing the drill chuck or taper shank drill to reduce the chance of damage should when they fall onto the table.
- Always clean the machine in off mode.
- If the drill binds in a hole, stop the machine and turn the spindle backwards by hand to release the bit.
- When drilling a deep hole, withdraw the drill bit frequently to clear chips and lubricate the bit.
- Always remove the drill chuck key or, the drill drift from the spindle immediately after using it.
- Let the spindle stop of its own accord after turning the power off. Never try to stop the spindle with your hand.
- Plexiglass and other brittle plastics can be difficult to drill. Ask the machine shop LS for advice on drill and coolant selection when drilling these materials.
- Wear protective safety glasses when drilling.

12.2.2. Milling Machine Tools

- Workpiece must be clamped securely in a vise and the vise clamped tightly to the table, or workpiece must be clamped securely to the table.
- Make sure cutter is rotating in the proper direction before cutting material.
- Appropriate cutting fluid must be chosen for the material. Ask the machine shop LS about the appropriate fluid for the material you are milling.
- Milling must be operated in correct speed according to diameter of milling bit and material.
- Do not approach movable parts of the milling machine during operation.

- Do not touch the tool or tool holder when rotating. Otherwise, user might be hauled by the rotating machine, which may result in serious injuries or accidents.
- Sharp and good condition cutters must be used.
- Don't place anything on the milling machine table such as wrenches, hammers, or tools.
- Feeding speed and weight must be determined.
- Remove the collet tightening wrench immediately after using it.
- Use the milling machine spindle brake to stop the spindle after the power has been turned off.
- Before cleaning the mill remove cutting tools from the spindle to avoid cutting yourself.
- Wear protective safety glasses when the milling machine tool is running.

12.2.3. Lathe (Turning Machine Tool)

- Make sure that the chuck, drive plate, or, faceplate is securely tightened onto the lathe spindle.
- Machine must be off, when removing/installing the chuck, drive plate, or faceplate.
- Move the tool bit a safe distance from the collet or chuck when inserting or removing work.
- Machine must be operated in proper cutting speed according to diameter of milling bit and material.
- In setting up the tool holder place it to the left side of the compound slide to prevent the compound slide from running into the chuck or spindle attachments.
- Always clamp the toolbit as short as possible in the toolholder to prevent it from breaking or chattering.
- Always make sure that the toolbit is sharp and has the proper clearance. Ask for assistance making adjustments.
- If any filing is done on work revolving in the lathe, file left handed to prevent slipping into the chuck. Never use a file without a handle.
- If work is turned between centers, make sure that proper adjustment is made between centers and that the tailstock is locked in place.
- If work is being turned between centers and expands due to heat generated from cutting, read just centers to avoid excessive friction.
- Do not grasp or touch chips or turnings with your fingers, but get rid of them using a blunt instrument. It is safer to turn off the lathe before clearing chips then to leave it running.
- Set the toolbit on the centerline of your work to prevent work from climbing over tool or cutting above center and dragging.
- Don't cut work completely through when turning between centers.
- Remove chuck key from chuck immediately after using.
- Turn chuck or faceplate through by hand before turning on the power to be sure there is no binding or clearance problem.
- Stop the machine before taking measurements.
- Before cleaning the lathe remove tools from the tool post and tailstock.

12.2.4. Band Saw

- The upper guide and guard should be set as close to the workpiece as possible.
- In case of band breaking, the power must be shut off the power and stand clear until the machine has stopped.
- The blade must be examined before installing to see if it is cracked, cracked blade must not be installed.
- Proper pitch blades must be used for the thickness of the material to be cut. There should be at least 2 teeth in the material when cutting aluminum and three teeth when cutting steel. Check the speed table for the material that you are cutting. Do not run the band saw too fast or the blade will wear out quickly.
- If the saw stalls in a cut, the power must be off and the blade must be reversed by hand to free it.
- Wear protective safety glasses when the saw is running.

12.2.5. Grinding Machine Tool

- Special training is required before using the surface grinder CNC machine tool.
- Abrasive wheel machinery shall not be operated without the appropriate guards in place.
- Never use a wheel that has been dropped or received a heavy blow, even though there may be no apparent damage. Such wheels may be weakened or unbalanced enough to fly apart on startup.
- Do not grind on side of wheel unless wheel is specifically designed for such use.
- Any cracked, broken or otherwise defective wheels must be reported to LS/LSS immediately.

- The new wheels must be mounted and balanced by the supervisor.
- Hold work securely while grinding, use the tool rest to support the work when off-hand grinding on bench or pedestal grinders.
- When grinding Aluminum extra precautions must be taken as the Aluminum dust is explosive. A proper grind and cutting parameters should be selected.
- If a magnetic chuck is being used, on the surface grinder, make sure it is holding the work securely before starting to grind.

12.3. SAFETY ISSUES WHEN USING HAND AND POWER TOOLS

Dimension and roughness mesurement tools located in Manufacturing Research Lab and other labs are used to measure precise dimensions. Therefore, they have high accuracy and misusage leads the tool to loose its function. Also improper usage of these tools may be hazardous for the user. Although they are safer than any other equipment in the lab, if users follow the rules below will not face any circumstanec that will lead to an accident.

12.3.1. CMM (Coordinate Measurement Machine)

- Since CMMs located at MRL have high accuracy and complicated user interface, untrained lab users must not use them.
- The probes should be changed while the machine is off.
- The probes are very vulnerable, therefore while carrying or changing the probes people should pay extra attention.
- User makes sure that there exists no obstacle on the table and the table is clean before starting the measurement.
- While measuring do not touch the axis or the probe with your body.
- After the measurement table should be cleaned and probes should be taken off.

12.3.2. Precision Measuring Tools

- Calipers have sharp tips. Users should not use the tips of the calipers other than for measurement.
- Johnson gauges are very accurate and have sharp edges. When carrying and using the gauges people should be careful.
- Micrometers are high accuracy measurement tools and should only be used to measure workpieces.
- Surface roughness touch probes have a needle like geometry. These devices should only be used to measure surface roughness. The touch needles must never be taken off from its cover.
- Nanofocus and dyno digital cameras have precise lenses. When focusing user should pay attention to not to break them.
- All precision measuring tools have their own storage area and cover. People should put the devices back once they finished the measurements.

12.3.3. Hand Tools

- Use only tools that are in good condition. If a tool is in poor condition, turn it over to the Responsible Faculty Member or the lab technician.
- Rough, broken or loose tool handles must be replaced before using them.
- Wrenches with sprung or spread jaws should not be used.
- Be sure the jaws of wrenches are adjusted to fit tightly on the nut, bolt or pipe before putting strain on the wrench. Always pull on the wrench if possible.
- Only polymer hammers must be used to strike hardened tools or machine surfaces.
- Worn screwdrivers with rounded or broken points must not be used.
- When using a screwdriver, place the workpiece on a bench or some solid object. Never hold the part in your hand.
- Tools must be used correctly. Do not use screw drivers as pry bars or chisels. Do not use wrenches as hammers.
- Sharp edges of tools with a shield must be protected or covered when they are being carried.

12.3.4. Power Tools

Portable power tools have hazards similar to stationary machine tools. There are additional risks associated with handling the tool. Typical injuries and hazards caused by portable hand tools include burns, cuts, and strains. Other sources of injury include electric shock, particles in the eyes, fires, falls, explosions and falling tools.

- Cords or hoses must not be left lying on the floor where they may be a trip hazard.
- Cords or hoses must not be hanged from nails, bolts or sharp objects.
- Cords and hoses must be kept away from oil, hot surfaces and chemicals.
- Wear protective safety glasses when operating a portable power hand tool.
- Appropriate respirator must be used when the use of a power tool may generate airborne dust, powders, etc.
- Never operate a power tool in the presence of combustible materials or liquids. Sparks from the tool itself, or from contact of the active tool with the work or surrounding area can easily ignite combustibles.
- Tools which generate excessive dust or debris may not be used in the machine shop area.

12.4. MATERIAL HANDLING

Strains, sprains, fractures and bruises are common injuries related to the handling of materials. They are caused primarily by improper lifting techniques, carrying too heavy of a load, incorrect grip, failure to observe foot and hand clearances, and failure to wear protective equipment.

- Inspect material for slivers, burrs, and rough or sharp edges.
- Keep your hands free of oil or grease, wipe off any grease or slippery objects before you move them.
- Keep a firm grip on the object to be moved.
- If an object is heavy or clumsy get help lifting it. Discuss beforehand how the object is to be moved and set down.
- Be sure the path over which an object is to be moved is clear of obstructions before you start.
- Always lift with your legs and not your back.
- Watch pinch points, especially when setting the object down.

References

- University of Auckland EH & S. *Safety guidelines of University of Auckland* (2015, March). Retrieved from http://www.science.auckland.ac.nz/uoa/science/for/staff/health_safety/mechanical_safety.cfm
- UC Santa Barbara. (2016). *Mechanical Engineering - UC Santa Barbara Safety Guidelines* (2015, March). Retrieved from http://www.me.ucsb.edu/course_pages/course_pages_w03/me12s/shop_safety_guideline
- California State University Sacramento (2016). *Laboratory Safety Rules*. (2015, March). Retrieved from http://www.ecs.csus.edu/me/undergraduate/MEMET projects/Lab Safety Rules_JH.doc.
- Harvard University EH & S. *Machine Shop Safety* (2015, March). Retrieved from https://www.ehs.harvard.edu/programs/machine-shop-safety
- The University Texas at Arlington. (2016). *Rules For The Robotics Lab Of The University Of Texas* (2015, March). Retrieved from http://mars.uta.edu/mae4345/syllabus/robpolicy4345_f07.pdf
- City University of Hong Kong (2016). *Safety training course of City University of Hong Kong* (2015, March). Retrieved from http://www.cityu.edu.hk/cse/safety/Safety_training/Course/ms/index.html

13. RADIATION SAFETY

13.1. RADIATION SAFETY (RS)

Sabanci University aspires to establish and operate safe and healthy work environment for students, employees. Implementations for radiation safety aims to minimise potential hazards originating from utilization of radioactive materials and ionizing radiation-emitting devices.

Objectives:

- Limitation and minimization of radiation exposure to lab users, working area and the environment
- Prevention of radioactive contamination
- Meeting the state based requirements and regulations about utilization and disposal of radioisotopes and outher ionizing radiation sources

FENS implements the campus radiation safety program that includes audits of all authorizations for the use of radionuclides and radiation producing machines (RPMs). Faculty ensures regulatory compliance and safety in the use of radiation and radioactive materials. Specific functions of LSS/LS includes, but is not limited to:

- Monitoring radiation exposure levels
- Investigating incidents involving ionizing radiation
- Consulting on safety matters
- Providing radiation-safety training and services
- Managing radioactive wastes

13.1.1. Turkish Standard for Radiation Safety

13.1.1.1. Terms and abbreviations

- Authority; Turkish Atomic Energy Authority (TAEK).
- Ionizing radiation; electromagnetic rays that can produce ion pairs during passage through material by interacting with it, like X and gamma rays, and corpuscular radiations like free neutrons, heavy ions and charged particles having kinetic energy. Sound waves, ultraviolet rays and the regions having larger wavelengths of the electromagnetic spectra are out of the scope of this definition. In this Decree, the term “radiation” is used instead of the term “Ionizing radiation”.
- Curie (Ci) and Becquerel (Bq); the units of the radioactivity. 1 Curie is radioactivity which gives 3.7 x 10^{10} disintegrations per second, 1 Becquerel is the number of disintegrations in one second. 1 Becquerel corresponds to 2.7 x 10^{-11} Curies.
- Rem (rem); the unit of biological equivalent dose used in the radiation protection; is equal to the multiplication of absorbed dose and quality factor. Rad (rad); the unit of absorbed dose and it means any radiation dose cause absorption of 100 ergs of imparted energy into 1 g of material.
- Radiation source; the radioactive materials which emit ionizing radiation and equipments which produce or emit ionizing radiation.
- Radioactive materials; materials containing an isotope, the nucleus of which has been disintegrated spontaneously by emitting one or more ionizing radiation, as alloy mixture, solvent or composite.
- Radiation emitting equipments; equipments containing radioactive materials and manufactured in order to emit one or more ionizing radiation within certain safety measures and under control.
- Radiation producing equipments; the equipments, like X-ray machines, betatron, linear accelerator, cyclotron and neutron generators, that are designated as to produce radiation through acceleration of the charged particles or heavy ions within certain safety measures and under control by use of any of electronically, magnetic or electro mechanic methods.
- Specific activity; is the amount of activity expressed as Curie for one gram of radioactive material and Becquerel for one kilogram of material.

- Controlled areas; areas where the entries or exits are subject to special supervision and interior studies depend on specific rules in terms of radiation safety.
- Radiation areas; areas where the users are exposed to ionizing radiation. According to the level of exposure, these areas are classified into two as follows;
  - Working condition A; where the annual exposure might exceed three-tenths of the equivalent dose limits.
  - Working condition B; where exceeding of the three-tenths of the annual equivalent dose limits is not expected.
- Radiation user; people who continuously work in the controlled area or work with the radioactive sources. Those users who temporarily or occasionally work in the controlled areas or work with the radioactive sources are not considered as radiation user.
- Radiation accident is the event of receiving dose exceeding the limits, too much, specified in radiation protection standards and occurrence of radioactive contamination as a result of unexpected.
- Radioactive fallout; is the fall of radioactive materials, that are spreaded into the atmosphere due to nuclear explosion, to the earth surface in various ways.

13.1.1.2. Basic standards for the radiation safety

The principles and measures related to radiation safety are regulated as to the basic standards of the radiation protection given below.

- The whole body dose due to internal and external sources of the people occupationally working with radiation sources and exposed to radiation should not exceed 5 rem per annum.
- The total dose due to internal and external sources of the member of the public and people not considered as radiation user, for whole body, should not exceed 0.5 rem per annum
- Age limitation: People under the age of 18 cannot work at the activities.

13.1.1.3. Dose limits

Concepts relevant to the dose limitations used in radiation protection are given below:

- Primary limits: Limits of annual “equivalent dose”, “effective dose”, “committed equivalent dose”, “committed effective dose” or “collective effective dose” of a determined individuals group those can be received by radiation users or individuals of community.
- Secondary limits: Dose limits when the primary dose limits cannot be applied directly. In case of external exposure secondary limits are indicated by “equivalent dose index” and in case of internal exposure, they are indicated by “annual by intake limits” (ALI).
- Derived limits: They derive limits from primary limitations according to a certain model and if this case is complied with, it will be accepted as complied with primary limits.
- Permitted limits: Limits those determined by the Authority and usually less than the primary and secondary limits.
- Operation limits: Limits determined by the license holder provided that they do not exceed the primary and secondary limits determined by the Authority for the entire radiation sources whatever their type is.

13.1.1.4. Reference levels

Levels determined in order to start a special application for any size used in radiation protection programs. Reference levels determined by the Authority are given below.

- Record Level: Records of equivalent dose, effective dose or body intake quantities must be taken and kept in order to provide radiation protection. Annual dose limit records should be kept if annual dose limits exceed 0.2 mSv for radiation users, 0.01 mSv for public.
- Inspection level: Equivalent dose, effective dose or intake quantity need to be inspected more. For one month, this level is 1/10 of annual dose.
- Intervention Level: Values which are predetermined by the Authority and indicate equivalent dose, effective dose or quantities of intake and intervention should be considered when exceeded. Also, it is a situation in which annual equivalent dose limit determined in taken at a time and exceeded in the same year. Levels of intervention;
  - Action Level: Equivalent dose rate and level of concentration of radioactivity that require remedial and protective actions in case of continuously irradiation or danger.
  - Guidance Level: It is a dose level which may require taking measures if exceeded.

Annual dose limits are determined separately for radiation users and public members in accordance with the international standards without any detriment to health. Annual total dose is the sum of the doses received from internal and external irradiations. Radiation dose exposing over those limitations due to sources under control and applications are not permitted and medical exposures and natural radiation doses are excluded from these limitations.

- Effective dose for radiation users cannot exceed 20 mSv for consecutive five years and 50 mSv for one year. Equivalent dose limit for hand and foot or skin is 500 mSv, for lens it is 150 mSv. Equivalent dose of a 1 cm^2 area exposed to highest radiation dose for skin is accepted as average skin equivalent dose regardless of the dose received by the other areas.
- Effective dose for community members cannot exceed 1 mSv. For special conditions 5 mSv per year can be permitted provided that it doesn't exceed 1 mSv average for consecutive five years. Annual equivalent dose limit for skin is 50 mSv, for lens it is 15 mSv.
- People younger than 18 years old cannot work in radiation works according to effective dose for students and interns between 16 and 18 years old, who need to be educated about radiation sources (cannot exceed 6mSv in any year). However, equivalent dose limit for hand, foot or skin is 150 mSv, for lens it is 50 mSv.

13.1.1.5. *Working conditions*

Working conditions of the people exposed to radiation in duty bound are classified as follows:

Working Condition A: Working condition with the possibility of exposing effective dose more than 6 mSv per year or exposing more than 3/10 of annual equivalent dose limits for lens, skin and feet.

Working Condition B: Working condition with the possibility of exposing radiation doses that will not exceed the values given in working condition A.

13.1.1.6. *Personal dosimeter obligatory*

People, who work in working condition A, are obliged to use a personal dosimeter. Dosimetry service is provided by the Authority and the organizations. Results of dosimetric evaluations are recorded to the central dose registration system. Eligibility criteria, operating procedures and principles of the organizations that provide dosimetry service are determined by the Authority.

13.1.2. User Responsibilities

Users are people who handle radioactive materials or use radiation-producing machines (RPMs). Every user's name must be listed in the personnel section of the radiation use authorization. Users are responsible for their own safety and for the safety of those around them; specifically, they must:

- Follow procedures and protocols and know where the RS can be found online and how to seek assistance from the LS/LSS.
- Ensure that training and safety equipment are adequate.
- Keep exposure to radiation under the limit which is given in the Turkish Standard and Radiation Safety Regulations (Radyasyon Güvenliği Yönetmeliği, Resmi Gazete Tarihi: 24.3.2000 Resmi Gazete Sayısı: 23999).
- Wear required personal protective equipment (PPE).
- Wear dosimetry and/or participate in the bioassay program if required.
- Inform the LS/LSS of any unsafe conditions.
- Keep personal items away from laboratory or use areas.
- Never eat, drink, smoke, or apply cosmetics in the laboratory.
- Place waste materials in appropriate, labelled containers.
- Label work areas, materials, and/or containers as required.
- Maintain appropriate security for radioactive materials and radiation-producing machines.
- If contamination is suspected, check with a suitable survey meter or by means of an "area wipe" and decontaminate if necessary.
- Wash hands and check for contamination before leaving the laboratory, using a suitable survey meter.
- Immediately report spills, personnel contamination or other radiation safety emergencies to LS/LSS.

13.1.3. General Radiation-Control Techniques

The following are general procedures for radiation control in a radionuclide laboratory:

- Do not bring personal belongings, other than those required for work, into the laboratory.
- Separate radiation work and storage areas from general personnel spaces. Store your lab coat away from your personal clothing.
- Do not eat, drink, smoke, or apply cosmetics in the laboratory where unsealed radioactive materials are present unless a designated "Clean Area" has been established.

- Cover work areas with absorbent paper to protect against spills. Use a spill tray when working with large volumes of liquids.
- Use appropriate shielding.
- Put waste materials in appropriate containers and keep liquid waste in secondary containment.
- Maintain good housekeeping in the laboratory.
- Restrict public access and properly control access by minors.
- Use appropriate signs.
- Wear impermeable gloves and use tongs.
- Use mechanical (remote) pipetting techniques.
- Do not work with radioactive materials if you have an open skin wound.
- Wear appropriate PPE over street clothes (e.g., fire resistant clothing if working with flammable materials).
- Clearly label contaminated glassware or equipment until it has been decontaminated.
- Use fume hoods when working with volatile materials.
- Label work areas, materials, and/or containers as required.
- Use radiation-detection equipment during manipulations of unsealed radionuclides to detect and prevent the spread of contamination.
- Check gloves, forearms and other PPE for contamination frequently.
- If contamination is suspected in the course of work, monitor the area using a suitable survey meter or area wipe, and decontaminate if necessary.
- Wash your hands and check them with a suitable survey meter before leaving the laboratory.

13.1.4. Procedures for Work with Radiation-Producing Machines

Sabanci University campus uses a wide variety of ionizing radiation–producing machines (RPMs). They are classified as follows:

- Class 1- Electron microscopes or other low-hazard machines
- Class 2- Cabinet X-ray machines, X-ray diffraction and fluorescence analysis machines, XRF machines, portable X-ray machines, diagnostic X-ray machines, or other medium hazard machines.

Radiation Producing Machine Safety Devices

Regulations mentioned above for radiation-producing machines require that they are equipped with certain safety devices. These typically include a fail-safe warning light, fail-safe interlocks, beam enclosures, and shielding. In addition, a radiation survey meter may be needed.

The following procedures apply to all radiation producing machines:

- Safety devices and precautions must be activated before the machine operation.
- Only authorized personnel may operate an radiation producing machine without using previously mentioned and regulation based precautions for maintenance and other reason.
- LS/LSS must be informed about the possible alterations on the safety devices. These alterations and modifications must be approved by the regulation and LS/SS before the operation.
- All devices are open to break-down or deactivation. X-ray cabinet interlock mechanisms rely on the shutting down the beam automatically when it is open or under abrupt impacts. Radiation survey for interlocks should be applied at every turn to verify absence of radiation before placing body where radioactive beam path might occur.
- Under all circumstances (even if the operation of RPMs become inconvenient or impossible), safety devices must be active and operational until alternative and equal protective safety device or method developed and approved by LS/LSS.
- If the safety precautions fails, try not to operate a radiation producing machine until the unit has been repaired and inspected by LS/LSS.
- Under unexpected radiation exposure or exposure suspicion, LS/LSS must be immediately notified. Material such as assigned dosimeters or other X-ray interfering materials are considered to proof/evidence of exposure.

13.2. RADIOACTIVE WASTE MANAGEMENT

The purpose of this part is to determine the conditions of discharge of wastes from the use of radioactive to the environment, by not giving damage to public, users and environment.

Issues mentioned in this regulation cover the limitations and conditions relevant with the discharge of wastes, resulting from the use of radioisotopes which have half life of less than 100 days and radioactive materials with C-14 and H-3 contents, in areas such as medicine, industry and research, to the environment after the user accumulated and kept them if necessary.

Sealed radioactive sources, radioisotopes which have a half life of more than 100 days, and wastes resulting from activities involving nuclear fuel cycle are out of the scope of this regulation.

This part is prepared on the basis of provisions of Turkish Atomic Energy Institution Law with no. 2690 and Radiation Safety Statute.

13.2.1. Turkish Standard for Waste Management

13.2.1.1. Terms and abbreviations

In this part;

Authority: Turkish Atomic Energy Authority (TAEK),

Statute: Radiation Safety Statute put into force with cabinet decision on 24/7/1985 and with no. 85/9727,

Radiation Safety Regulation: Regulation issued in the Official Gazette dd. 24/3/2000 and no. 23999,

Regulation on Control of the Medical Wastes: Regulation issued in the Official Gazette dd. 20/5/1993 and no.21586,

Radioactive Waste: Every kind of radioactive material which are not to be reused or other equipment contaminated with radioactive materials,

License holder: Official or private person or institutions who has acquired a license from Authority in order to store and use radioactive materials in accordance with the provisions of Radiation Safety Regulation,

Sealed Radioactive Source: Radioactive material that is sealed in a capsule or coated with a coating material in order to provide imperviousness under normal usage and possible accident conditions.

ALI: Intake limit of radioactive materials to the body annually in Becquerel (Bq) units, (ALI is initials of “Annual Limits on Intake”)

ALI min: Two different ALI values are determined by accepting that radioactive material scan be taken into body from digestive and/or respiratory system. ALI min values given in this regulation are the lowest values of the said two values,

Half Life: The time passed for the initial activity value of a radioactive material fall down at half value.

Discharge to the Environment: Discharge of liquid wastes into the sewer system, solid wastes to the medical waste disposal facilities, wastes in gas form such as vapor, aerosol and dust particles to the atmosphere in the forms explained and in quantities not exceeding the limits indicated in this regulation.

13.2.2. Limitations on Discharge of the Wastes Generated from the Use of Radioactive Material to the Environment

13.2.2.1. Limitations on Discharge of Liquid Wastes to the Sewer System

Liquid wastes can only be given to the sewer system in the limitations given below, under the responsibility of the license holder, provided that fulfillment of the provisions designated in the Authority law and following the concentration values being found acceptable after Authority’s evaluation of the information relevant with the waste system of body provided by the organization.

- Total quantity of radioactivity in the waste which can be discharged to the sewer system by one organization at once cannot be more than 2.5 times of the ALI min value given in Table 13.1 and cannot exceed 100 MBq.
- Scintillation solvents for laboratories and liquid wastes with similar organic solvent contents cannot have alpha radioactivity. Concentration of solvents with beta and gamma radioactivity content do not exceed 3.7 Bq value in millimeter, radioactivity concentration ofsolvents with H-3 and C-14 contents do not exceed 37 Bq value in millimeter. For the wastes exceeding those values, the provisions in paragraph (a) of Article 7 of this Regulation are applied.

- Radioactivity quantity that can be discharged to the sewer system in one month for one organization cannot be more than 25 times of the ALI min value given in Table 13.1. Wastes exceeding those values are subject to paragraph (a) of Article 7 of this Regulation.
- If waste includes more than one radioisotope, ratio of each radioisotope activity to its own ALI min value calculated then the sum of those ratios is taken. In order to discharge those wastes to the sewer system, that sum cannot be greater than 2.5 for each discharge and cannot be greater than 25 for monthly total discharge.
- Liquid wastes with the urine and feces of patients who are under I-131 treatment, shall be connected to the sewer system out of the hospital at one point, a radiation warning sign shall be put up and regular measurements shall be made. At this point I-131 concentration value cannot exceed 10 Bq value.

13.2.2.2. *Limitations on the Discharge of Solid Wastes to the Environment*

Equipment contaminated during the usage of radioactive materials and solid radioactive materials which cannot be used are classified as waste and can be discharged to the environment under the responsibility of the license holder within the limitations given below.

a) Radiation dose rate on the surface of radioactive waste bags which will be sent to the medical waste disposal facilities shall not exceed 1 µSv/hour in anyway. Measurements shall be made by an appropriate detection device that can measure the emission of radiation of the radioactive material.

b) Alpha-releasing solid wastes cannot be discharged to the environment. For those wastes application must be made to the Authority.

13.2.2.3. *Limitations on the Discharge of Gas Wastes to the Atmosphere*

Wastes in gas form are discharged to the atmosphere under responsibility of the license holder under the conditions determined in the licensing and facility projecting phase.

Table 13.1 Frequently Used Radioisotopes

Radio-Isotope	Half Life	ALI_{min}(Bq) (ICRP-61)	Radio-Isotope	Half-Life	ALI_{min}(Bq) (ICRP-61)
H-3	12.15 years	1×10^{9}	Sr-35	64.84 days	1×10^{7}
C-14	5730 years	4×10^{7}	Sr-89	50.55 days	6×10^{4}
F-18	109.74 minutes	4×10^{8}	Y-90	64.1 hours	5×10^{6}
Na-24	15 hours	5×10^{7}	Zr-95	64.02 days	3×10^{6}
P-32	14.29 days	5×10^{6}	Nb-95	35.06 days	1×10^{7}
P-33	25.4 days	3×10^{7}	Mo-99	66.02 hours	1×10^{7}
S-35	87.44 days	3×10^{7}	Tc-99m	6.02 hours	1×10^{9}
Cl-38	37.21 minutes	2×10^{8}	Ru-103	39.35 days	8×10^{6}
K-42	12.36 hours	5×10^{7}	In-111	2.83 days	5×10^{7}
K-43	22.6 hours	9×10^{7}	In-113m	1.685 hours	9×10^{8}
Ca-47	4.536 days	1×10^{7}	Cd-115	53.42 hours	1×10^{7}
Sc-46	83.8 days	3×10^{6}	Sb-124	60.2 days	3×10^{6}
Cr-51	27.704 days	2×10^{8}	I-123	13.13 hours	9×10^{7}
Mn-52	5.591 days	1×10^{7}	I-125	60.14 days	1×10^{6}
Mn-56	2.5785 hours	9×10^{7}	I-130	12.36 hours	1×10^{7}
Fe-52	8.275 hours	1×10^{7}	I-131	8.04 days	8×10^{5}
Fe-59	44.63 days	5×10^{6}	I-132	2.3 hours	7×10^{7}
Co-56	78.76 days	2×10^{6}	Ba-140	12.789 days	6×10^{6}
Co-58	70.8 days	7×10^{6}	La-140	40.22 hours	8×10^{6}
Cu-64	12.701 hours	2×10^{8}	Ce-141	32.5 days	8×10^{6}
Cu-67	61.88 days	5×10^{7}	Dy-165	2.334 hours	2×10^{8}
Zn-62	9.26 hours	2×10^{7}	Yb-169	31.97 days	9×10^{6}
Ga-67	3.261 days	8×10^{7}	W-185	75.1 days	3×10^{7}
Ga-68	68 minutes	2×10^{8}	Ir-192	74.02 days	3×10^{6}
As-73	80.3 days	2×10^{7}	Au-198	2.696 hours	1×10^{7}
As-74	17.77 days	9×10^{6}	Hg-197	64.14 hours	6×10^{7}
Br-77	57.04 hours	2×10^{8}	Tl-201	73.06 hours	3×10^{8}
Br-82	35.3 hours	4×10^{7}	Hg-203	46.6 days	1×10^{7}
Rb-86	18.66 days	8×10^{6}			
Rb-88	17.8 minutes	2×10^{8}			
Rb-89	15.44 minutes	4×10^{8}			

13.3. EMERGENCY PROCEDURES

When an emergency (fire, explosion, chemical exposure, or other event that endangers life and/or property) is accompanied by the presence of radioactive material and radiation, it is important to deal first with those hazards that have the greatest potential impact. Fire, injuries and all life-threatening situations take precedence over radiation issues.

In an academic setting, the quantities and types of radiation used are generally at levels low enough that fire and medical response personnel can deal with severe threats to life, health, and/or property without concern for the radioactive materials and radiation present.

Nonetheless, responders should use their usual personal protective equipment (PPE), be monitored for radioactive material contamination, and be decontaminated (as necessary) after addressing the problem at hand and before leaving the scene.

Any of the following situations must immediately reported to LS/LSS:

- When your skin contaminated by the radioisotopes or radioactive emission
- When you ingest radioactive material
- Unexpected radiation exposure to personnel
- Severe contamination of equipment or areas
- Spread of contamination, or difficulty cleaning up a contaminated area
- When radioactive materials or radiation-producing machines (RPMs) get lost or stolen.

When in doubt, call 7444, LS/LSS.

Radioactive material spill or unexpected release must be promptly controlled and immediately reported to LS/LSS.

13.3.1. Laboratory User Contamination

Immediately call 7444 or have someone call LS/LSS when radioactive contamination or suspicion of contamination occurs.

In the case of a radiation accident; action plan given in order below:

- Treat medical issues first and apply first aid as appropriate. Appeal for aid if anybody is around. Usually decontamination can be delayed until the victim is in stable condition.
- Immediately take off contaminated apparel and flush skin with water.

For skin contamination, follow decontamination procedures given below:

- Contaminated surface must be washed using a mild soap and water. Do not use hot water or excoriate or irritate the skin. Do not use brushes that could wear/irritate the skin.
- If the contamination spreads widely, a shower with mild soap and warm water will remove most of the contamination. After the shower, inspect the person to control the decontamination procedure and to localize any contamination remnant.
- LS/LSS may recommend additional or specialized decontamination treatment if further decontamination is necessary.
- Contaminated clothing and materials must be delivered to LS/LSS. Further details about decontamination or disposal will be given by LS/LSS.

13.3.2. Procedures for Major Spills

Everyone who are not involved in accident should leave the area immediately but assemble nearby. Call 7444 or have someone call LS/LSS ask for radiation safety assistance.

- Evaluate everyone who could possibly have been contaminated.
- Once potentially contaminated personnel have been examined and check the contamination level, record their names and release them. When feasible, contamination level must be confined to minimum.
- Prevent unintended entry or re-entry into the contaminated area. Post all entrances to the room or area with sign(s) warning others that a spill of radioactive material has occurred. Post similar signs in the general vicinity, indicating the location of the spill.
- Wait for LSS direction before taking further action. Follow the instructions of the LS/LSS regarding decontamination techniques, surveys, provision of bioassay samples, requested documentation, etc.

- Do not allow work to resume in the area until approved by the LS/LSS.
- Place contaminated clothing and materials in bags labelled with contents, radioisotope, and date.

13.3.3. Procedures for Minor Spills

- When a spill accident occurs, people in the building/facility must be notified.
- Only trained and equipped personnel should be allowed to enter the area.
- PPE must be worn in case of necessity.
- Call immediately 7444 or have someone call LS/LSS.
- Contamination must be covered with absorbent paper if it is liquid. In case of solid contamination, paper should be dampened. Spill could be cleaned up by the absorbent paper. This technique is an effective prevention from spread.
- Inspections should be performed with appropriate equipment periodically after spill decontamination process. This procedure will also determine efficiency of decontamination process.
- Absorbent papers, gloves and any other utilized material during and after the decontamination process must be folded, sealed and labelled in appropriate bag.
- Decontaminated area and its around must be checked with appropriate technique in case of residue and fixed contamination.
- People who are involved in the decontamination process should also be inspected by checking their outfit and hands. Zero contamination-resulted people will be recorded and released.
- If personal contamination is detected, "Laboratory User Contamination" procedure must be applied.

13.3.4. Procedures for Radiation Producing Machine (RPM) Accidents

- Machine must be turned off. If possible, cut off the circuit.
- Call 7444 or have someone call LS/LSS immediately.
- Medical issues should be treated and first aid should be managed immediately. Treatment of injuries takes priority over radiation exposure and radiation suspicion.
- LS/LSS and other responsibles in the area must be informed immediately.
- All related material about the incident, including operating voltage and current, exposure time, and distance from the radiation source should be informed. All these material and data must be given to LS/LSS.

NOTE: Biological effects of the radiation exposure coming from the X-ray machines are not immediately observed. LS/LSS must be informed and exposed personnel should be consulted by medical team and specialized representatives to assess dose and confirm essential treatment.

References

- Berkeley University of California (2013). *Radiation Safety Manual* (2015, March). Retrieved from http://www.ehs.berkeley.edu/sites/default/files/lines-of-services/radiation-safety/RS2013.pdf
- Yale University Office of Environmental Health & Safety (2000). *Radiation Safety Procedures* (2015, March). Retrieved from http://ehs.yale.edu/sites/default/files/rad%20manual%20(1).pdf
- TC Resmî Gazete (24.03.2000). *RADYASYON GÜVENLİĞİ YÖNETMELİĞİ* (2015, March). Retrieved from http://mevzuat.basbakanlik.gov.tr/Metin.Aspx?MevzuatKod=7.5.5272&MevzuatIliski=0&sourceXmlSearch=Radyasyon%20G%C3%BCvenli%C4%9Fi%20Y%C3%B6netmeli%C4%9Fi
- TC Resmî Gazete (02.06.2004). *Radyoaktif Madde Kullanımından Oluşan Atıklara İlişkin Yönetmelik* (2015, March). Retrieved from http://mevzuat.basbakanlik.gov.tr/Metin.Aspx?MevzuatKod=7.5.5276&MevzuatIliski=0&sourceXmlSearch=radyoaktif
- University of Washington. *Radiation Safety Manual* (2015, March). Retrieved from https://www.ehs.washington.edu/manuals/rsmanual/

14. LASER SAFETY

14.1. PURPOSE AND REQUIREMENTS

This guide presents a summary of the basics of laser safety, biological effects, and exposure limits to be used at Sabancı University. This guide applies to all laser classes (1 to 4). Some recommendations will improve laser safety in the laboratory. Because of the wide variety of lasers and laser uses that are possible, this guide provides performance based goals rather than prescriptive requirements.

14.2. RESPONSIBILITIES

Each laser user is responsible for the operational safety of the device. This includes applicable recommendations of the position and termination of all beams and reflections, using appropriate entryway controls, and using appropriate eye protection. Laser users shall not bypass or defeat entryway safety features, barriers, or interlocks. Doing so is a serious safety violation and may lead to loss of laser use privileges.

14.3. STANDARDS

The international and national resources for laser applications and safety are given below:

- TS EN 60825-4/A1 - Safety of laser products - Part 4: Laser guards
- TS-EN-60825-1 - Safety of laser products - Part 1: Equipment classification and requirements (IEC 60825-1:2014)
- ANSI Z136 Standards (Laser Institute of America)

14.4. TRAINING

The level of training shall be appropriate to the level of the laser hazard being used. LSS provides general laser safety training that is to be supplemented by specific in-lab training by the Responsible Faculty Member or experienced user designated by the Responsible Faculty Member to provide training.

- Class 1 and 2 – training not required
- Class 1M and 2M – application dependent, contact the LSS
- Class 3a and 3R – training not required
- Class 3b and 4 – training is required

Refresher training is required every two years.

14.5. BASICS

The word LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. Lasers are used as research tools in many programmes at Sabanci University.

In this document, the word laser will be limited to electromagnetic radiation-emitting devices using light amplification by stimulated emission of radiation at wavelengths from 180 nanometers (nm) to 1 millimeter (mm). The electromagnetic spectrum includes energy ranging from gamma rays to radiofrequency. Figure 14.1 illustrates the total electromagnetic spectrum and wavelengths of the various regions.

The lasers used at Sabanci University include the ultraviolet, visible and infrared regions of the spectrum. Ultraviolet radiation for lasers consists of wavelengths between 180 and 400 nm. The visible region consists of radiation with wavelengths between 400 and 700 nm. This is the portion we call visible light. The infrared region of the spectrum consists of radiation with wavelengths between 700 nm and 1 mm.

A laser generates a beam of very intense light. The major difference between laser light and light generated by white light sources (such as a light bulb) is that laser light is monochromatic, directional and coherent. Monochromatic means that all of the light produced by the laser is of a single wavelength. White light is a combination of all visible wavelengths (400 - 700 nm). Directional stands for the beam of light with very low divergence.

The color or wavelength of light being emitted depends on the type of lasing material being used.

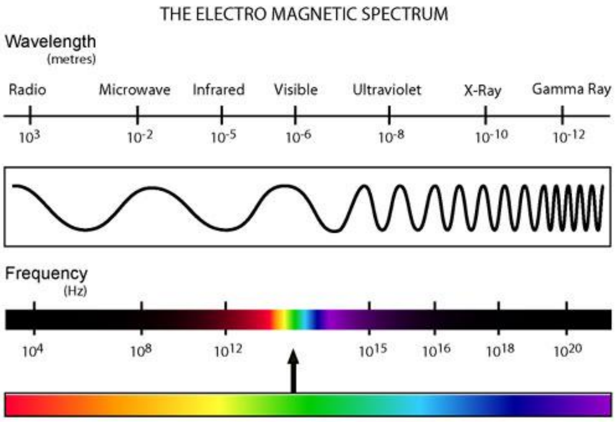


Figure 14.1 Electromagnetic spectrum
(Courtesy of UIUC)

Table 14.1 illustrates various types of material currently used for lasing and the wavelengths that are emitted by that type of laser. Note that certain materials and gases are capable of emitting more than one wavelength. The wavelength of the light emitted in this case is dependent on the optical configuration of the laser.

Coherent means that the waves of light are in phase with each other. A light bulb produces many wavelengths, making it incoherent.

Table 14.1 Common laser classifications by wavelength

Type	Wavelength (nm)
Ultraviolet (180-400 nm)	
Argon Fluorid(ArF)	193
Krypton Chloride(KrCl)	222
Krypton Fluoride(KrF)	249
Xenon-Chloride(XeCl2)	308
Nitrogen(N2)	337
Helium-Cadmium(HeCd)	325
Visible (400-700 nm)	
Helium-Neon(He-Ne)	543, 594, 612,633
Krypton(Kr)	647
Ruby	694
Argon(Ar)	468 to 515
Nd; YAG(second harmonic generation)	532
Infrared (700 nm to 1 µm)	
Galium-Arsenide(diode)	850
Carbon dioxide(CO2)	10600
Nd; YAG	1064
Ho; YAG	2100

14.6. LASER CLASSES AND HAZARDS

The following is a summary of laser classification taken from ANSI Z136.1.

14.6.1. Laser Classes

14.6.1.1. Class 1 lasers

A Class 1 laser is considered to be incapable of producing damaging radiation levels and is therefore considered safe under normal working conditions. These lasers are exempt from most control measures. Many lasers in this class are lasers which are imbedded in an enclosure that prohibits or limits access to the laser radiation.

14.6.1.2. Class 2 lasers

Class 2 lasers are low power lasers that emit visible radiation, but do not exceed a power output of 1 mW. For this laser class, the normal human aversion response of (0.25 seconds) to bright radiant sources affords eye protection if the beam is viewed directly. The potential for eye hazard exists if this normal reflex motion is overcome and the exposure time is greater than 0.25 seconds.

14.6.1.3. Class 1M lasers

A Class 1M laser is considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with an optical instrument such as an eye-loupe or a telescope.

14.6.1.4. Class 2M lasers

A Class 2M laser emits visible radiation (400 to 700 nm) with a power output below 1 mW. Like Class 2 laser products, Class 2M lasers pose ocular hazards to the unaided eye, but are potentially hazardous when viewed with optical aids.

14.6.1.5. Class 3R lasers

Class 3R lasers are potentially hazardous under some direct and specular reflection viewing conditions, but the probability of an injury is small. Class 3R lasers do not pose either a fire hazard or diffuse-reflection hazard. The output power of a Class 3R laser is between 1 and 5 times the Class 1 power limit for wavelengths shorter than 400 nm (UV lasers) or longer than 700 nm or a output power of 5 mW for 400 nm to 700 nm wavelengths (visible lasers).

14.6.1.6. Class 3B lasers

Class 3B lasers are medium power lasers that have an output power of 5 mW – 500 mW. Viewing these lasers under direct beam and specular reflection conditions are hazardous. The diffuse reflection is usually not a hazard except for higher power Class 3B lasers. A Class 3B laser is not normally a fire hazard.

14.6.1.7. Class 4 lasers

Class 4 lasers are high power lasers with a power output above 500 mW. Exposure to the direct beam, specular reflections, or diffuse reflections presents a hazard to both the eye and skin. A Class 4 laser may be a fire hazard (radiant power > 2 W/cm^2 is an ignition hazard). In addition, these lasers can create hazardous airborne contaminants and have a potentially lethal high voltage power supply. Always enclose the entire laser beam path, if possible, or enclose most of the beam path to reduce the potential hazards.

14.6.2. Hazards

Improperly used laser devices are potentially dangerous. Effects can range from mild skin burns to irreversible injury to the skin and eye. The biological damage caused by lasers is produced through thermal, acoustical and photochemical processes.

Possible hazards according to laser classes are given in Table 14.2.

Thermal effects are caused by a rise in temperature following absorption of laser energy. The severity of the damage is dependent upon several factors, including exposure duration, wavelength of the beam, energy of the beam, and the area and type of tissue exposed to the beam.

Acoustical effects result from a mechanical shockwave, propagated through tissue, ultimately damaging the tissue. This happens when the laser beam causes localized vaporization of tissue, causing the shockwave analogous to ripples in water from throwing a rock into a pond.

Beam exposure may also cause photochemical effects when photons interact with tissue cells. A change in cell chemistry may result in damage or change to tissue. Photochemical effects depend greatly on wavelength. Table 14.3. summarizes the probable biological effects of exposure of eyes and skin to different wavelengths.

The visible and near infrared lasers have potential for retinal injury, Human cornea and lens are transparent to those wavelengths and laser light and energy can be focused by the lens onto the retina. The maximum absorption of laser energy onto the retina occurs in the range from 400 - 550 nm. Argon and YAG lasers operate in this range, making them the most hazardous lasers with respect to eye injuries. Lasers working under 550 nm wavelengths can cause a photochemical injury similar to sunburn. Photochemical effects are cumulative and result from long exposures (over 10 seconds) to diffuse or scattered light. Table 14.3 summarizes the most likely effects of overexposure to various commonly used lasers.

Table 14.2 TS-EN-60825-1 Laser classes and hazards

Class	Hazard	Warning statement
Class 1	Safe under reasonably foreseeable conditions (NOTE: Class 1 lasers include high-power that are fully enclosed, such that potentially hazardous radiation is not accessible during use).	
Class 1M	Safe for the naked eye, except if magnifying optics are used.	Do not stare directly with optical instruments.
Class 2	Safe for short exposures(less than 0.25s). The eye is protected by the blink reflex.	Do no stare into the beam.
Class 2M	Safe for shorts exposures(less than 0.25s). The eye is protected by the blink reflex except if magnifying optics are used.	Do not stare into beam or view directly with optical instruments.
Class 3R	Safe if handled with care, may be dangerous if mishandled. Risk is limited by the blink reflex and natural response to heating of cornea for infrared radiation.	Avoid direct eye exposure.
Class 3B	Direct viewing is hazardous. Protective eyewear necessary if the beam accessible. Safety interlocks are required to prevent access to hazardous laser radiation.	
Class 4	Can burn the skin and cause permanent eye damage. Class 4 lasers can also present a fire hazard. Safety interlocks with manual reset are required to prevent access to hazardous laser radiation.	Avoid eye or skin exposure to direct or scattered radiation.

The warning statements accompany the title: 'laser radiation' and laser product type statement on laser product labels in the format:

LASER RADIATION
Warning statement
CLASS x LASER PRODUCT
Additional labelling may also be required dependent upon the laser class and beam accessibility

Thermal burns to the skin are rare. They usually require exposure to high energy beams for an extended period of time. Carbon dioxide and other infrared lasers are most commonly associated with thermal burns, since this wavelength range may penetrate deeply into skin tissue. The resulting burn may be first degree (reddening), second degree (blistering) or third degree (charring).

Some individuals are photosensitive or may be taking prescription drugs that induce photosensitivity. Particular attention must be given to the effect of these (prescribed) drugs, including some antibiotics and fungicides, on the individual taking the medication and working with or around lasers.

Table 14.3 Summary of laser biological effects

Photobiological Spectral Domain	Eye	Skin
Ultraviolet C (200 nm - 280 nm)	Photokeratitis	Erythema (sunburn) Skin cancer Accelerated skin aging
Ultraviolet B (280 nm - 315 nm)	Photokeratitis	Increased pigmentation
Ultraviolet A (315 nm - 400 nm)	Photochemical cataract	Pigment darkening Skin burn
Visible (400 nm - 780 nm)	Photochemical and thermal retinal injury	Pigment darkening Photosensitive reactions Skin burn
Infrared A (780 nm - 1400 nm)	Cataract and retinal burn	Skin burn
Infrared B (1.4µm - 3.0 µm)	Corneal burn, aqueous flare, cataract	Skin burn
Infrared C (3.0 µm - 1000 mm)	Corneal burn only	Skin burn

14.6.2.1. Electrical hazards

- The use of lasers or laser systems can present an electric shock hazard. This may occur from contact with exposed utility power utilization, device control, and power supply conductors operating at potentials of 50 Volts or more. These exposures can occur during laser set-up or installation, maintenance and service, where equipment protective covers are often removed to allow access to active components as required for those activities. The effect can range from a minor tingle to serious personal injury or death. Protection against accidental contact with energized conductors by means of a barrier system is the primary methodology to prevent electrical shock.
- Another particular hazard is that high voltage electrical supplies and capacitors for lasers are often located close to cooling water pumps, lines, filters, etc. In the event of a spill or hose rupture, an extremely dangerous situation may take place. During times of high humidity, over-cooling can lead to condensation which can have similar effects.

14.6.2.2. Collateral and plasma radiation

Collateral radiation, i.e., radiation other than that associated with the primary laser beam, may be produced by system components such as power supplies, discharge lamps and plasma tubes. Such radiation may take the form of X-rays, UV, visible, infrared, microwave and radio-frequency radiation. “Home-built” lasers are again of particular concern and should be independently examined. In addition, when high power pulsed laser beams (peak irradiance of the order of 10^{12} Watts/cm^2) are focused on a target, plasma is generated which may also emit collateral radiation. X-rays may be generated by electronic components of the laser system (e.g., high voltage vacuum tubes, usually greater than 15 kV) and from laser-metal induced plasmas.

14.6.2.3. Fire hazards

Class 4 laser systems represent a fire hazard. Enclosure of Class 3 laser beams can result in potential fire hazards if enclosure materials are likely to be exposed to irradiances exceeding 10 Watts/cm^2. The use of flame retardant materials is encouraged.

Opaque laser barriers (e.g., curtains) can be used to block the laser beam from exiting the work area during certain operations (please see PPE Section and Appendix 14.1) While these barriers can be designed to offer a range of protection, they normally cannot withstand high irradiance levels for more than a few seconds without some damage, including the production of smoke, open fire, or penetration. Users of commercially available laser barriers should obtain appropriate fire prevention information from the manufacturer.

Operator of Class 4 lasers should be aware of the ability of unprotected wire insulation and plastic tubing to ignite from intense reflected or scattered beams, particularly from lasers operating at invisible wavelengths.

14.6.2.4. Compressed gases

Many hazardous gases are used in laser applications, including chlorine, fluorine, hydrogen chloride, and hydrogen fluoride. The use of mixtures with inert gases, rather than the pure gases is generally preferred. Hazardous gases should be stored in appropriately exhausted enclosures, with the gases permanently piped to the laser using the recommended metal tubing and fittings. An inert gas purge system and distinctive coloring of the pipes and fittings is also prudent.

Compressed gas cylinders should be secured from tipping. Other typical safety problems that arise when using compressed gases are:

- working with free-standing cylinders not isolated from laboratory users
- regulator disconnects, releasing contents to atmosphere
- no remove shut-off valve or provisions for purging gas before disconnect or reconnect
- labeled hazardous gas cylinders not maintained in appropriate exhausted enclosures
- gases of different categories (toxics, corrosives, flammable, oxidizers, inerts, high pressure and cryogenics) not stored separately

14.6.2.5. Laser dyes

Laser dyes are complex fluorescent organic compounds which, when in solution with certain solvents, form a lasing medium for dye lasers. Certain dyes are highly toxic or carcinogenic. Since these dyes frequently need to be changed, special care must be taken when handling, preparing solutions, and operating dye lasers. The SDS for dye compounds should be available to and reviewed by all appropriate users.

The use of dimethylsulfoxide (DMSO) as a solvent for cyanide dyes in dye lasers should be discontinued, if possible. The DMSO aids in the transport of dyes into the skin. If another solvent cannot be found, low permeability gloves should be worn by users any time a situation arises where contact with the solvent may occur.

Preparation of dye solutions should be conducted in a fume hood. Personal protective equipment, such as lab coats, appropriate gloves, and eye protection are necessary when preparing solutions.

14.7. WORKING WITH LASERS

14.7.1. Before You Start

- Inform lab users of the types of activities you will be engaged in and any precautions that need to be taken, for example, removal of barriers, need for protective eyewear, venting a chamber, using cryogens, etc.
- Remove all watches, rings, bracelets, earrings and ID badges. These items can reflect light, which can be hazardous. If these items cannot be removed (i.e. a ring), cover it with tape, which will produce a diffuse reflection.
- There should be no line of sight between the room entrance and optics on the optical table(s). In addition to actual safety precautions, it is also important to reduce the perception that passers-by are at risk. Perimeter guards, enclosures around the table, and a curtain at the door also reduce the perception of risk to uninformed visitors.
- Glass in the lab and even laminated posters are possible reflection hazards. They can send reflections to totally unexpected areas. Contain the beam to the optical table to avoid this hazard.
- Enclosure of the laser equipment or beam path is the preferred method of control, since the enclosure will isolate or minimize the hazard. When engineering controls do not provide adequate means to prevent access to direct or reflected beams at levels above the Maximum Permissible Exposure (MPE), it may be necessary to use personal protective equipment (please see Appendix 14.2.). Note that use of personal protective equipment may have serious limitations when used as the only control measure with higher power Class 4 lasers or laser systems. The protective equipment may not adequately reduce or eliminate the hazard and may be damaged by the incident laser radiation.

Table 14.4 Eyewear selection chart

Simplified Method for Selecting Laser Eye Protection for Intrabeam Vieving
for Wavelengths between 400 and 1400 nm

Q-Switched Lasers (1 ns to 0.1 ms)		Non-Q-Switched Lasers (0.4 ms to 10 ns)		Continious Lasers Momentary (0.25 to 10 s)		Continuous Lasers Long-Term Staring Greater than 3 hours		Attenuation	
Maximum Output Energy(J)	Maximum Beam Radiant Exposure (J-cm^{-2})	Maximum Laser Output Energy(J)	Maximum Beam Radiant Exposure (J-cm^{-2})	Maximum Power Output Energy(W)	Maximum Beam Irradiance (W-cm^{-2})	Maximum Power Output Energy(W)	Maximum Beam Irradiance (W-cm^{-2})	Atteniuation Factor	OD
10	20	100	200	NR	NR	NR	NR	1 x 10^{8}	8
1.0	2.0	10	20	NR	NR	NR	NR	1 x 10^{7}	7
10^{-1}	2 x 10^{-1}	1.0	2	NR	NR	1.0	2	1 x 10^{6}	6
10^{-2}	2 x 10^{-2}	10^{-1}	2 x 10^{-1}	NR	NR	10^{-1}	2 x 10^{-1}	1 x 10^{5}	5
10^{-3}	2 x 10^{-3}	10^{-2}	2 x 10^{-2}	10	20	10^{-2}	2 x 10^{-2}	1 x 10^{4}	4
10^{-4}	2 x 10^{-4}	10^{-3}	2 x 10^{-3}	1.0	2	10^{-3}	2 x 10^{-3}	1 x 10^{3}	3
10^{-5}	2 x 10^{-5}	10^{-4}	2 x 10^{-4}	10^{-1}	2 x 10^{-1}	10^{-4}	2 x 10^{-4}	1 x 10^{2}	2
10^{-6}	2 x 10^{-6}	10^{-5}	2 x 10^{-5}	10^{-2}	2 x 10^{-2}	10^{-5}	2 x 10^{-5}	10	1
NR= Not Recommended									

Protective eyewear is necessary for Class 3 and 4 laser use where irradiation of the eye is possible. Such eye protection should be used only at the wavelength and energy/power for which it is intended (Table 14.4). Eye protection may include goggles, face shields, spectacles or prescription eyewear using special filter materials or reflective coatings (or a combination of both) to reduce exposure below the MPE. The following information is needed to select the appropriate laser safety eyewear:

- Wavelength(s)
- Mode of operation (continuous wave or pulsed)
- Maximum exposure duration (assume worst case scenario)

- Maximum irradiance (W/cm^2) or radiant exposure (J/cm^2)
- Maximum permissible exposure (MPE)

Optical density (OD) could be calculated easily (https://www.lia.org/evaluator/od.php)

14.8. LASER CLEARANCE AND BLACKOUT CURTAINS

Laser curtains are a type of protective barrier. They are used in conjunction with Class 3B and 4 lasers to block direct and diffusely scattered laser radiation in excess of the maximum permissible exposure (MPE) limits from exiting into other areas. A barrier may be used at the entrance way to a dedicated laser laboratory, to cover windows, as a perimeter guard around all or part of an optical table, or during laser servicing and alignment.

Class 3B and 4 lasers are considered high power lasers and represent both an eye and skin hazard. Laser curtains provide protection by preventing the laser radiation from exiting the laser control area. Thus, they are intended to protect people outside the laser control area from accidental exposure. Laser curtains are not intended to serve as long-term beam blocks – they are rated by their ability withstand short term (i.e. 100 sec) exposures. Examples of blocks whose purpose is to terminate the beam within the laser control area for more than an incidental period of time are beam dumps, beam blocks and beam traps. The effectiveness of a laser curtain is a function of its ability to withstand damaging radiant exposures. This is evaluated by determining the burn-through time (penetration threshold level or PTL), which is a function of the incident power, material thickness and material type [a]. In addition and related, the laser curtain material must be fire-resistant. Class 4 lasers beams can result in potential fire hazards if materials are exposed to irradiances exceeding 10 W/cm^2 or beam powers exceeding 0.5 W [b, c]. Under some situations where flammable compounds or substances exist it is possible that fires can be initiated by Class 3B lasers [b, d].

Figure 14.2 below displays the minimum requirements for laser lab clearance:

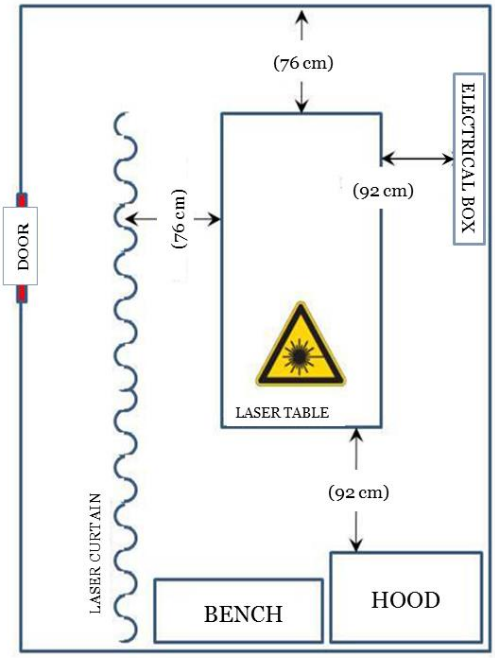


Figure 14.2 Laser lab clearance (minimum requirements)

The testing protocol is based on the ability of a barrier to withstand beam penetration when exposed for 100 seconds at a maximum incident irradiance level. In addition, laser barriers should not support combustion or release laser gas air contaminants (LGAC) following an exposure. Barriers are tested over a range of beam diameters (3-10 mm) under standardized conditions. Evaluation is based on first appearance visible damage, power level at which beam breakthrough of the material occurs (penetration threshold level or PTL), and analysis of laser generated air contaminants (LGAC) if flame and thermal distortion or air contamination are observed. The standard ANSI Z136.7 specifies the minimum information to be provided on the barrier label by the manufacturer as the (1) threshold limit and exposure time for which the limit applies and the exposure conditions under which protection is afforded and (2) manufacturer and model number or barrier material [a].

References

- Table of Electromagnetic Spectrum (2015, March). Retrieved from http://www.ces.fau.edu/nasa/images/Energy/VisibleLightSpectrum.jpg
- Harvard University EH & S. *Laser Hazard Classification* (2015, March). Retrieved from https://www.ehs.harvard.edu/sites/ehs.harvard.edu/files/laser_hazard_classification_0.pdf
- Turkish Standards Institution. (1996). *Standard: TSE - TS 8496 EN 60825-1 SAFETY OF LASER PRODUCTS PART 1: EQUIPMENTS CLASSIFICATION, REQUIREMENTS AND USER'S GUIDE*. (2015, March). Retrieved from https://intweb.tse.org.tr/standard/standard/Standard.aspx?081118051115108051104119110104055047105102120088111043113104073083102073077105049077097054086099
- Laserfxcom (2008). *Basic Laser Safety - Eye and Skin Hazards* (2015, March). Retrieved from http://www.laserfx.com/BasicSafety/BasicSafety2.html
- Yale University Office of Environmental Health & Safety (1997). *Laser Safety Manual* (2015, March). Retrieved from http://ehs.yale.edu/sites/default/files/laserman%20%281%29.pdf
- Harvard University EH & S (2002). *Laser Safety Manual* (2015, March). Retrieved from https://www.ehs.harvard.edu/programs/lasers

15. NMR SAFETY

NMR device is operated by a dedicated specialist and the device and its components are not to be handled or removed without any permission under any circumstance. The following text is only intended to inform you about the device.

15.1. SUPERCONDUCTING MAGNET

A superconducting magnet is an electromagnet that is built using superconducting coils.

Our 500 MHz magnet system comprises of a fully persistent 11.74 Tesla magnet which is immersed in a bath of liquid helium (-269 °C) at which temperature the resistance of the coil is zero; once energized the magnet can run continuously.

The helium vessel is shielded from room temperature by a vessel filled with liquid nitrogen (-196 °C) and an outer vacuum to keep the liquid helium from rapidly boiling off.

The liquid helium and liquid nitrogen are not pressurized but are allowed to boil-off over a number of weeks; liquid helium and nitrogen must be added periodically.

The magnet is always on.

Magnetic Field Strength

Magnet strength is described in terms of Gauss or Tesla units (1 T = 10,000 G).

- Earth's magnetic field: 0.6 Gauss at the equator
- Small bar magnet: 100 Gauss
- Refrigerator magnet: 100 - 150 Gauss
- MRI medical scanners: 0.3 - 1.5 Tesla (3 - 15,000 G)

High magnetic field NMR spectrometers and other superconducting magnets:

- 200 MHz: 4.7 Tesla (47,000 G)
- 300 MHz: 7.0 Tesla (70,000 G)
- 500 MHz: 11.7 Tesla (117,000 G)
- 800 MHz: 18.8 Tesla (181,000 G)

Surface of a neutron star: 1x10^{8} Tesla (1012 Gauss)

Warning

Exposure to strong magnetic fields can cause serious injury or death and significant damage to personal property, equipment and data.

15.2. NMR SAFETY

- 5-gauss perimeter should be minded by individuals with medical devices (e.g. cardiac pacemakers and metal prostheses). People using pacemakers, prosthetic parts and metal blood vessel clips should contact their physicians about the possible health risks before entering the NMR room because of the fact that the NMR spectrometers generate strong magnetic fields.
- Strong magnetic fields surrounding the NMR spectrometers can damage floppy disks, tapes, cards with magnetic strips, cellular phones, laptops and mechanical watches, so they should remain outside the 5-Gauss perimeter.
- Strong magnetic fields attract objects containing steel, iron, and other ferromagnetic materials (i.e., electronic equipment, compressed gas cylinders, steel chairs, and steel carts), so they should remain outside the 5-gauss perimeter. Personal injury and extensive damage to the probe, Dewar, and superconducting solenoid may be caused as these objects can fly toward the magnet. Only non-ferromagnetic materials are allowed to be used near the instruments.

- The magnet/Dewar has a high center of gravity and may collapse in an earthquake or if struck by a large object. People near the magnet may face serious injuries and the sudden release of nitrogen and helium gases from the Dewar will displace breathable oxygen in the room. The instruments are supported by anti-vibration legs that are attached to the floor.
- In the event of a "magnet quench" (sudden release of gases from the Dewar), leave the room immediately and contact NMR LS. Rapid expansion of liquid helium or nitrogen gas can displace breathable oxygen in the room creating the possibility of asphyxiation. Do not re-enter the room until the oxygen level has returned to normal. See specific **"Cryogenic** Purge **– Quench"** instructions.
- Handling cryogens is dangerous and can cause serious burns. Therefore, only individuals who have had special training and wear safety glasses, gloves and closed toed shoes should transfer liquid helium and nitrogen to the instruments.
- If you're performing a temperature change experiment, always wear safety glasses near the magnet. Sample subjected to a temperature change can build up excessive pressure which can break the sample tube and broken glass and hot or toxic chemicals can cause injury. To avoid this hazard, establish the freezing and boiling points of a sample and never rapidly heat or cool a sample.
- Extra caution should be provided about the sample tubes as they are fragile and break easily. Removing the probe, the top of the sample tube can break off. The sample should be ejected before removing the probe from the magnet. Use extreme caution when removing the probe if the sample cannot be ejected.
- In the presence of flammable gases or fumes, NMR spectrometers should not be operated as there is risk of injury or death from inhalation, fire and explosion created by flammable gases or fumes.
- If a probe is in place, looking down the barrel of an NMR spectrometer should be avoided. Pneumatic ejection of a sample from the probe could cause injury.

15.3. WARNING SIGNS

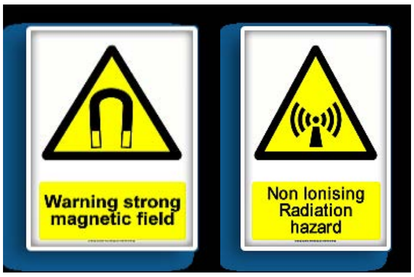


Figure 15.1 Warning sign

In our lab, warning signs (Figure 15.1) and coloured bands are displayed in areas where the field exceeds 5 Gauss; the location of the 10 Gauss region is located slightly inside the 5 Gauss region:

10 GAUSS WARNING - between RED and ORANGE BAND (Figure 15.2) STRONG MAGNETIC FIELD

Pacemaker, Metallic Implant hazard

Strong magnetic and RF fields can cause serious injury that may result in death of people with implanted or attached medical devices, such as pacemakers and prosthetic parts. Such people must not go closer to the magnet than this sign until safety at a closer distance is identified by a physician or device manufactures.

Magnetic Media, ATM/Credit Cards

Strong magnetic and RF fields are present that can erase magnetic media, disable ATM and credit cards and damage some watches. Do not take such objects closer to the magnet than this sign.

5 GAUSS WARNING – between red and green band (Figure 15.2.b)

STRONG MAGNETIC FIELD

Tools and Equipment

Strong magnetic and radio frequency fields are present that can cause magnetic items suddenly fly toward the magnet, which could cause personal injury or serious damage. Do not take tools, equipment or personal items containing steel, iron or other magnetic materials closer to the magnet than this sign.

The warnings at the NMR Lab door are shown below in Figure 15.2.a:

Figure 15.2 NMR room warning signs (a), NMR spectrometer warning signs and bands (b)

15.4. CRYOGENIC PURGE – QUENCH

The cryogens used in the NMR facility are liquid nitrogen and liquid helium.

The magnet cryostats continuously expel a small quantity of gaseous He and N_2 into the air. This does not present a hazard since the air is constantly changed in the NMR room by the air-conditioning system during everyday use.

During the quench helium and nitrogen suddenly evaporate and expand their volume leaving no air in the room. This is an extremely dangerous condition since exposure to atmospheres containing 8-10% or less oxygen will bring about unconsciousness without warning and so quickly that the individuals cannot help or protect them. Therefore, it is imperative that in the event of quench (which is quite obvious because of the noise of escaping gases and clouds of vapor) all lab users should instantly evacuate the area. Since helium is less dense than air, exiting the laboratory by crawling on the floor is recommended. Doors to the laboratory should be left open to aid in the dispersal of helium and nitrogen gases.

The room will be safe after a few minutes.

A purge of liquid cryogens will be very fast and may only take a few seconds. A loud hissing sound will occur and gaseous nitrogen and/or helium will be observed exiting the top of the equipment. The visible cloud is condensed water vapor from humidity in the air due to the cold gasses escaping the instrument.

All lab users must leave the area immediately!

Assist any injured user to the exit. Close the door. Dial 7666 for emergency medical assistance and 7444 to inform LSS.

The emergency assembly area is outside the NMR laboratory in the L-floor hallway. All laboratory users should reassemble at that point and account for all users:

- Make sure all lab users are present at the assembly area in the hallway outside the laboratory.
- Do not re-enter the lab or allow anyone else to enter the laboratory until the purge has ceased and fresh air has been introduced to the lab.

Under no circumstances are users to re-enter the laboratory until the purge is complete and fresh air has been provided. The continued presence of an oxygen deficient atmosphere in the laboratory is a life-threatening condition

Please consult Cryogenic Safety section of this document for more detailed cryogenic safety information.

15.5. OTHER HAZARDS

15.5.1. Electrical Hazards

The NMR spectrometer in the lab operate on either 240 volts and have several high-voltage DC components, all of which can be hazardous or fatal if accidental electrocution occurs. To prevent accidents, the following precautions and prohibitions shall apply to all NMR users and visitors to the NMR laboratory:

- No person may access the instruments without proper training and authorization from the NMR facility manager.

- Extreme caution should be used whenever the instruments are being tuned or otherwise used in a way that makes it necessary to be near the console or magnet.
- No user shall access the instrument panels or spectrometer consoles unless under the observation and guidance of the LSS and NMR LS.
- Any accumulation of water around or near the instruments should be reported to the LSS and NMR LS and the wet areas should be avoided to prevent electrocution.
- Any accidental exposure to electricity must be reported to the LSS and NMR LS.

For further information on electrical hazards see Electrical Safety section.

15.5.2. Cryogenic Liquids

Please consult Cryogenic Safety section procedure for more detailed cryogenic safety information.

Liquid nitrogen and liquid helium are used in the NMR laboratory and both are extremely hazardous. In order to prevent accidental exposure to liquid cryogens, and to avoid asphyxiation in the event of a magnetic quench, the following precautions and prohibitions should apply to all NMR users and visitors to the NMR laboratory:

- Cryogenic liquids in the NMR laboratory should not be used without a training.
- The the LSS and NMR LS must be notified before using cryogenic liquids in the NMR laboratory.
- Individuals handling cryogenic liquids in the NMR laboratory and people in the near vicinity should wear protective clothing including lab coats, gloves and eye-protection.
- NMR laboratory should immediately be evacuated in the event of a magnetic quench (that is, the sudden evaporation of cryogenic liquids in the magnet. See Cryogenic Purge – Quench section instructions.
- Any accidental exposure to cryogenic liquids must be reported to the the LSS and NMR LS.

15.5.3. Transferring cryogenics

When transferring liquid nitrogen or helium, the following steps should be observed to avoid accidents:

- Gloves, eye protection, and closed shoes must be worn.
- Doors should be propped open to increase ventilation.
- Tanks on wheels must be chocked or held by another person.
- The transfer must be continuously attended and helium transfers must be done in buddy pairs.

Since the possibility of a helium quench is higher when filling the magnet, and since the transfer involves manual operations, there is a remote possibility that an operator could be rendered unconscious at the time of a quench. Fills must only be done by two operators particularly if a Helium fill is being carried out.

15.5.4. Electromagnetic Radiation

Strong magnetic fields and several sources of electromagnetic radiation are present in the NMR laboratory that may present unique hazards to individuals. The following precautions and prohibitions apply to all NMR users and visitors to the NMR laboratory:

- Users in the NMR laboratory are subject to exposure limits to static magnetic fields like those found in the NMR laboratory.
- People with pacemakers, defibrillators, or metal surgical implants or prosthetics must stay at least 120 cm away from the magnets at all times.
- Personal articles such as hairpins or jewelry must be kept away from the magnets at all times.
- Metal tools, carts, and gas cylinders must be kept away from the magnet at all times.

15.5.5. Glass Tubes and Evacuated Storage Dewars

The following precautions and prohibitions apply to all NMR users and visitors to the NMR laboratory:

- NMR tubes must be handled with extreme caution. They are thin-walled glass and can cause dangerous wounds. Never force an NMR tube into the NMR spinner holder and never force the cap on or off an NMR tube.
- Broken glass should be cleaned up under the supervision of the LSS and NMR LSand should be disposed of in approved glass waste containers.
- All injuries related to broken glass must be reported to the LSS and NMR LS.

15.5.6. Chemical Hazards

The following precautions and prohibitions apply to all NMR users and visitors to the NMR laboratory:

- NMR solvents must be handled as specified in the Chemical Safety section. Because there are no fume hoods in the NMR laboratory, samples requiring a hood for safe handling must be prepared outside of the NMR laboratory.
- Chemical spills or accidental exposure to NMR solvents must be reported to the LSS and NMR LS (See Chemical Safety, Spill Cleanup Procedures).

15.5.7. Physical Hazards

The following precautions and prohibitions apply to all NMR users and visitors to the NMR laboratory:

- Cryogenic storage Dewars can also be overturned quite easily. They should never be pulled from the top, but rather from the handles provided.
- All injuries related to physical hazards in the NMR laboratory must be reported to the LSS and NMR LS.

References

- Indiana University Superconducting Magnets and NMR Safety (2015, March). Retrieved from http://www.ehs.iu.edu/docs/NMR-Safety.pdf
- Boston College NMR Center Safety Plan (2015, March). Retrieved from http://www.bc.edu/sites/nmr/NMR_Safety_Plan.pdf
- Utah State University College of Science NMR Safety (2015, March). Retrieved from http://www.chem.usu.edu/htm/facilities/nmr/nmr-safety

16. NANOMATERIAL SAFETY

The US National Institute for Occupational Safety and Health (NIOSH) is the lead federal agency for research on the occupational safety and health implications of nanomaterials. In this role, NIOSH recognizes that the research community is at the front line of creating new nanomaterials; testing their usefulness in a variety of applications, and determining their toxicological and environmental impacts.

Although the risks of nanomaterials to human health and the environment are largely unknown, it is prudent to be aware of current information and recommendations for handling nanomaterials from NIOSH and other authoritative sources. This section offers an outline of current best practices in Nanomaterial Safety as of 2012.

16.1. DEFINITION

Nanotechnology is the engineering and manipulation of structures with dimensions ranging from 1 to 999 nanometers. These are often incorporated into a larger matrix known as a nanomaterial. In many cases, particles created at the nanoscale are found to have different chemical and physical properties than larger particles of the same material. These manufactured nanomaterials are also known as engineered nanomaterials.

Different types of the materials that are used in nanotechnology research and application vary widely; however here are a few of the more common ones: Carbon, Silver, Gold, Silica, Titanium and Polymers.

16.2. RECOMMENDATIONS FOR NANOMATERIAL SAFETY

The information below is a summary of NIOSH Publication No. 2012-147: General Safe Practices for Working with Engineered Nanomaterials in research laboratories: Hazards of Nanoparticles.

The characterization and potential for release of the nanomaterial is a challenge. NIOSH is conducting research of its own and summarizing the results of studies to determine when nanomaterials are likely to pose a safety and health threat to exposed users, the general public and the environment. Different types of nanomaterials are made or used in various processes. To determine whether these nanomaterials pose a hazard, scientists must know the following:

- the identity of the chemical constituents,
- the shape of the nanomaterials,
- the resulting physical and chemical properties of the nanomaterials, and
- the concentrations of the nanomaterials in the environment.

Based on these considerations, the primary health and safety concerns are:

Nanomaterial Safety

Fire, explosion and other unexpected reactions involving nanomaterials are the main safety hazards. Materials at the nanometer scale may unexpectedly become chemical catalysts and result in unanticipated reactions.

Health

Laboratory studies with animals have shown that when some types of nanoparticles are inhaled, they may reach the blood, brain, and other organs of laboratory animals. Some studies have shown adverse effects such as inflammation and fibrosis in the lungs and other organs. These studies are ongoing to better define the health impacts of nanomaterials.

Environment

There are many ongoing studies of the impact of nanomaterial releases into the general environment, whether by air or waste water or in the handling of hazardous waste. These have not progressed far enough for any regulatory Authority to establish limits for these emissions. For this reason, it is recommended that disposal of all nanomaterials should be done through hazardous waste program.

Laboratory Safety

The processes of producing nanomaterials require the use of a variety of highly reactive materials such as concentrated mineral acids, organic solvents and strong oxidizers. Careful management of these chemicals must be an important consideration using prudent laboratory practices.

Although more research is needed to predict the effects of nanomaterial exposures on humans, sufficient information is available to provide interim recommendations and guidance about occupational exposures. NIOSH recommends a prudent approach for manufacturing and using nanomaterials in industry. Steps should be taken to minimize exposures until more information is available.

16.3. CONTROLLING PERSONAL EXPOSURE TO NANOMATERIALS

Several factors affect exposure to nanomaterials:

The concentration, duration, and frequency of exposure to nanoparticles all affect user exposure.

In addition, the ability of nanoparticles to be easily dispersed as a dust (e.g. a powder) or an airborne spray or droplets will impact exposure of the users.

Use of protective measures such as engineering controls (e.g. fume hoods) and personal protective equipment (e.g. gloves) can reduce user exposure.

Job-related activities may also influence user exposure:

Active handling of nanomaterials as powders on the benchtop pose the greatest risk for inhalation exposure; NIOSH recommends the use of HEPA filters, either in respirators or local ventilation equipment to control such powders

Tasks that generate aerosols of nanomaterials from slurries, suspensions, or solutions pose a potential for both inhalation and dermal exposure. In some cases, it has been found that nanomaterials have penetrated both gloves and skin.

Clean-up and waste disposal of nanomaterials may result in exposure if not properly handled. Maintenance and cleaning of production systems or dust collection systems may result in exposure if deposited nanoparticles are disturbed.

Machining, sanding, drilling, or other mechanical disruptions of materials containing nanomaterials may lead to aerosolization.

16.3.1. Measurement of Nanomaterials

Traditional industrial hygiene sampling methods such as airborne dust measurements have been used to measure airborne nanomaterials. However, these methods require careful interpretation. Scientists are developing more sensitive and specific sampling techniques to evaluate occupational exposures. Sampling in the workplace should include background measurements and measurements before, during, and after production or handling of these materials. These measurements can determine if emissions and possible exposures are occurring.

16.3.2. Exposure Controls

Elimination or substitution of a less hazardous substance is a basic principle of laboratory safety and health. Certain aspects of a process may be changed and result in a less hazardous situation to exist.

Reducing user exposures to nanomaterials can be achieved by Engineering Controls such as source enclosure (isolating the generation source from the user) and local exhaust ventilation systems. Exhaust ventilation systems that use high-efficiency particulate air (HEPA) filters are very effective in removing nanomaterials. In Table 16.1 (provided by NIOSH), recommendations of installing control measures depending on the nanomaterial used in specific activities are presented.

By means of engineering controls, operational procedures, such as reducing the time the employee is handling the material, specifying good housekeeping and other good work practices, training employees, and implementing proper labeling and storage of materials, limit the exposure to nanomaterials.

If engineering and administrative controls cannot control exposures, personal protective equipment, such as respirators and appropriate gloves and coveralls, should be considered.

Recommended safety procedures for handling nanomaterials:

- Use good general laboratory safety practices as found in Chemical and Biological Safety sections of this handbook and individual laboratory operating procedures. Wear gloves, lab coats, safety glasses, face shields, closed-toed shoes. Avoid getting nanoparticles in eyes, mucous membranes, on skin, or in respiratory tract.
- Wash your hands BEFORE you leave the lab.
- Be sure to consider the hazards of precursor materials in evaluating process hazards. (For example, some powders are more dangerous until they are mixed into a solution, whereby they become safer to handle and there isless possibility of inhalation of floating particles.)
- Avoid skin contact with nanoparticles or nanoparticle-containing solutions by using appropriate personal protective equipment. Do not handle nanoparticles with your bare skin.
- Handle nanoparticles only inside a HEPA-filtered powered-exhaust laminar flow hood, wear appropriate respiratory protection. If this is not possible, consult with LSS on obtaining respiratory protection.
- Use fume hoods to expel fumes from tube furnaces or chemical reaction vessels.
- Place the waste that contains nanoparticles in puncture proof sealable containers, or double bag in 6 mL plastic, clearly mark with contents and disposed of through hazardous waste channels.
- Clean up spilled nanoparticles accomplished with a HEPA filtered vacuum or call LSS.
- Become familiar with the SDS associated with the basic material; be alert for the onset of any symptoms associated with the chronic effects of these materials.

No certain set of rules will cover all situations.

Given the differing synthetic methods and experimental goals, no blanket recommendation can be made regarding aerosol emissions controls. This should be evaluated on a case by case basis.

Consideration should be given to the high reactivity of some nanopowders materials with regard to potential fire and explosion hazards (Table 16.1).

Table 16.1 Criteria for exposure potential and recommended minimum controls

State of the nanomaterial	Employee activity	Potential exposure source	Recommended engineering controls
Bound or fixed nanostructures (polymer matrix)	Mechanical grinding, alloying, etching, lithography, erosion, mechanical abrasion, grinding, sanding, drilling, heating, cooling	Nanomaterials may be released during grinding, drilling, and sanding. Heating or cooling may damage the matrix, allowing release of nanomaterial.	Local exhaust ventilation Laboratory chemical hood with HEPA-filtered exhaust HEPA-filtered exhausted enclosure (glovebox) Biological safety cabinet class II type A1, A2, vented via thimble connection, or B1 or B2
Liquid suspension, liquid dispersion	Synthesis methods: chemical precipitation, chemical deposition, colloidal, electrodeposition crystallization, laser ablation (in liquid) pouring and mixing of liquid containing nanomaterials sonication, spraying, spray-drying	Exposures may result from aerosolization of nanoparticles during sonication or spraying, equipment cleaning and maintenance, spills or product recovery (dry powders).	Laboratory chemical hood (with HEPA-filtered exhaust) HEPA-filtered exhausted enclosure (glovebox) Biological safety cabinet class II type A1, A2, vented via thimble connection, or B1 or B2
Dry dispersible nanomaterials and agglomerates	Collection of material (after synthesis), material transfers, weighing of dry powders, mixing of dry powders	Exposures may occur during any dry powder handling activity or product recovery.	Laboratory chemical hood with HEPA-filtered exhaust HEPA-filtered exhausted enclosure (glovebox) Biological safety cabinet class II, B1 or B2
Nanoaerosols and gas phase synthesis (on substrate)	Vapor deposition, vapor condensation, rapid solidification, aerosol techniques, gas phase agglomeration, inert gas condensation (flame pyrolysis, high temperature evaporation), or spraying	Exposures may occur with direct leakage from the reactor, product recovery, processing and packaging of dry powder, equipment cleaning, and maintenance.	Glovebox or other sealed enclosure with HEPA-filtered exhaust Appropriate equipment for monitoring toxic gas (e.g., CO)

Adopted from The University of North Carolina at Chapel Hill, Environmental Health & Safety Department.

16.4. EMERGENCY PROCEDURES

Because of the considerations described above, NIOSH recommends a specific spill kit for responding to nanomaterial spills. Laboratories working with these materials should review the NIOSH spill management guidelines and develop specific procedures for managing these events. Contact LSS for assistance in developing these plans.

The information above is based on NIOSH Publication No. 2012-147: General Safe Practices for Working with Engineered Nanomaterials in Research Laboratories. However, best practices in this field are evolving rapidly and these other references should be reviewed to assure that the most current information is being used in managing the safety and health aspects of your work.

References

- National Institute for Occupational Safety and Health, Department of Health and Human Services. Approaches to Safe Nanotechnology: Managing the Health and Safety Concerns Associated with Engineered Nanomaterials (2015, March). Retrieved from http://www.cdc.gov/niosh/docs/2010-112c/
- Green Nanotechnology Challenges and Opportunities from the American Chemical Society (2011, June). Retrieved from http://portal.acs.org/portal/fileFetch/C/CNBP_027847/pdf/CNBP_027847.pdf
- The Nano Risk Framework, a nano risk management approach developed by Dupont and the Environmental Defense Fund (2015, March). Retrieved from http://www.nanoriskframework.com
- The Nanomaterial Registry (a fully curated resource that provides information on the biological and environmental implications of well-characterized nanomaterials) (2015, March). Retrieved from https://www.nanomaterialregistry.org/
- Working Safely with Nanomaterials in Research and Development (2015, March). Retrieved from http://www.safenano.org/UKNanosafetyPartnership.aspx
- Project on Emerging Nanotechnology (2015, March). Retrieved from http://www.nanotechproject.org/
- OSHA FactSheet: Working Safely with Nanomaterials (2015, March). Retrieved from http://www.osha.gov/Publications/OSHA_FS-3634.pdf
- The EPA and Green Nano (2015, March). Retrieved from http://www.epa.gov/research/greenchemistry/
- General Safe Practices for Working with Engineered Nanomaterials in Research Laboratories (2015, March). Retrieved from http://www.cdc.gov/niosh/docs/2012-147/pdfs/2012-147.pdf

A. WASTE MANAGEMENT

A.1 INTRODUCTION

Waste management is all the activities and action required to manage waste from its inception to its final disposal. This includes amongst other things, collection, transport and disposal of waste together with monitoring and regulation. It also encompasses the legal and regulatory framework that relates to waste management encompassing guidance on recycling.

Sabancı University FENS waste management regulations include laboratory performed all activities resulting in the waste category (hazardous, non-hazardous) by preventing harm to environment by means of storage, collection and disposal.

A.1.1. Personal Training

LS or LSS should be contacted for the personal training of the management of hazardous and non-hazardous wastes in Sabancı University FENS laboratories.

A.1.2. General Waste Management Procedures And Waste Determination Process

Sabancı University FENS has strict regulations concerning the management, storage, and disposal of hazardous materials. Within specific activities, LS and LSS will provide advice and technical assistance regarding hazardous wastes. However, it is the responsibility of each individual to know the possible dangers associated with any material being used or generated, and know how the material should be handled and disposed of before a project begins. The schematic below shows the waste management process (Figure A.1):

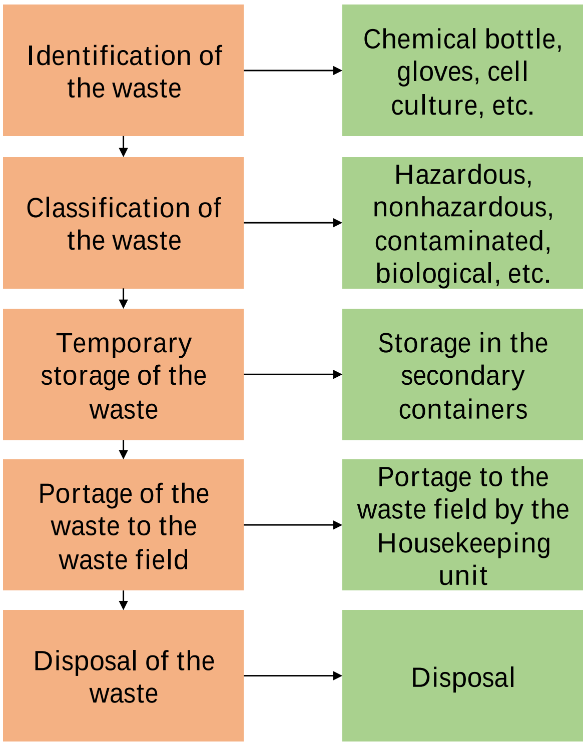


Figure A.1 Waste management process

Materials for which waste management programme is responsible:

- Chemical waste
- Highly toxic materials
- Examples include inorganic cyanides, pesticides, and arsenic compounds
- Used oil
- Biological/infectious waste
- Batteries
- Radioactive waste (Please see Radiation Safety section)
- Sharps
- Broken glass
- Empty compressed gas tanks and pressurized containers
- Electronic waste, which includes unwanted computers, monitors, televisions, audio equipment, printers, laptops, fax machines, telephones and other electronic equipment. When electronic equipment breaks or becomes obsolete, it must be properly disposed of or recycled.

A.1.3. Types of Waste

Laboratory waste in Sabancı University is classified according to the schematic below (Figure A.2):

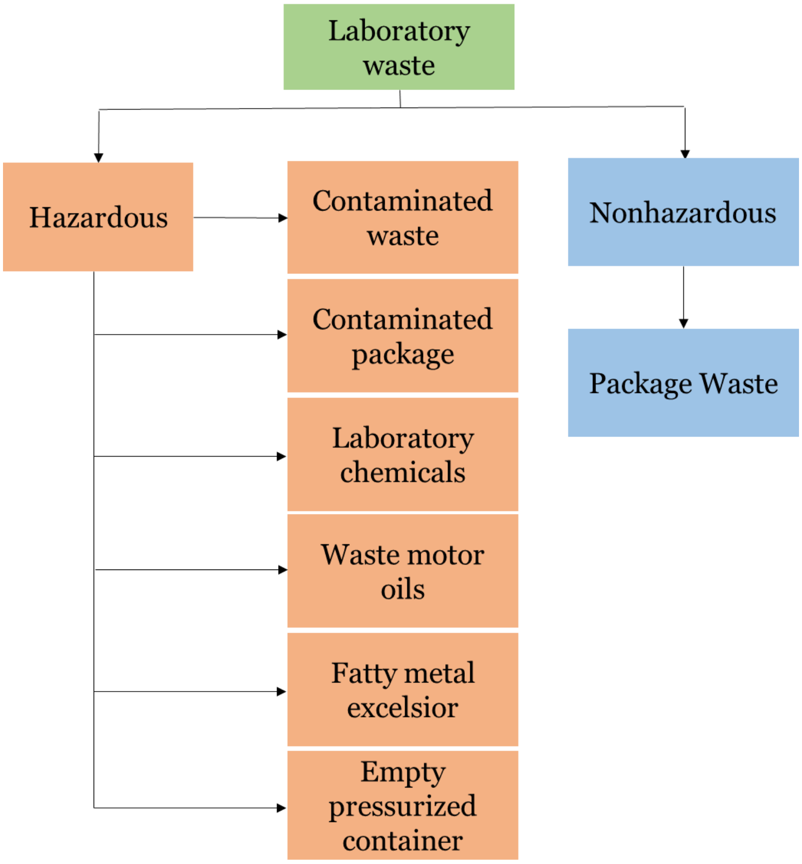


Figure A.2 Laboratory waste classification

Hazardous Waste

- Contaminated waste
- Gloves, respirators, filters, lab coats and materials used in the laboratory
- Contaminated waste – autoclaved
- Bacteria, yeast etc. microbiological waste, live/dead tissue waste
- Contaminated packages
- Rust solver, chemical spray boxes
- Empty pressurized containers
- Rust solver, chemical spray boxes, compressed gas tanks
- Laboratory chemicals
- Fatty metal excelsior
- Waste motor oils
- Sharps
- Broken glass

Non-hazardous Waste

- Package waste

Please see Appendix A.1. Laboratory Waste Guide Table.

A.1.4. Container Labels

All chemical/contaminated/electronic etc. wastes should carry a label identifying their content.

A.1.5. Waste Minimization

Only the quantity of material that will be completely used within a reasonable time frame should be purchased. If the products are stockpiled for future use, valuable space is unnecessarily used and the disposal of the hazardous chemicals are much more difficult when not used.

- Limit the amount you order. Review chemical stocks and needs before ordering.
- Do not stockpile chemicals.
- Avoid duplication - Check your inventory to avoid ordering chemicals that are already in stock. Keep inventories up to date.
- Rotate chemical stocks to use up chemicals before their shelf lives expire. This impacts research and may impact the credibility of results: some chemicals, both organic and inorganic, may degrade or otherwise have reduced or modified reactions over time.

The following guidelines are a checklist to accomplish waste minimization – they are not intended to restrict activities:

- Before beginning a project, determine the hazards associated with the material. Where possible substitute less hazardous substances.
- Use small batch or micro-level reactions where possible.
- Order and maintain minimum quantities of chemicals.

Certain chemicals are difficult and/or costly to dispose of and should be given special consideration. Some types are:

- Heavy metals, *e.g.,* mercury, barium, cadmium, chromium, beryllium, silver, selenium, tellurium, either elemental or in compounds.
- Chlorophenols, dioxins, and cyanides.
- Compressed gases (to include lecture bottles) or containers with liquids under pressure (especially if the substance is poisonous). Where possible arrange with the supplier to accept return of used containers.

Good purchasing decisions are the first steps in minimizing waste generation. Every effort must be made to keep purchase quantities to a minimum. Remember "LESS IS BEST" when planning work and ordering chemicals.

A.2 CHEMICAL WASTE DISPOSAL

Prior to generating chemical waste, you must classify it by determining its hazardous properties. By doing this first, you will be able to choose a compatible container to collect the waste, know how to label the container and stay within the accumulation time limits.

Flammable/Ignitable. (1) Liquids (with less than 50% water by weight) with a flashpoint of less than 60 °C (e.g., gasoline, benzene, alcohols, acetone, and ethers); (2) solids that can cause fire through friction, absorption of moisture, or spontaneous chemical changes, and when ignited burn so vigorously and persistently that it creates a hazard; and (3) ignitable compressed gases.

Corrosive. (1) Liquids with a pH of less of ≤ 2 (e.g., sulphuric acid); (2) liquids with a pH ≥ 12.5 (e.g. potassium hydroxide); (3) solids, that when mixed with an equivalent weight of water, produce a solution having a pH ≤ 2 or ≥ 12.5 (e.g., hydrated lime, acetamide, cupric bromide).

Reactive. (1) Liquids or solids that are normally unstable and readily undergo change without detonation, react violently with water, or generate toxic gases or fumes when mixed with water; (2) chemicals containing cyanide or sulphur and which generate toxic gases when exposed to pH conditions between 2 and 12.5; (3) chemicals which are capable of detonation if subjected to a strong initiating source, or heated under confinement; or (4) chemicals capable of detonation at standard temperature and pressure. Examples: pyrophoric liquids, sodium cyanide, potassium sulphide, potassium metal, dry picric acid.

Toxic. This is the default hazard waste characteristic for chemical waste that is not flammable, corrosive or reactive. Unless you have documentation, such as a toxicity assessment or bioassay testing, which clearly shows that the waste is non-toxic, label your waste as toxic. LS/LSS can assist you with sampling and waste analyses.

Oxidizer. Oxidizer is a secondary hazardous property. Indicate on the waste label the primary hazard of the oxidizer in addition to "Oxidizer" (e.g., Piranha waste is a corrosive acid and an oxidizer). Oxidizers cause or enhance the combustion of other materials and are a fire hazard if stored or transported incorrectly.

For more information, please see Chemical Safety section.

A.2.1. Waste Management Program

Sabancı University FENS has chemical waste management regulations and here are the general guidelines for chemical waste disposal:

- Eliminate the need for disposal of unused chemicals by not purchasing more than the quantity of chemicals needed for your experiments.
- Try to use non-hazardous chemicals in place of hazardous chemicals whenever possible.
- Do not dispose of flammables, organic solvents, toxic materials, corrosive materials, reactive materials, odorous chemicals, or water insoluble materials down the drains.
- Dispose of ethidium bromide as a chemical hazardous waste (Please see section A.3.5 Disposal of Ethidium Bromide Waste).
- Place all hazardous waste containers in a secondary containment.
- Separate incompatible chemical waste.
- The containers must be kept properly and securely closed.
- Attach the hazardous waste tag to each waste container. Complete all information requested.
- When waste container is ready for pickup, put the container in the defined waste area of the laboratory, create an “inquiry” from call center 9988 and inform LSS.

A.2.2. Chemical Waste Containers

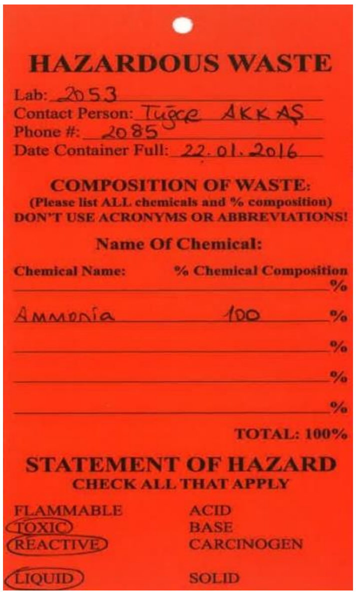
All waste containers must be labelled with the words “hazardous waste” the chemical composition of the waste, its hazards, and the accumulation start date (the date the waste is first produced).

“Hazardous Waste Tag” should be completed and placed on the container when it is first designated as a waste. See Figure A.3 for an example tag.

Accumulation time limits: SU policy states that waste can only be stored in a lab for 90 days. Full containers are required to be removed from labs within 2 weeks.

Container and packaging requirements:

- The waste must be accumulated in containers that are in good condition and it should be compatible with the container it is stored in.
- The container must be kept closed except when the waste is being added to or removed from the container.
- Liquids must be collected in containers with screw tops or sealed lids.
- Do not completely fill the container. Leave the container less than 75% full.
- Dry waste must be double bagged in clear plastic bags.
- Paper towels are not hazardous waste unless hazardous chemicals are spilled on the towel.
- Liquids are required to be separated from solids.
- Mercury must be collected in a screw cap bottle. Double bag mercury contaminated items and broken thermometers in clear plastic bags (Use mercury spill kit and be aware of the danger). Please see Emergency Procedures section.



HAZARDOUS WASTE

Lab: 2053
Contact Person: Tuğçe AKKAŞ
Phone #: 2085
Date Container Full: 22.01.2016

COMPOSITION OF WASTE:
(Please list ALL chemicals and % composition)
DON'T USE ACRONYMS OR ABBREVIATIONS!

Name Of Chemical:

Chemical Name:	% Chemical Composition
	%
Ammonia	100 %
	%
	%
	%

TOTAL: 100%

STATEMENT OF HAZARD
CHECK ALL THAT APPLY

FLAMMABLE   ACID
[✓ TOXIC]   BASE
[✓ REACTIVE]   CARCINOGEN

[✓ LIQUID]   SOLID

Figure A.3 Waste bottle label example

Waste storage amount limits: The maximum amount of waste allowed to be stored in a laboratory is:

- 1 liter acute / extremely hazardous waste
- The maximum amount of solvent allowed to be stored in a lab is 50 liters including waste solvents.

A.2.3. Chemical Waste Pick-up Procedure

Chemical waste is picked up by Housekeeping Unit staff upon an 'inquiry from call center (9988)'. Each laboratory must package, tag, and hand their waste at the scheduled time.

Separate incompatible chemicals during transport and storage. Store and transport chemicals by hazard classes:

- Flammable solid
- Flammable or combustible liquid/solvent
- Nonhalogenated, halogenated
- Corrosives
- Acids – also separate organic, inorganic, nitric
- Bases
- Oxidizers
- Poisons or toxic
- Carcinogens, mutagens, irritants, formaldehyde
- Explosives/shock sensitive
- Water reactives
- Organic peroxides
- Heavy metals

These items will not be accepted at chemical waste pick-ups:

- Leaky containers
- Containers with exterior chemical contamination
- Containers which are too full. Do not fill containers over 90%.
- Radioactive waste
- Bags containing protruding glass and other sharps such as needles, blades or glass pipettes
- Bench diapers unless hazardous chemicals were spilled on the diaper

A.2.4. Dangerous Chemical Waste, Unknowns

Acutely dangerous waste:

Do not move acutely dangerous or unknown wastes which are shock sensitive or whose containers are leaking due to corrosion or which have no labels.

Peroxide forming chemicals (PFCs):

Once a peroxide forming chemical has been opened, the lab has one year to use it. After one year, it has to be disposed of as hazardous waste. PFCs normally will not start forming explosive peroxides if they are not expired.

A.2.5. Empty Cylinders

If a compressed gas tank is empty please follow the regulations below and inform LS.

- Remove the regulator and replace the cylinder cap.
- Mark the cylinder as empty or MT and store in a designated area for return to the supplier.
- Do not store full and empty cylinders together.
- Do not have full and empty cylinders connected to the same manifold. Reverse flow can occur when an empty cylinder is attached to a pressurized system.
- Do not refill empty cylinders. Only the cylinder supplier should refill gases.
- Do not empty cylinders to a pressure below 25 psi (172 Kpa). The residual contents may become contaminated with air.

A.3 BIOLOGICAL WASTE DISPOSAL

A.3.1 Biohazard Bag

Biohazardous wastes should be put into “white bags with an autoclave sign”.

A.3.2 Sharp Containers

All sharp containers must be rigid, puncture resistant and leak resistant. Cardboard does not meet these requirements.

Sharp containers (Figure A.4) must be labelled with the words, “Sharps Waste”.

Figure A.4 Example of sharp container

A.3.3 Bag and Container Use

If the container is empty or it is not in use, lids must be kept on containers.

Sharps should be placed entirely inside the sharps container.

Bags should not be used for transporting non-biohazardous items, or covering equipment such as microscopes.

Biohazardous waste should not be removed from the bag once it has been placed in the bag.

Items that can pierce the bag should not be placed in.

A.3.4 Human Tissues and Biohazardous Animals

Human tissues and biohazardous animals are required to be placed in red biohazard bags which should be placed inside a leak resistant container labelled with the words “Medical Waste”.

The bags must be tagged with the date and a description of the contents when storing human tissues or biohazardous animals that are waste in a freezer.

A.3.5 Disposal of Ethidium Bromide Waste

Ethidium bromide (EtBr) is both an irritant and a mutagen and a frame shift mutagen, which inserts double-stranded DNA and RNA resulting in the inhibition of DNA synthesis. It may be harmful by inhalation, ingestion, or skin absorption. Eyes, skin, mucous membranes, and upper respiratory tract may be irritated by the material. Chronic effects include the possible alteration of the genetic material.

If possible, a less hazardous material or micro or semi-micro techniques should be used to minimize the generation of hazardous waste.

Ethidium bromide crystals or powder, stock solutions, gels, running buffers and contaminated labware (microfuge tubes, pipet tips, lab bench diapers, gloves, etc.) should be handled as hazardous waste. Dilute solutions of ethidium bromide (less than 0.01 mg/L) may be deactivated in the lab by pouring the dilute solution through a commercially available filter cartridge designed to sequester EtBr and disposing the filtered liquid down the drain. Used cartridges should also be handled as hazardous waste.

The following procedures apply only for chemical waste, and not medical or radioactive waste.

Preparation for waste collection and storage gels: Collect gels in clear containers that can be closed or sturdy (>4mm thick) clear bags. Double bag the gels. Seal the bags or close containers with tight sealing lids. Label the container or outer bag with a “Hazardous Waste Tag” and store in a secondary container.

Crystals, powders, and stock solutions: Label the original container or stock solution container with a “Hazardous Waste Tag” and store in a secondary container.

Contaminated labware (Dry waste): Place contaminated labware in a robust (>4mm thick) clear bag. Double bag dry waste. Red biohazard bags containing EtBr dry waste will not be accepted. Sharps must be placed in an approved sharps container before being placed in a clear bag. Seal the bags and label the outer bag with a completed "Hazardous Waste Tag". The description should state "Ethidium Bromide Dry Waste."

A.3.6 Transport and Storage

Tie-close filled waste bags before transporting them.

All closed and filled bags must be transported inside a rigid bag container and may be placed on a cart. The bag itself may not be transported in an autoclave pan, cardboard box, or on a cart. They may not be carried by hand.

Do not set or store full bags on the floor, in an autoclave pan or cardboard box. They must be inside a bag container at all times except when inside the autoclave.

Store containers of waste in a secure area such as a laboratory or autoclave room. Do not set or store them in the hallway.

Do not store waste for more than 7 days at a temperature above freezing. Dispose of the bags as soon as possible.

Do not store full sharps containers for more than 7 days at a temperature above freezing. Dispose of the full sharps containers as soon as possible.

Do not store waste, full sharps containers or human tissues and animals that are waste for more than 90 days in a freezer.

Do not compact bags of waste when placing them in a storage container.

A.3.7 Disposal

The container should not be overfilled. The lid must fit on tightly on the container.

"Contaminated waste" bags must be used for biohazardous waste which have been autoclaved before.

Biohazard waste containers must be sanitized when soiled with waste. They must be sanitized by exposure to hot water at 180 °C for 15 seconds or exposure for 3 minutes to any of the following disinfectants: hypochlorite (i.e., bleach) solution (500 ppm available chlorine), phenolic solution (100 ppm active agent), Iodoform solution (100 ppm iodine) or quaternary ammonium solution (400 ppm active agent).

Waste or sharps waste combined with hazardous chemical waste must be disposed of as hazardous chemical waste.

Liquid wastes should be mixed with household bleach to make a 10% bleach solution. After 30 minutes of a contact time, waste should be disposed into the laboratory sink, flushing with cool water.

A.3.8 Non-biohazardous Sharps Waste Disposal

What Are Sharps?

- Needles with or without attached syringe or tubing
- Blades, scalpels, razors
- Glass: broken pipettes, whole or broken Pasteur pipettes, broken vials.

Disposal Procedures

- Do not discard sharps into the regular trash can. They can cause injury to the custodians.
- Do not recap or clip needles.

As sharps are used or generated, place them into a sharps container. A sharps container is "a rigid puncture-resistant container which, when sealed, is leak-resistant and cannot be reopened without great difficulty". Do not use cardboard sharps containers because they leak. Use plastic or other kinds of leak-proof containers.

Place sharps into a sharps container. These containers do not have to be labelled in a specific way. When the container is nearly full, seal it and dispose of the sealed container with broken glass.

When the container is 3/4 full, it should be disposed of into the contaminated waste container. The empty sharp container can be supplied from LS/LSS.

A.4 GLASS DISPOSAL

- Do not mix broken or unbroken glass with regular trash. Glass mixed with regular trash could cause an injury to your custodian.
- Dispose of large glass containers such as solvent bottles in the dumpsters located in the loading dock area. Rinse and dry the glass containers before disposal.
- Dispose of broken glass in a separate trash container designated for and labelled "Broken Glass".

A.5 DRAIN DISPOSAL

Please see Appendix A.2. “Safe for Drain Disposal”.

If accidentally any other chemical is poured into the drain, please call 7444 to contact LS or LSS and inform them about the laboratory, name of the spilled chemical, concentration and the hazardous characteristics of it.

References

- University of California, EH & S Information for the Berkeley Campus, Responsibility for Environment, Health and Safety (2015, March). Retrieved from http://www.ehs.berkeley.edu/responsibility-environment-health-and-safety
- Georgia Institute of Technology EHS Hazardous Waste Procedures (2015, March). Retrieved from https://www.ehs.gatech.edu/chemical/lsm/13

B. EMERGENCY PROCEDURES

B.1. SPILL, FIRST AID, AND EMERGENCY KITS

Response kits should be maintained at laboratories for potential use. These kits should be inspected by the LS/LSS routinely. (*i.e*, semi-annually and after use) to make sure they are available and ready to use. A specific person (or people on a roster) should be allocated to inspect the kits on a periodic basis.

B.1.1. Chemical Spill Clean-Up Kits

Chemical spill kit (Figure B.1.a) content may differ with the chemicals in laboratory needs. Kit contents are listed in Table B.1.

Figure B.1 PIG® HazMat Spill Kit (a) and PIG® Hydrofluoric Acid Neutralizing Spill Kit (b)

Table B.1 Spill kit content

Spill kit content	Amount
ext. dia. 3" x 46" L PIG® HazMat Chemical Absorbent Sock (124CR)	5
15" W x 60' L PIG® Rip-&-Fit® HazMat Mat Roll in Dispenser Box (MAT342)	1
8" W x 8" L x 1" H PIG® HazMat Chemical Absorbent Pillow in Dispenser Box (PIL302)	4
7" L PIG® Multi-Purpose Epoxy Putty (PTY201)	1
18" W x 30" H "Caution - Handle with Care" Polyethylene Disposal Bags (BAG201-S)	5
Instructions	1

Hydrofluoric Acid Spill Kit

Hydrofluoric acid (HF) has a number of physical, chemical, and toxicological properties that make it especially hazardous to handle. Both anhydrous hydrofluoric acid and aqueous solutions are clear, colorless, and highly corrosive liquids. When exposed to air, anhydrous HF and concentrated solutions produce pungent fumes, which are also dangerous. HF shares the corrosive properties common to mineral acids, but possesses the unique ability to cause deep tissue damage and systemic toxicity. Prevention of exposure or injury must be the primary goal when working with HF. However, any HF user must be intimately familiar with the appropriate first aid in case of an exposure.

HF Spill Kit (Figure B.1.b) must be supplied to HF using laboratories. The spill kit content is given below Table B.2:

Table B.2 Hydrofluoric acid neutralizing spill kit content

Spill Kit Content	Amount
PIG® Hydrofluoric Acid loose absorbants	2
15" W x 20" L PIG® HazMat Mat Pad (MAT301)	10
18" W x 30" H Polyethylene Disposal Bags (BAG201-S)	5
Economy Goggles (GLS290-AF)	1
13" L Showa-Best Chem Master™ Neoprene Gloves (GLV213-XL)	2
Instructions	1

B.1.2. First Aid Kits

First aid kit and supplies must be available to all users in case of emergency. First aid kits as size and content may vary upon number of people and particular laboratory situations.

For example, laboratories using hydrofluoric acid (HF) must supply calcium gluconate ($C_{12}H_{22}CaO_{14}$) gel in case of skin contact. Each laboratory must also set up procedures to assure that supply stock in first aid kits are required level. Table B.3 shows First Aid Kit Contents, lists contents of the typical first aid kit.

Table B.3 First aid kit content
Absorbent gauze
Adhesive bandages
Bandage compress
Scissors and tweezers
Triangle bandages
Antiseptic soap/pads
Kling bandage
Surgipad dressing
Adhesive tape
Multi-trauma dressing
Kerlix dressing

B.1.3. Burn Kits

Corrosive and irritant chemical products react with the biological components of the skin or eye. This gives rise to skin or eye lesions or burns, the consequences of which may be very serious.

In the event of contact between a corrosive or irritant chemical product and the skin or eye, it is essential to limit the reactions between these products and the tissues. The chemical product will react with the tissue for as long as it is in contact with the latter and no action halts its aggressiveness.

B.1.3.1. Diphoterine Wall-Mounted Station

Diphoterine (Figure B.2.a) solution is an emergency rinsing solution for splashes of chemical products. Its rapid use in case of contact between the skin or eye and a chemical product is intended to quickly eliminate the residual chemical product on the skin or in the eye. This makes it possible to limit the extent of the burns and lesions caused. Diphoterine facilitates secondary treatment of the burn injuries by restricting the extent and severity of the lesions.

How to use Diphoterine

- Apply Diphoterine solution within the first minute following the accident.
- Uncap the 500 ml Diphoterine bottle and placed it on the affected eye. Use the full contents of a bottle on the affected eye.
- In case of skin splashes uncap the 200 ml of Diphoterine sprayer and use the full contents on the affected skin (face or arm).
- A 200 ml bottle of Afterwash II restores the physiological balance of the eye, and reduces the unpleasant sensations due to the chemical splash. Use the full contents on the affected eye.
- After the accident seek expert medical attention.

B.1.3.2. Hexaflourine Wall-Mounted Station

Hexaflourine (Figure B.2.b) solution is a special emergency treatment product that actively washes and decontaminates HF acid splashes to the eye and skin. It was specifically developed in order to eliminate the dangers and risks associated with the use of hydrofluoric acid.

How to use hexaflourine

- Apply hexafluorine within the first minute following the accident.
- Uncap the 500 mL hexafluorine bottle. The entire contents of the bottle must be used on the affected eye.
- In case of skin splashes uncap the 50 mL of calcium gluconate gel and use the full contents on the affected skin (face or arm).
- After the accident seek expert medical attention.

B.1.3.3. Water-Jel Kit

Water-Jel Burn Kit (Figure B.2.c) is a special water based gel that draws heat from the burn. It reduces pain, cools the skin and prevents airborne infection. It prevents the deepening of the burn when it is applied quickly enough. It is used for all types of burns (heat, steam, electricity, combustion, explosion, radiation).

How to use Water-Jel

- In case of accident, open the thermal burn kit.
- Select a dressing in accordance with size of burn.
- Tear foil package open and remove the dressing.
- Unfold and apply dressing immediately to burn area and pour the excess gel remaining in the package over the dressing and any debris or clothing adhering to the burn.
- Leave the dressing in place. Seek expert medical attention.

Instructions for using burnjel

- Use for minor burns.
- Apply the gel to burn area.
- Leave the gel on the burn area for app. 45 minutes.

Figure B.2 Chemical and thermal burn kits; Diphoterine (a), Hexafluorine (b), Water-Jel (c)

B.2. FIRE EXTINGUISHERS, EYEWASH STATIONS, SAFETY SHOWERS AND EMERGENCY CONTACT

B.2.1. Fire Extinguishers

Portable fire extinguishers are supplied in FENS building and are available to trained users. These types of extinguishers are based on the types of combustible and flammable materials in the lab (see Table B.4.). People who have been tutored in fire extinguisher use and the hazards involved may attempt to extinguish small and early stage of fires if there is an escape route. People who are not trained in the proper use of extinguishers should not use one during a fire.

Many fire extinguishers on campus are the multi-purpose type, or ABC, which perform well on most fires with one major exception, combustible metal fires. Combustible metal (Class D) extinguishers are not typically provided for laboratories unless the need has been identified. Laboratories may request the addition of a CO_2 extinguisher (Class BC). It is not as effective as a dry chemical extinguisher, but will require less clean up after use. Some pressurized water fire extinguishers (Class A, B, C and bioversal) are still found in hallways but they are only suitable for use on ordinary combustible materials (paper, wood, plastic, etc.). Fire extinguishers should be conspicuously located, wall mounted, and easily accessible (Table B.4).

Table B.4 Classes of fires and proper fire extinguishers

Class of Fire	Description	Proper extinguisher
A	Ordinary combustibles such as wood, cloth, and paper.	Dry Chemical (ABC) or water
B	Flammable liquids such as gasoline, oil, and oil-based paint.	Carbon Dioxide (BC) or Dry Chemical (ABC)
C	Energized electrical equipment including wiring, fuse boxes, circuit breakers, machinery, and appliances.	Carbon Dioxide (BC) or Dry Chemical (ABC)
D	Combustible metals such as aluminium, magnesium or sodium	Special Extinguisher (D)

Fire hoses may only be used by firefighters. Fire blankets are not recommended for laboratory use because they may trap heat in when a victim has burning clothes and cause more injury than would otherwise occur.

B.2.2. Eyewash Stations

If chemicals in use can cause eye damage, irritation or splash, an eyewash station (Figure B.3) is required.

Laboratory users must be able to reach eyewash stations *within ten seconds**. The eyewash should be within ten seconds walking distance of chemical use locations, although this distance may be less if doorways interfere with access. Chemical splashes can cause temporary or permanent blindness, which can make it very difficult for someone to find the eyewash on their own in an emergency.*

People who are involved in laboratories should know the location and how to operate eyewash stations in their area. It is recommended to the people to practice eyewash stations while keeping their eyes closed. The path to the eyewash station must be kept clear. Eyewashes must be tested in appointed period to monitor operation quality.

How to use Eyewash Station

- Push the red button off and the flushing fluid will begin to flow out from the conical head.
- Get your eyes directly in the stream of the flushing fluid.
- Keep your eyes open by holding your eyelids apart with your fingers.
- Gently roll your eyes from left to right and up and down to be sure that the fluid is flushing all of the areas of your eye.
- Continue flushing your eyes for a full 15 minutes. This is important because you want to fully dilute the chemical and wash it out of your eyes. Any time less than 15 minutes is not enough time to accomplish this.
- If you have contact lenses in your eyes, you can gently take them out while you are flushing. Don’t delay the flushing to take out your lenses but make sure that you take them out because they could trap the chemical in your eyes.

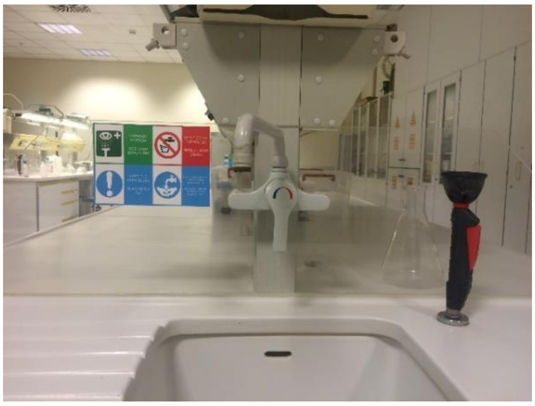


Figure B.3 Eyewash station

B.2.3. Emergency Showers

Laboratory users should know the location and how to use emergency showers (Figure B.4) in their location.

Laboratory users must be able to reach showers within 10 seconds walking distance. The area underneath the shower and the path to the emergency shower must be kept always clear.

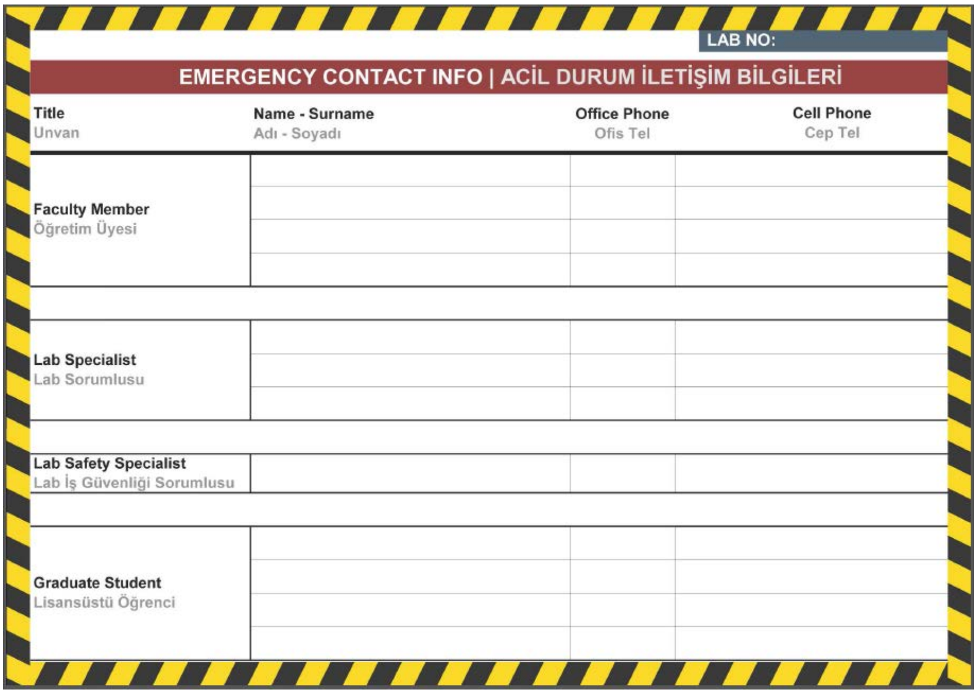
How to Use Emergency Shower

- Call out to co-workers, LS/LSS or other students for help immediately after exposure to a harmful agent.
- Make your way to the emergency shower quickly. Another person should guide you into the shower if you cannot see.
- Pull down the handle or lever as soon as you get under the nozzle.
- Take off your clothes and any other possibly contaminated items such as glasses or jewelry.
- Stand under the shower for at least 15-to-20 minutes, even if the water is very cold. You should hold your eyelids open the entire time to rinse out your eyes.

Figure B.4 Emergency shower

B.2.4. *Emergency Contact Information Form*

Each laboratory room should have emergency contact information (Figure B.5) posted at the door. In the event of an emergency, such as a fire or hazardous spill, “response team” will need to contact those responsible for the laboratory. The sign should include the names of the LS, LSS and responsible Faculty Member and student contact. Office and cell phone numbers and/or other contact information should be provided on the sign. An example of an emergency contact information sign can be found below.



LAB NO:

EMERGENCY CONTACT INFO | ACİL DURUM İLETİŞİM BİLGİLERİ

Title Unvan	Name - Surname Adı - Soyadı	Office Phone Ofis Tel	Cell Phone Cep Tel
Faculty Member Öğretim Üyesi			
Lab Specialist Lab Sorumlusu			
Lab Safety Specialist Lab İş Güvenliği Sorumlusu			
Graduate Student Lisansüstü Öğrenci			

Figure B.5 Emergency contact form

B.3. SECURING EQUIPMENT AND SUPPLIES

B.3.1. *Attaching Equipment to Walls or Supports*

Heavy or hazardous items that could collapse and create a danger or block emergency exits must be secured to the walls or floor by Operation and Technical Services unit. These items include shelving units, equipment racks, and tall file cabinets, distillation units, gas cylinders (attach at two heights, approximately one third and two thirds of the cylinder height), and cryogenic dewars which are taller than two and a half times their base diameters.

Any new apparatus should be constructed robustly and secured to supporting fixtures. If you need to route gas lines between apparatus mounted to different supports, the lines should either be made of a compatible material that is flexible, or have flexing joints if made of solid lines.

B.3.2. Modifying Shelves and Cabinets

Shelves holding chemical containers must have protective restraint measures to prevent chemical containers from being eluded the shelf.

Cabinets used to store chemical containers should have a closure device to prevent the door from being shaken open.

B.4. PROTECTIVE PROCEDURES

Users should be:

- Ensuring there is clear access to exits, fire extinguishers, eyewash stations, and safety showers.
- Closing containers when not in use.
- Closing fume hood sashes when not in use.
- Maintaining good housekeeping, including not placing chemical containers on the floor.
- Not storing boxes or large items within 40 cm of the ceiling if the room has fire sprinklers.

References

- University of Wisconsin-Madison Division of Facilities Planning and Management, Environment, Lab Safety Guide, Chapter 5, Emergency Procedures (2015, March). Retrieved from http://www.ehs.wisc.edu/chem/LabSafetyGuide-Chapter05.pdf
- New Mexico State University Research and Lab Safety Guide, Emergency Information (2015, March). Retrieved from http://safety.nmsu.edu/programs/lab_safety/l_saf_guide09.htm
- The University of Texas at Austin Environmental Health and Safety, Emergency Instructions for labs (2015, March). Retrieved from https://www.utexas.edu/safety/ehs/lab/manual/2_emergency.html
- The University of Chicago Environmental Health and Safety, Emergencies and Quick Response Guide (2015, March). Retrieved from http://safety.uchicago.edu/guides/index.shtml
- Recommended Medical Treatment for Hydrofluoric Acid Exposure, Honeywell (Industrial Fluorines), An informational and medical guide prepared by the largest industrial producer of hydrofluoric acid (2000, May). Retrieved from www.hfacid.com
- Segal, E. B. (2000, February). First Aid for a Unique Acid: Hydrofluoric Acid. Retrieved from http://depts.washington.edu/cosmolab/chem/hfsafety.pdf

C. RESPONSE TO SPECIFIC INCIDENTS/ACCIDENTS

C.1. ACCIDENTS RESULTING IN PERSONAL INJURY OR CONTAMINATION

C.1.1. Involving Human Contamination by Hydrofluoric Acid

Symptoms of HF exposure are often delayed for several hours. If you suspect you may have been exposed to HF but are not experiencing any immediate symptoms, apply immediate first aid nonetheless. A quick response can substantially reduce injury.

No person exposed to HF should be allowed to go home or return to work without having seen a doctor who is aware of the nature and extent of the exposure.

Prevent cross contamination: The victim of HF exposure should perform the following actions on him/herself whenever possible. Anyone who provides assistance should use the proper gloves, and other personal protective equipment mentioned in this document, in order to prevent contaminating themselves. Do not use latex gloves; they do not provide an effective barrier against chemicals, especially HF.

Skin exposure:

- Immediately flush affected areas with cold running water (shower if available). While flushing, remove all contaminated clothing as well as jewelry that could trap HF. Wash the contaminated area with copious amounts of running water for 5 minutes. Speed and thoroughness in washing off the acid is essential. If calcium gluconate gel (2.5%) is not available, continue flushing with water for at least 15 minutes or until medical treatment is given.
- While the victim is being rinsed with water, someone should call 7666 and say:
  - The person has been exposed to hydrofluoric acid.
  - The person can be found at [give location of victim].
  - Please send an ambulance.
- Wear a new pair of chemical resistant gloves (to prevent possible secondary HF burns) and massage calcium gluconate gel (2.5%) freely over the affected site. Apply the gel as soon as the washing is done. The affected area does not need to be dried first. The gel will turn white (CaF_2 precipitate) upon reaction with the acid.
- Soak the affected area in, or apply compresses of, iced Zephiran solution (a 0.13% aqueous solution of benzalkonium chloride).
- After these actions have begun, re-examine the victim to ensure no exposure/burn sites have been overlooked.
- Calcium gluconate gel (2.5%) should be re-applied, or Zephiran soaking repeated, every 10-15 minutes until the ambulance arrives or a physician/EMT gives medical treatment.
- Provide the following information to the the medical staff:
  - The concentration of the hydrofluoric acid and its SDS.
  - Date, time of exposure, duration of exposure, and how exposure occurred.
  - Body parts affected or exposed, and the percent of body surface area affected.
  - Summary of first aid measure given, including when calcium gluconate gel or Zephiran was first applied, the body areas to which the treatment was applied, and how many times the treatment was applied in total.

Eye exposure:

- Immediately flush eyes with Hexafluorine or cool flowing water, preferably at an eyewash station. Hold the eyelids open and away from the eye during irrigation to allow thorough flushing of the eyes. If sterile 1% calcium gluconate solution is available, start using it within the first 5 minutes (via continuous drip into eyes), and continue using it as the preferred flushing agent (Do not use 2.5% calcium gluconate gel for the eyes). If sterile 1% calcium gluconate solution is not available, wash with copious amounts of water for 15 minutes while holding eyelids apart.
- While washing the eye, have someone call 7666 for emergency medical assistance, calcium gluconate solution (1%), eyewash, clean water, or ice water compresses should be used to continue to irrigate the eye(s) while transporting the victim.

Inhalation of Vapors:

- Immediately move affected person to fresh air and call 7666 for medical assistance.
- Keep victim warm, comfortable and quiet.
- 100% oxygen (10 to 12 L/min flow rate) should be administered as soon as possible by a trained individual.
- A nebulized solution of 2.5% calcium gluconate may be administered with oxygen by inhalation.
- Do not give stimulants unless instructed to do so by medical staff.
- The victim should be examined by a doctor and held for observation for at least 24 hours. The reason is that inhalation of HF fumes may cause swelling in the respiratory tract up to 24 hours after exposure. A person who has inhaled HF vapors may require prophylactic oxygen treatment. Vapor exposure can cause skin and mucous membrane burns and damage to pulmonary tissue. Vapor burns to the skin are treated the same as liquid HF burns.

Ingestion:

- Do not induce vomiting. Never give anything by mouth to an unconscious person.
- Have the victim drink large amounts of room temperature water as quickly as possible to dilute the acid.
- Call 7666 for medical assistance.
- Have the victim drink several glasses of milk or several ounces of milk of magnesia, Mylanta, Maalox or similar products, or eat up to 30 Tums, Caltrate or other antacid tablets. The calcium or magnesium in these substances may act as an antidote. Avoid administering bicarbonates at all costs, the carbon dioxide by product could severely injure the victim.

C.2. FIRES AND EXPLOSIONS

Students and all other unauthorized people should never fight the fire under any circumstances. *Activate the alarm system (or call 7555) and evacuate the building by nearest emergency stairs. If there is smoke in the air stay low to the ground to reduce inhalation exposure. Go to the emergency assembly area and wait further instructions from emergency personnel.*

When you hear the fire/emergency alarm, evacuate the building by the nearest stairs. Do not use elevators. Always leave the building when you hear the alarm, even if you think it may be a false alarm or result of a test.

If a person's hair or clothing is on fire, smother the flames with a coat or by having the person roll on the floor. Assist the victim to medical treatment. Assist others to evacuate as needed. Remain at a location known to the on-scene emergency responders to provide any details they may need.

Report all fires and explosions immediately. Even if the fire was small, contained and readily extinguished by laboratory users, and you did not call 7555, immediately report the incident to the LS/LSS on the main campus at 7555.

If you are uncertain about calling 7555, the best course of action is to call LS/LSS and let the dispatch operator assist in deciding a proper response.

Submit an accident report to LS/LSS.

C.3. CHEMICAL SPILLS

When a chemical is spilled, you should decide whether the spill has minor or major (Figure C.1) property or personal risk to yourself and others.

Figure C.1 Minor spill and major spills

Hazardous chemical or unknown material spill should only be handled by trained users. In case of any chemical spill SDS must be addressed and the according procedures followed. While spills can be divided into general risk categories (as described bellow), an educated choice of action for any specific spill is in order. The flow chart below (Figure C.2) generalizes the decision making process to be applied while handling a spill.

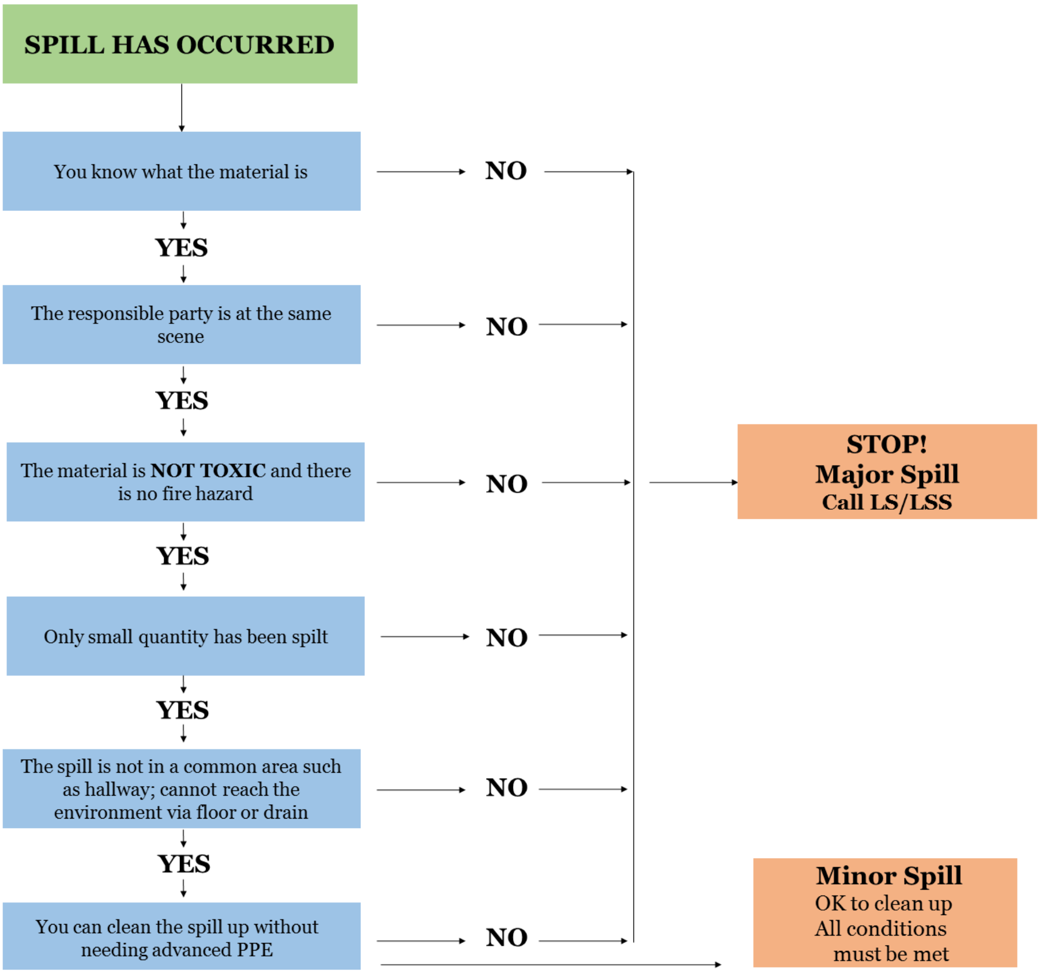


Figure C.2 Required course of action in the event of spills

C.3.1. Minor Risk

Spills that are stable, contained, isolated from public areas, and not posing an immediate health or environmental threat may be cleaned up by laboratory users who have been trained and are properly equipped to handle the situation. Spill kits are available in 2107 and G049.

When you notice a spill, if you think that it may be hard to find it again if you were to leave to get a spill clean-up kit, any absorbent towel or a lab coat should be placed over the spill should not be located around or so as to identify its location.

When the chemical spilled is likely to react with the towel or coat. Leave a warning sign or let co-workers know of the spill before you leave.

If the spill injured someone or damaged equipment or facilities, submit an accident report on 7444 and report LS/LSS.

C.3.2. Major Risk

For spills that present an immediate or significant physical, health or environmental risk, do the following:

- Evacuate all lab users from the area. If there is a risk to surrounding labs, pull the fire alarm to evacuate the area. Attend to injured lab users to the best of your training and experience.

When placing an emergency call, give the following information:

- Report the incident LS/LSS with your name, room location, room and cell phone number and brief injury/emergency description.
- Remain at a safe location in the area to help emergency responders. Do not hang up until directed to do.
- LS/LSS will assist and advise departments on proper cleaning, packaging, and removal of any hazardous waste left behind. For some spills, faculty may need to bear the cost of clean up by an outside contractor.
- Submit an accident report on LS/LSS.

C.3.3. Mercury Spills

The following discussion primarily pertains to metallic mercury (such as is in a mercury thermometer). Mercury may be easily absorbed through skin. Though, skin contact must be avoided during the cleaning-up process.

The inhalation is also the more serious way to expose to mercury, if the system involves heat. Because metallic mercury vaporizes very slowly at room temperature, mercury exposure will probably not be a health concern as long as the mercury is completely cleaned up.

Users must be trained in spill clean-up and use appropriate techniques and materials. Laboratories which use mercury or mercury-containing equipment should have a mercury clean-up kit immediately available. Users should evacuate the area and routine operations should not be conducted until after the area has been shown to be clean.

Mercury spills at elevated temperatures may cause significant exposure and require immediate actions to turn off the heating elements and to evacuate the room until the surfaces involved in the spill have cooled.

An accident report must be submitted to LS/LSS.

C.3.4. Spill Clean-Up Waste

Waste generated from a spill clean-up should be placed in a container with a screw top closure or double bagged with waste procedure. Attach a chemical waste label with secondary waste boxes.

C.3.5. Hydrofluoric Acid Spill

If a major HF spill occurs, follow spill policy:

- Alert nearby users and evacuate to a safe distance.
- If a fire, explosion, or toxicity hazard exists, pull the fire alarm and follow building evacuation procedures, provide the relevant SDS.
- If you have not pulled the fire alarm, close doors of affected areas and prevent re-entry. Put up “Do Not Enter” signs or barrier tape.
- Call 7444 LS/LSS to inform them of the situation.
- Do not re-enter the area until instructed to do so by LS/LSS.

If a minor spill occurs and you feel that you and your lab-mates are capable of addressing the spill, follow the Minor Spill Protocol with the following modifications:

- Notify LS/LSS.
- LS/LSS can assist with the cleanup.
- Obtain a HF spill kit from your lab and employ the HF neutralizer found therein. Only HF specific absorbents should be used to address an HF spill. If such absorbents are not available, a large excess of dilute, aqueous calcium or magnesium hydroxide can be employed. The neutralization should be performed slowly in order to avoid an exothermic reaction (heat will vaporize HF and increase the risk of exposure).

Do not attempt to neutralize HF with the following:

- Sodium or potassium carbonate ("soda ash", "caustic soda"): The reaction of Na_2CO_3 or K_2CO_3 with HF generates sodium or potassium hydrogen bifluoride ($NaHF_2$ or KHF_2) as intermediates, which release gaseous HF when exposed to heat.
- Potassium or sodium hydroxide (found in many acid-neutralizing kits): The neutralization of HF with potassium or sodium hydroxide is more exothermic than with sodium or potassium carbonate and also generates potassium or sodium hydrogen bifluoride ($NaHF_2$ or KHF_2) as intermediates, which release gaseous HF when exposed to heat.
- Silicon-based absorbent materials (common in most solvent spill kits) react with HF to generate silicon tetrafluoride, which is a toxic and corrosive gas.

C.4. EARTHQUAKE RESPONSE

Drop, cover, and hold! Take shelter under a workbench or other protective cover until the earth movement stops.

Afterwards, if safe to do so, shut down any procedures which may be underway and cap any open containers. Aid injured if you are able. Determine if you need to evacuate the work area. When evacuating, take keys, emergency kits, etc. because you may not be allowed to re-enter until the building has been assessed for hazards. Try to note the extent of building damage while evacuating. Assemble at the emergency assembly point. Await further instructions. Do not re-enter the building until after it has been assessed for structural damage by trained users and re-entry is authorized by university officials.

C.5. GAS LEAKS OR OTHER ODORS

C.5.1. Natural Gas Leaks

- Natural gas leaks can cause explosions due to the explosive nature. Natural gas contains an odorant that is easily detected by smell. If a weak odor is smelled inside a building:
- Check laboratory gas outlets for open valves.
- Call 9988 and 7444 LS/LSS to have the location of the gas leak identified.
- For strong, widespread (in many rooms), and/or quickly worsening odor:
- Pull the emergency alarm.
- Close the emergency gas valve for your floor or area if one exists.
- Evacuate the building immediately, following your building evacuation plan.
- If your assembly area is downwind of the building, move to second assembly area.
- Do not return to an evacuated building unless told to do so by the on-scene Authority (fire department, police department or other users).
- Submit an accident report on LS/LSS.

C.5.2. Leaking Gas Cylinders

Do not overtighten the valve in an attempt to stop the leak. If the valve continues to leak, consider whether room evacuation and building evacuation is necessary. Take the following actions:

Flammable, Oxidizing or Inert Gases: If necessary, PPE must be equipped. If possible, allow the cylinder to exhaust into a well ventilated area (such as a fume hood) with few or no combustible absorbent materials in the area (such as cardboard). Post a sign warning of the leaking cylinder. Avoid sparks and open flames.

Toxic or Corrosive Gases: If necessary, PPE must be equipped. Exhaust cylinder into an absorbent or neutralizer if possible. If no absorbent or neutralizing system is available, exhaust the cylinder into an operating fume hood. Post a sign warning of the leaking cylinder.

C.5.3. Unknown Odors

Check with users to determine if they are doing something to produce an odor. If not, check adjacent labs to determine if the odor is widespread or if the source is obvious. Try to relate the odor to possible causes – such as whether it smells like a sewer, or rotting food, or over-heating electronics, or a distinct chemical. If the source is obvious, take action if possible to eliminate the cause or control the odor, such as taking a chemical reaction off the benchtop and putting it into a working fume hood.

If the odor isn't immediately found but appears to be appreciably stronger in one location, there is likely a source nearby, which can be a dried sink drain or floor drain (if a sewer-like or chemical-like odor), a chemical process gone wrong (if a rotting or unknown chemical odor), over-heating electronics (if devices are over-heating), or a chemical spill or a leaking process (if a distinct chemical). There are an unlimited number of potential sources, but familiarity with the lab's activities should help narrow the possibilities.

C.6. UTILITY OUTAGE

You should consider both your personal safety and that of others working in the same area. Under these circumstances; people should remain calm and assess the situation. If the situation escalates out control or is dangerous, the area must be evacuated and others must be assisted to evacuate. Once the area is evacuated, do not re-enter the building until the competent Authority has determined it is safe to do so.

If you cannot conduct work but your exit can be safely delayed, notify the responsible Faculty Member or LSS, shut off work in progress that could cause hazards, close containers, close fume hood/biosafety cabinet sashes, and return hazardous material containers to their proper storage locations. Some utility failures may have insignificant impact on your operations, and you can safely continue work as determined by LS/LSS.

If the failure appears likely to last for a long period, and directions of LS/LSS. Keep refrigerator and freezer doors closed for as long as possible and implement backup procedures as necessary, such as obtaining dry ice to keep specimen refrigerators cold. When systems return to normal operation, immediately assess the work area (even on weekends if that is when service is restored) for any hazards that may be present, such as electric devices (heaters, ovens, centrifuges, etc.) left on when the outage occurred.

C.6.1. Electrical Failure

- Assess the extent of the outage in your area.
- Report the outage to Operation and Technical Services and LS.
- Help other users in darkened work areas move to safe locations.
- Implement pre-planned response actions, as necessary. Do not treat the outage as "business as usual."
- If practical, secure current experimental work, then move it to a safe location.
- Close any open containers of hazardous materials.
- Close sashes on fume hoods and biological safety cabinets.
- If you move chemicals on carts between floors, get assistance. Hazardous spills pose significant risk during transport.
- Keep lab refrigerators or freezers closed throughout the outage.
- Unplug personal computers, non-essential electrical equipment, and appliances.
- Open windows for additional light and ventilation (during mild weather).
- If you are asked to evacuate your building, secure any hazardous materials work and leave the building.
- Release users during an extended outage if directed to do so by LS.
- When power is restored, immediately assess the affected area for potentially hazardous situations, such as devices left "ON". This is also required if power is restored at a time that the facility would be normally unoccupied.

C.6.2. HVAC/Fume Hood Fan Failure

- Notify other occupants of the situation.
- If necessary; evacuate area (and pull fire alarm if the situation is widespread)
- Notify your LS and responsible Faculty Member.
- Shut down work in progress if safe to do so:
  - Shut off equipment and supplied gases and liquids;
  - Close open containers.
  - Close sashes on fume hoods, biological safety cabinets, *etc.*
  - Note the step in the process when work was stopped.
  - Return specimens to freezer, storage containers, *etc.*
  - Open windows if users are to remain in the workplace.
- If users remain in the workplace, periodically check on their well being and evacuate if anyone is adversely affected.
- Prior to re-starting work in the area, review work to identify possible hazards.
- If the outage caused damage, submit an accident report to LS/LSS.

C.7. LABORATORY FLOODS

If your laboratory is affected by flooding:

- Find the source of the water. If safe, shut the water off.
- If it is safe to shut down any equipment that could cause a dangerous electrical situation during a flood and use plastic film for covering equipment and desks if water or sewage is dripping onto them.
- Get help quickly. During work hours, contact your LS. Notify the users, Responsible Faculty Member in charge of the flooding laboratory as soon as possible. He/she will assume responsibility as soon as he/she arrives.
- If foreign materials such as sewage, ceiling tiles, or leaking chemicals have contaminated the flood water, the situation should be assessed by hazardous material staff who can be contacted through Operation and Technical Services. The best method to clean up uncontaminated water is by using one water vacuum on the scene of the flood and another on the affected area below.
- After the cleanup, submit an accident report on LS/LSS.

C.8. OTHER EMERGENCIES

For other emergencies (such as criminal emergency), see SU Emergency Procedures Plan document.

References

- Wilkes, G.; Cowan, E. (2006, August). Hydrofluoric Acid Burns. Retrieved from www.emedicine.com/emerg/topic804.htm
- Gates, B. (2002, May). Harvard Department of Chemistry and Chemical Biology, Guidelines for the Safe Use of HF. Retrieved from https://chemistry.harvard.edu/files/chemistry/files/safe_use_of_hf_0.pdf?m=1368038513
- Guidelines for the Safe Use of Hydrofluoric Acid, University of Pittsburgh (2005, September). Retrieved from www.ehs.pitt.edu/chemhyg/GuideHydrofluoricAcid.pdf
- Guidelines For Using Hydrofluoric Acid, Desert Research Institute (2004, November). Retrieved from http://safety.dri.edu/Hazards/HydrofluoricAcidGuidelines.pdf (checked August 2006)

APPENDIX

Visual Capture Test (Dry ice test)

A visual capture test is the surest way to tell if your fume hood is capturing properly so you may choose to conduct your own to see how well your hood is performing. EN 14175 provides a procedure to supplement face velocity with a visual test for capture called a dry ice test.

Procedure:

SAFETY: Dry ice is extremely cold and can burn the skin on contact. Also, dry ice generates CO_2 gas as it warms and in an enclosed space can produce an oxygen deficient environment. Employees must read the dry ice SDS and be aware of the hazards before handling any dry ice.

The face velocity for the hood should be tested first followed by the dry ice test:

- Eye protection and insulated gloves should be worn when conducting this test.
- Weigh dry ice, grind it up using the grinder, and place it into our insulated container. Put our account number on the clipboard and you information. Always use protective gloves and eye protection when handling dry ice.
- The sash should be positioned at 45 cm. Fill the stainless steel bowl to the black line (about half-way) with hot water. Put a 5 or 6 pellets of dry ice into the bowl and wait a few seconds. Place the bowl into the center of the hood, with the edge of the bowl 15 cm from the plane of the sash and wait a few seconds. If the hood is too crowded, place the bowl as close to 15 cm back as you can.
- Observe for about 15 seconds. If no vapors or a trivial amount of vapors break the plane of the sash then the test passes. If however, vapors consistently break the sash plane, then the test fails.
- Challenge the hood during the test by reaching into the hood or crossing in front of the hood to create possible eddy currents. You may also move the bowl closer to the hood face and operate any equipment while testing. These actions can simulate actual conditions encountered by the user and may give indication of what could contribute to leakage. This information can be considered in your assessment.
- Make sure all doors are closed and test for negative pressure by cracking the door open and putting the dry ice near the opening outside the door. The vapors should be sucked into the room.
- When disposing of the dry ice pour the left over pellets into the sink holding the bowl next to the side. Try not to let the pellets go into the drain since it could freeze the trap and burst the pipe.

Sabancı Üniversitesi

FACULTY OF ENGINEERING AND NATURAL SCIENCES

Laboratory Specific Orientation Form	
New Employee/Student Name	
Faculty member/LS Name	
Date	
Lab No	

Item #	Items discussed
	Outside of the lab
1.	Location of the nearest building emergency exit
2.	Location of the nearest fire alarm pull station
3.	Location of emergency assembly point, in the event of evacuation
	Inside the lab
4.	Keeping clear of the emergency exits and locations
5.	Number and location of available eyewashes
6.	Number and location of available showers
7.	Number, type and location of available fire extinguishers
8.	Wearing safety glasses at all times
9.	Wearing lab coats, storage and laundry policy of them
10.	Wearing gloves, types and location of them
11.	Spill kit(s) usage and location
12.	Waste accumulation area location
13.	Waste accumulation rules (labels, secondary containers, storage conditions)
14.	Waste pick up calls
16.	Sharps disposal
17.	Fume hood operation, alarms
18.	Fume hood emergency setting (when applicable)
22.	Location of electrical boxes/power kill switch
23.	Chemical Storage: flammable cabinet, acid, base storage
	Specific hazards in the lab
26.	HF- hazards, handling instructions, and the location of PPE and eyewash kit
27.	Nano materials, hazards, handling instructions, PPE
28.	Lasers

New Employee/Student Signature	
Faculty Member/LS Signature	

FACULTY OF ENGINEERING AND NATURAL SCIENCES

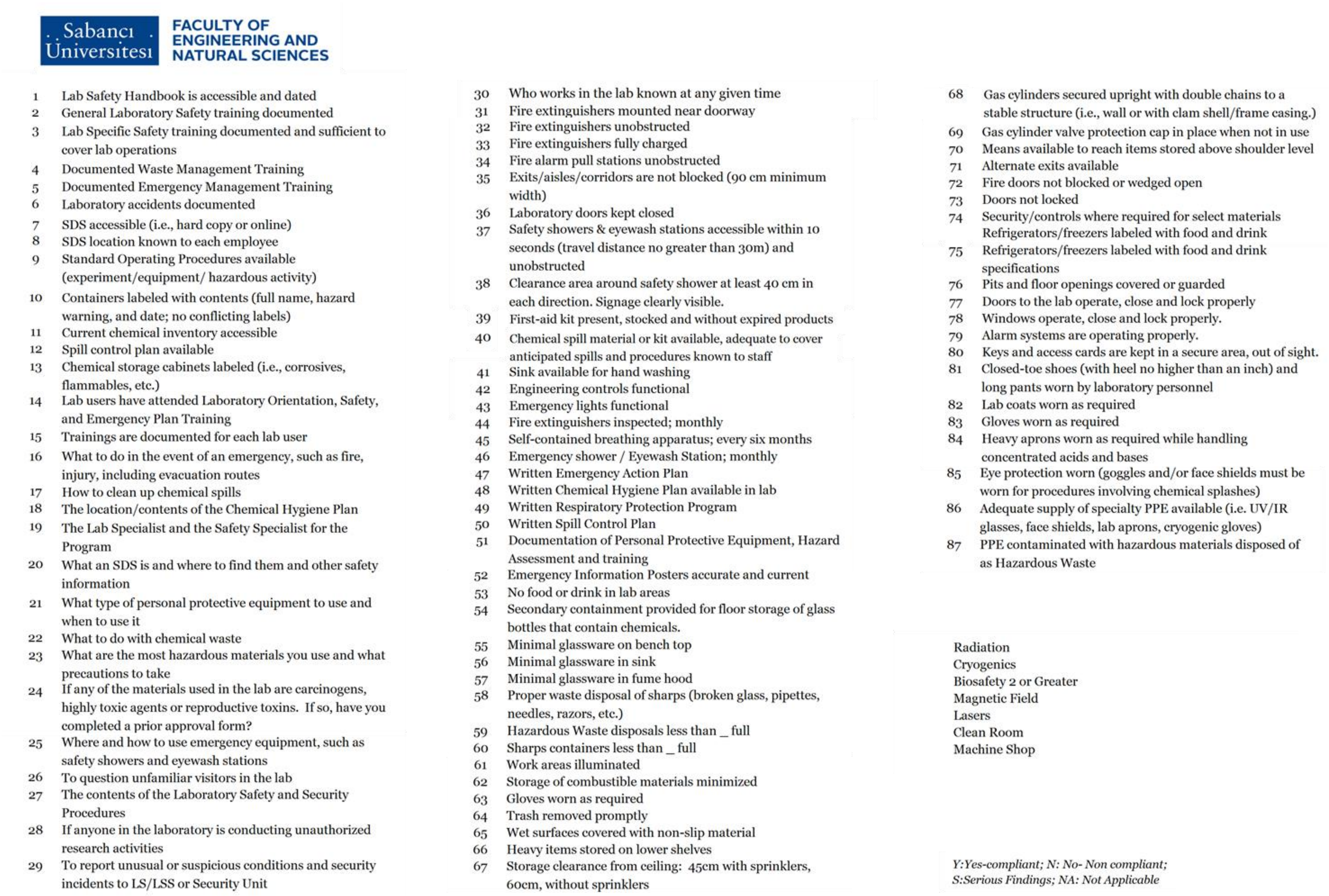
Graduate Student

Laboratory Check-Out Form

Student Name:
Student ID:
Program:
Lab No:
Laboratory Specialist:
Faculty Member/ Supervisor:

Tasks	Date Completed	NA
Working area vacated and cleaned		
All samples (chemical/biological/electronic) disposed		
PPE handed over to Lab Specialist		
Lab keys handed over to Lab Specialist		
All tools and equipments handed over to Lab Specialist.		
Lab notebooks and research documentation transferred to Responsible Faculty Member(s)		
Lab visit performed with Faculty Member		

Approved by			
	Initials	Signature	Date
Graduate Student			
Laboratory Specialist			
Faculty Member/ Supervisor			



Sabancı Üniversitesi FACULTY OF ENGINEERING AND NATURAL SCIENCES

1 Lab Safety Handbook is accessible and dated
2 General Laboratory Safety training documented
3 Lab Specific Safety training documented and sufficient to cover lab operations
4 Documented Waste Management Training
5 Documented Emergency Management Training
6 Laboratory accidents documented
7 SDS accessible (i.e., hard copy or online)
8 SDS location known to each employee
9 Standard Operating Procedures available (experiment/equipment/ hazardous activity)
10 Containers labeled with contents (full name, hazard warning, and date; no conflicting labels)
11 Current chemical inventory accessible
12 Spill control plan available
13 Chemical storage cabinets labeled (i.e., corrosives, flammables, etc.)
14 Lab users have attended Laboratory Orientation, Safety, and Emergency Plan Training
15 Trainings are documented for each lab user
16 What to do in the event of an emergency, such as fire, injury, including evacuation routes
17 How to clean up chemical spills
18 The location/contents of the Chemical Hygiene Plan
19 The Lab Specialist and the Safety Specialist for the Program
20 What an SDS is and where to find them and other safety information
21 What type of personal protective equipment to use and when to use it
22 What to do with chemical waste
23 What are the most hazardous materials you use and what precautions to take
24 If any of the materials used in the lab are carcinogens, highly toxic agents or reproductive toxins. If so, have you completed a prior approval form?
25 Where and how to use emergency equipment, such as safety showers and eyewash stations
26 To question unfamiliar visitors in the lab
27 The contents of the Laboratory Safety and Security Procedures
28 If anyone in the laboratory is conducting unauthorized research activities
29 To report unusual or suspicious conditions and security incidents to LS/LSS or Security Unit

30 Who works in the lab known at any given time
31 Fire extinguishers mounted near doorway
32 Fire extinguishers unobstructed
33 Fire extinguishers fully charged
34 Fire alarm pull stations unobstructed
35 Exits/aisles/corridors are not blocked (90 cm minimum width)
36 Laboratory doors kept closed
37 Safety showers & eyewash stations accessible within 10 seconds (travel distance no greater than 30m) and unobstructed
38 Clearance area around safety shower at least 40 cm in each direction. Signage clearly visible.
39 First-aid kit present, stocked and without expired products
40 Chemical spill material or kit available, adequate to cover anticipated spills and procedures known to staff
41 Sink available for hand washing
42 Engineering controls functional
43 Emergency lights functional
44 Fire extinguishers inspected; monthly
45 Self-contained breathing apparatus; every six months
46 Emergency shower / Eyewash Station; monthly
47 Written Emergency Action Plan
48 Written Chemical Hygiene Plan available in lab
49 Written Respiratory Protection Program
50 Written Spill Control Plan
51 Documentation of Personal Protective Equipment, Hazard Assessment and training
52 Emergency Information Posters accurate and current
53 No food or drink in lab areas
54 Secondary containment provided for floor storage of glass bottles that contain chemicals.
55 Minimal glassware on bench top
56 Minimal glassware in sink
57 Minimal glassware in fume hood
58 Proper waste disposal of sharps (broken glass, pipettes, needles, razors, etc.)
59 Hazardous Waste disposals less than _ full
60 Sharps containers less than _ full
61 Work areas illuminated
62 Storage of combustible materials minimized
63 Gloves worn as required
64 Trash removed promptly
65 Wet surfaces covered with non-slip material
66 Heavy items stored on lower shelves
67 Storage clearance from ceiling: 45cm with sprinklers, 60cm, without sprinklers

68 Gas cylinders secured upright with double chains to a stable structure (i.e., wall or with clam shell/frame casing.)
69 Gas cylinder valve protection cap in place when not in use
70 Means available to reach items stored above shoulder level
71 Alternate exits available
72 Fire doors not blocked or wedged open
73 Doors not locked
74 Security/controls where required for select materials Refrigerators/freezers labeled with food and drink
75 Refrigerators/freezers labeled with food and drink specifications
76 Pits and floor openings covered or guarded
77 Doors to the lab operate, close and lock properly
78 Windows operate, close and lock properly.
79 Alarm systems are operating properly.
80 Keys and access cards are kept in a secure area, out of sight.
81 Closed-toe shoes (with heel no higher than an inch) and long pants worn by laboratory personnel
82 Lab coats worn as required
83 Gloves worn as required
84 Heavy aprons worn as required while handling concentrated acids and bases
85 Eye protection worn (goggles and/or face shields must be worn for procedures involving chemical splashes)
86 Adequate supply of specialty PPE available (i.e. UV/IR glasses, face shields, lab aprons, cryogenic gloves)
87 PPE contaminated with hazardous materials disposed of as Hazardous Waste

Radiation
Cryogenics
Biosafety 2 or Greater
Magnetic Field
Lasers
Clean Room
Machine Shop

Y:Yes-compliant; N: No- Non compliant;
S:Serious Findings; NA: Not Applicable

88 Less than 40L of flammables located outside flammable storage cabinet
89 Maximum of 180L flammable liquids per flammable cabinets per lab/fire area.
90 Flammable storage refrigerator/freezer approved&labeled
91 Minimal acids and bases stored outside safety cabinets
92 Strong acids&strong bases stored in secondary containers
93 Incompatible materials properly segregated
94 Chemicals stored safely
95 Combustible materials not stored with flammables
96 Chemical storage cabinets clearly labeled (i.e. flammables, corrosives, etc.)
97 Chemical containers in good condition
98 Corrosive chemicals stored below eye level
99 Ethers and other peroxide formers dated
100 Water reactive chemicals segregated, contained, and labeled
101 Carcinogens segregated and stored in designated areas.
102 Pyrophoric chemicals segregated, contained, and labeled
103 Shelving adequate for loads imposed
104 Refrigeration units for chemical storage labeled No Food
105 Refrigeration units for food labeled Food Only
106 Chemical storage cabinets properly labeled
107 Ventilated gas cabinets used for highly toxic gases
108 No volatile chemical storage in unventilated environmental chambers
109 Containers clearly labeled with chemical name(s)
110 Containers kept closed except during transfers
111 Storage strictly limited in actively used fume hoods
112 Containers compatible with the chemical
113 Chemicals segregated to avoid incompatibilities
114 Large/heavy containers stored on lower shelves
115 Corrosives not stored above eye level
116 Storage quantities minimized
117 Secondary containers used during transport of more than 250 ml of chemicals
118 Materials with shelf lives dated and disposed of per supplier's recommendations
119 Lab check-out procedures for borrowing chemicals in place
120 Used in fume hood or well-ventilated area
121 Refrigerators approved for flammables storage
122 Flammables separated from strong oxidizers
123 Class ABC or BC fire extinguisher available
124 Flammable liquids not stored near hot plates or other ignition sources
125 Used in well-ventilated area
126 Toxic, flammable, corrosive gases used in fume hood
127 Storage quantities minimized
128 Secured from tipping in use
129 Regulators compatible with gas cylinder and gas type
130 Cylinder carts used for transport
131 Protective valve caps in place
132 Empty/unused gas cylinders promptly returned to supplier
133 Personal protective equipment used to avoid skin contact
134 Used/dispensed with good ventilation
135 Containers vented or pressure relief devices provided
136 Low temperature embrittlement considered
137 Glass dewars shielded
138 Certified and yearly inspected
139 Proper sash height indicated
140 Sash at or below marked approval level
141 Sash stoppers functional where present
142 Hood illumination functional
143 Audible/visual alarm functional
144 Minimal clutter in hood (equipment, chemicals)
145 Functional fume hood not used for storage
146 Fume hood vents (baffles) unobstructed
147 Fume hoods used with sash in appropriate position
148 Chemical storage strictly limited in actively used hoods
149 Other local exhaust devices surveyed
150 Laminar Flow Cabinets functional
151 Calcium gluconate present / expiration date not past
152 Special protection present
153 Safety cans available and labeled for disposal of solvents
154 Containers available and labeled for disposal of hazardous waste
155 Chemical waste containers in good condition and kept closed (i.e. no funnels in place)
156 Sturdy cart available for transport of hazardous waste
157 Hazardous waste in secondary containment
158 Designated hazardous waste storage areas
159 Chemical waste disposed when full or within 3 days
160 Dry hazardous waste double-bagged in transparent bags
161 Hazardous chemicals/materials not found in regular trash.
162 Storage limited to < 1L of acutely hazardous waste
163 Separate disposal containers available for broken glass
164 Shelving and file cabinets 150cm or over anchored/bolted
165 Storage shelves have seismic restraints (lips,bars,bungee cords)
166 High overhead storage is secured
167 Heavy items stored on lower shelves
168 Area posted with appropriate 3b/4 laser sign
169 Lighted laser sign outside room using class 3b/4 laser
170 Class 3b/4 laser SOP posted
171 Appropriate laser eyewear available / intact
172 Class 3b/4 laser registered with RPP
173 Radioactive Material Inventory / Use Logs not out of date
174 Radioactive Material waste inventory cards properly filled out
175 Stock radioactive material secure
176 Survey meter out of calibration / working
177 Radioactive Materials sign posted
178 Moveable parts guarded on equipment as appropriate
179 Electric panels accessible
180 Nothing posted on electric panel
181 Plugs, cords, outlets in good condition
182 No overloaded outlets, no daisy-chained power strips
183 Extension cords only present for immediate use and do not pose trip hazards (i.e., taped down, covered)
184 Power strips secured off the floor and away from liquids
185 No power cords found under doors, carpets, through ceilings
186 Machine/instrument access panels in place
187 No exposed electrical conductors (50 volts or more)
188 Multiplug adapters have overload protection
189 System components properly designed
190 Pressure relief devices provided and inspected
191 Corrosion prevention considered
192 Written operating procedures available
193 Inspection/Maintenance procedure in place
194 Failure analysis and hazard control documented
195 Glass vessels shielded/enclosed
196 Operators trained/authorized
197 Biosafety cabinet (BSC) grates not obstructed
198 BSCs Certified / certification expired
199 BSCs Vacuum aspirator/inline filter set up correctly
200 Equipment used with biological materials and/or agents properly biohazard labeled
201 Bio waste containers have biohazard labels
202 Soap at hand washing available on sink
203 Appropriate liquid disinfectant available
204 Work surfaces decontaminated with cleaner/disinfectants for biological materials
205 Bio sharps managed
206 Bio waste managed
207 Autoclave waste being logged
208 Needles / syringes secured
209 Exposure Control Plan Available
210 BL1/ BL2 / BL2+ posting available

Laser Clearance and Additional Blackout Curtains

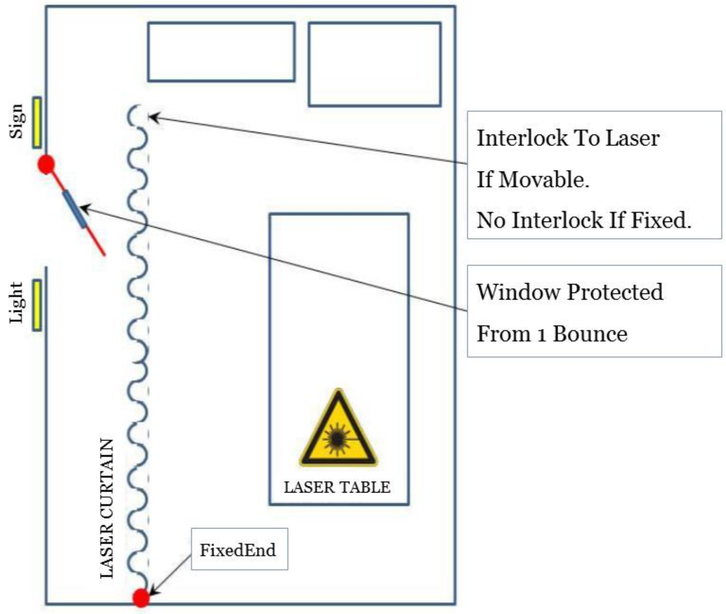


Figure 1. Example of high power Class 3b or Class 4 entryway protection (setting A)

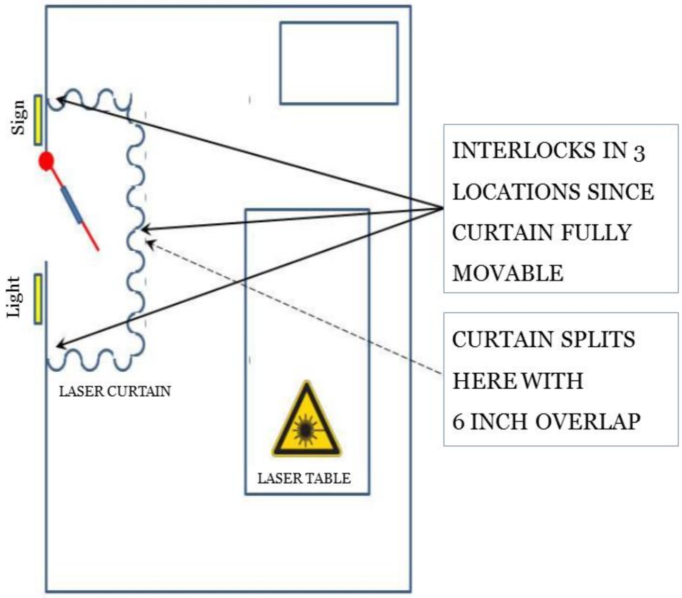


Figure 2. Example of high power Class 3b or Class 4 entryway protection (setting B)

Adopted from Cornell University Environmental Health & Safety Department.

MPE Calculations and Limits

Eye exposure to a CW Nd:YAG laser

Wavelength (λ) = 1.064 μm = 1,064 nm

Assume accidental eye exposure (probably from specular or diffuse reflection).

Exposure duration T = 10 s (since not in 400 to 700 nm visible range)

MPE = 5.0 C_C x 10^{-3} W/cm^2.

Using C_C = 1 from Table below for λ = 1.064 μm, MPE = 5.0 x 10^{-3} W/cm^2 or 0.005 W/cm^2.

Skin exposure to a CW Nd:YAG laser

Assume exposure duration is 10 s or longer.

MPE = 0.2 C_A W/cm^2. From Table below, C_A = 5.0 for λ = 1.064 μm. MPE = 1.0 W/cm^2

Eye exposure to single-**pulsed Ruby laser λ = 694 nm**

Pulse duration 30 ns,

FWHM For pulses between 10^{-9} and 18 x 10^{-6} seconds, MPE = 0.5 x 10^{-6} J/cm^2

Eye exposure to Repetitively-Pulsed Nd:YAG laser

Pulse Repetition Frequency (PRF) = 30 Hz (pulses per second)

Variable pulse width, from 7 to 30 ms

Rule 1 – No single pulse in a chain may exceed the MPE.

For worst case, use smallest pulse width (7 ms)

For λ = 1.064 μm, MPE$_{SP}$ = 9.0 CC t 0.75 x 10^{-3}

From table bellow, C_C = 1.0, so MPE$_{SP}$ = (9.0)(1.0)(7x10^{-3}) 0.75 x 10^{-3} J/cm^2, so MPE$_1$ = 0.218 mJ/cm^2.

Rule 2 – Average Power MPE

The exposure from any group of pulses delivered in time T must not exceed the MPE for time T.

For infrared region T = 10 seconds.

Divide MPE for a 10-second exposure by the number of pulses, n, during the 10-second period.

For this example, n = 300, so MPE/pulse = ((9.0)(1.0)(100.75) mJ/cm^2)/300), so MPE$_2$ = 0.169 mJ/cm^2.

Rule 3 – Multiple-Pulse MPE

For thermal injury, the exposure for any single pulse within a group of pulses must not exceed the single-pulse MPE multiplied by a multiple-pulse correction factor C_P.

From Table below, C_P = $n^{-0.25}$, where n is the number of pulses in T_{max} = 10 seconds.

So if C_P = 300 $^{-0.25}$ = 0.240, MPE$_3$ = 52.3 μJ/cm^2.

Conclusion: Rule 3 produces the most limiting case, so MPE/pulse = 52.3 μJ/cm^2. To express the limit as average irradiance MPE, multiply by the PRF = 30 Hz MPE$_E$ = 1.57 mW/cm^2 or 1.57x10^{-3} W/cm^2.

Parameters and Correction Factors Table

Parameters/Correction Factors	Wavelength(µm)
$T_1=10\text{x}10^{20(\lambda-0.450)}$*	0.450 to 0.500
$T_2=10\text{x}10^{(\alpha-1.5)/98.5}$**	0.400 to 1.400
$C_B=1.0$	0.400 to 0.450
$C_B=10^{20(\lambda-0.450)}$	0.450 to 0.600
$C_A=1.0$	0.400 to 0.700
$C_A=10^{2(\lambda-0.700)}$	0.700 to 1.050
$C_A=5.0$	1.050 to 1.400
$C_P=n^{-0.25}$***	0.180 to 100
$C_E=1.0$ $\alpha< \alpha_{min}$	0.400 to 1.400
$C_E= \alpha< \alpha_{min}$ $\alpha_{min}<\alpha< \alpha_{max}$	0.400 to 1.400
$C_E= \alpha^2/(\alpha_{max} \alpha_{min})$	0.400 to 1.400
$C_C=1.0$	1.050 to 1.150
$C_C=10$	1.150 to 1.200
$C_C=8$	1.200 to 1.400
* T_1=10 s for λ=0.450 µm, and T_1=100 s for λ=0.500 µm ** T_2=10 s for α<1.5 mrad, and T_2=100 s for α>100 mrad *** see ANSI ZI136.1-2000 Section 8.2.3 for discussion fo C_P and Section 8.2.3.2 for discussion of pulse repetition below 55 kHz(0.4 to 1.05 µm) and below 20 kHz(1.05 to 1.4 µm)	
Notes: ▪ For wavelengths between 0.400 and 1.400 µm; α_{min}=1.5 mrad and α_{max}=100 mrad ▪ Wavelengths must be expressed in micrometers and angles in miliradians for calculations. The wavelength region means $\lambda_1< \lambda< \lambda_2$ e.g. 0.550 to 0.700 µm means 0.550< λ<0.700 µm.	

FENS LABORATORY WASTE GUIDE TABLE

Waste Type	Waste Code*	Waste Name	Waste Type	Waste Box	Storing the Waste (In the Laboratory)	Disposing of the Waste (From the Laboratory)	Legal Regulation
Hazardous Waste	**15 02 02**	Contaminated Waste (Gloves, respirators, filters, lab coats and materials used in the laboratory)	Fundamentally plastic and paper	Contaminated waste box - red plastic bag	Wastes are thrown into waste box.	Collected daily by the housekeeping unit.	Waste Management Regulations
			Glass	Contaminated waste glass box	Wastes are thrown into contaminated glass waste box.	A ticket is created by the Lab Specialist/Lab Safety Specialist.	
			Metal sharps (metal tips like needle and razor)	Sharps metal waste box	Collected in the disposable sharps waste box. When the box is 3/4 full, it is thrown into the contaminated waste box.	Collected daily by the housekeeping unit.	
			Metal	Contaminated metal waste box	Wastes are thrown into contaminated metal waste box.	A ticket is created by the Lab Specialist/Lab Safety Specialist.	
			Textile	Contaminated waste box - red plastic bag	Lab coats or chemically contaminated textile products are thrown into contaminated waste box.	Collected daily by the housekeeping unit.	
		Contaminated Waste (Bacteria, yeast etc. microbiological waste, live/dead tissue waste-**autoclaved**)	Solid	Contaminated waste box - red plastic bag	Autoclaved and thrown into contaminated waste box.	Collected daily by the housekeeping unit.	Control of Medical Waste Regulations
			Liquid	In its original container	Liquid wastes are kept in their original containers or liquid-convenient containers.	Can be sterilized with a bleach and poured into the drain.	
Hazardous Waste	**15 01 10**	Contaminated Packages (Dye boxes, chemical packages etc.)	Plastic	Contaminated plastic package box-plastic	Wastes are thrown into contaminated plastic package waste box.	A ticket is created by the Lab Specialist/Lab Safety Specialist.	Waste Management Regulations
			Glass	Contaminated waste glass box	Wastes are thrown into contaminated waste glass box.	A ticket is created by the Lab Specialist/Lab Safety Specialist.	
			Metal	If formed, will be collected in another box	If contaminated metal package waste is formed, relevant Laboratory Specialist (if not available, Safety Specialist) is informed.	A ticket is created by the Lab Specialist/Lab Safety Specialist.	
	15 01 11	Empty Pressurized Container (Rust solver, chemical spray boxes)	Metal	Empty pressurized container box	Wastes are thrown into identified waste box.	A ticket is created by the Lab Specialist/Lab Safety Specialist.	

FENS LABORATORY WASTE GUIDE TABLE

Waste Type	Waste Code*	Waste Name	Waste Type	Waste Box	Storing the Waste (In the Laboratory)	Disposing of the Waste (From the Laboratory)	Legal Regulation
Hazardous Waste	**16 05 06**	Laboratory Chemicals	Dangerous liquids (acid, base, solvent, etc.	With inside bottles, in secondary containers	Bottles are collected in secondary containers with red stickers on them.	Lab Specialist (if not available, Lab Safety Specialist) is informed. Lab Specialist/Lab Safety Specialist fills in the waste tag. A ticket is created and the housekeeping unit takes the barrel.	Waste Management Regulations
			Dangerous solids (powder chemicals, gels, etc.)	Dangerous solid waste box - yellow plastic bag	Wastes are collected in the dangerous solid waste box.	Lab Specialist (if not available, Lab Safety Specialist) is informed. Lab Specialist/Lab Safety Specialist fills in the waste tag. A ticket is created and the housekeeping unit takes the barrel.	
	12 01 20	Fatty Metal Excelsior	Metal	Greasy metal waste box - black plastic bag	Wastes are collected in the greasy metal waste box.	A ticket is created by the Lab Specialist/Lab Safety Specialist and the housekeeping unit takes the box.	
	13 02 08	Waste Motor Oils	Liquid	With inside bottles, in secondary containers	Bottles are collected in secondary containers with red stickers on them.	Lab Specialist (if not available, Lab Safety Specialist) is informed. Lab Specialist/Lab Safety Specialist fills in the waste tag. A ticket is created and the housekeeping unit takes the barrel.	
Non-hazardous Waste	**15 01 07**	Package Waste	Glass	Recycling waste boxes	Glass is thrown into recycling waste box.	Collected daily by the housekeeping unit.	
	15 01 03		Wood		If wood waste is formed, relevant Laboratory Specialist (if not available, Lab Safety Specialist) is informed.		
	15 01 04		Metal		Metal is thrown into recycling waste box.		
	15 01 02		Plastic		Plastic is thrown into recycling waste box.		
	15 01 01		Paper		Paper is thrown into recycling waste box.		

* Wastes, that are in the waste list within the scope of Waste Management Regulations, are described with their six digit waste codes.

PS: If a waste formed which cannot be found in the above classification, please contact LS or LSS.

SAFE FOR DRAIN DISPOSAL

The following materials are the only allowable discharges to laboratory drains:

- Inorganic solutions with pH 5.5 and 12
- Soaps / detergents
- Infectious / Biological materials that have been properly treated as described in each laboratory's registration protocols
- Non-contaminated growth media
- Purified biological materials such as amino acids and proteins in aqueous or buffer solutions
- Sugars and sugar alcohols (polyols) such as glycerol, xylitol and sorbitol
- Buffer solutions
- Disinfectants listed for drain disposal (See Laboratory Safety Handbook Waste Management)

Inorganic salts for which both cations and anions are listed in the following table:

Cations	Anions
Al^{3+}, NH_4^+, Ca^{2+}, Cs^+, Fe^{2+}, Fe^{3+}, Li^+, Mg^{2+}, Mn^{2+}, Mn^{3+}, Mn^{4+}, Mn^{7+}, K^+, Na^+, Sr^{2+}, Sn^{2+}, Ti^{3+}, Ti^{4+}, Zr^{2+}	BO_3^{3-}, $B_4O_7^{2-}$, Br^-, CO_3^{2-}, Cl^-, HCO_3^-, HSO_3^-, HSO_4^-, F^-, OH^-, I^-, NO_3^-, NO_2^-, O^{2-}, PO_4^{3-}, SO_4^{2-}, SO_3^{2-}, $S_2O_3^{2-}$

All other materials must be collected and managed as hazardous waste.

Please check Sabancı University Laboratory Safety Handbook, Waste Management section and call Laboratory Safety Specialist / Laboratory Specialist for assistance in evaluating your waste disposal needs.

Index