Kingdom of Saudia Arabia
Ministry of Education
Taibah University
Deanship of Scientific Research

RESEARCH LABORATORIES SAFETY GUIDLINES

Prepared by

Research laboratories Safety Committee

1437 H

PREFACE

The deanship of scientific research at Taibah University presents this laboratory safety manual for staff, researchers and technicians work at research centers of Taibah University. We hope it will be useful to establish a safe environment for the scientific research at Taibah University. The safe use, storage, handling, waste and emergency management of chemicals and biological material in the laboratory environment are the subject of this manual. Chemicals are used, to one degree or another, in most university laboratories. Details on specific types of chemical hazards as well as commonly used equipment and procedures are outlined on the following pages. The information in this manual is meant to meet the needs of those who work, study and teach in laboratories at the Taibah University. The information included in this manual has come from a variety of reliable sources. This manual is intended for the use of Taibah University personnel as an appropriate starting point for the development of safe and best management practices in Taibah University laboratories where hazardous chemicals are used. The material contained within is correct to the best of our knowledge. However, there is no guarantee or warranty that it is without errors or omissions.

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I. Introduction

1.1 Laboratories Safety Committee (LSC)

Laboratories Safety Committee (**LSC**) is a newly established committee by Taibah University is responsible for:

- Developing and maintaining effective accident prevention programs;
- Providing the University community with required training;
- Assisting the University in complying with health, safety and environmental regulations; and
- Enhancing departmental services.

LSC's major programs comprise:

- Chemical Safety
- Biosafety
- Radiation Safety
- Environmental Safety

1.2 Duties and Responsibilities

The university, acting through administrative heads of units, is responsible for providing a safe, healthy and secure working environment for all those involved in the university's activities.
Supervisors are responsible for the following: identifying all hazards; ensuring that there are safe work procedures and appropriate emergency procedures; ensuring that all workers and students know and follow those procedures; and correcting unsafe conditions and practices. A supervisor is anyone who has been delegated responsibility for others working or studying at Taibah University.
All researchers and members of faculty and staff are responsible for learning and following safe work procedures and emergency procedures as well as reporting all unsafe conditions and incidents or accidents.

1.3 Incident/Accident Reporting

Taibah University Incident/Accident Report form must be completed for every incident or accident, even if no injuries were sustained Any event that involves injury to a person or damage to property, or has the potential to do so, must be reported to Laboratories Safety Committee within 24 hours of occurrence.

1.4 Chemical Safety Program

The Chemical Safety Program promotes the safe handling, storage and disposal of chemicals that is compliant with the regulations and recognized best practices. Through this program employees receive chemical safety training, advice and guidance.

1.5 Environmental Services Facility

The Environmental Services Facility at Taibah University is provided by SEPCO Environment. The purpose of this facility is to safely manage hazardous waste generated at Taibah University in accordance with provincial, local and federal regulations. Chemical waste is collected regularly and taken to the Environmental Services Facility in the campus. It is sorted, treated and packaged according to type before being shipped for disposal. Highly reactive compounds, such as picric acid or old containers of diethyl ether, are picked up at the generator's site by a contractor licensed to handle such materials.

II. General Laboratory Safety Rules

2.1 Work Habits

- Do not store food or beverages in the laboratory environment.
- Do not pipette by mouth.
- Do not casually dispose of chemicals down the drain
- Wash hands before and after work in a laboratory, and after spill clean-ups.
- Restrain loose clothing (e.g. sleeves, full cut blouses, neckties etc.), long hair and dangling jewelry.
- Protection should be provided for the lab worker and for nearby co-workers.
- Always inform co-workers of plans to carry out hazardous work before starting.
- First aid and CPR training is recommended for all lab personnel.
- Review all procedures before commencing any work
- Always wash your hands before leaving lab.
- Never work alone

2.2 Safety Wear

- Lab coats must be worn at all times in the laboratory.
- Closed toed shoes and long pants must be worn in the lab.
- Wear gloves that will resist penetration by the chemical being handled and which have been checked for pinholes, tears, or rips.
- Always wear approved eye or face protection when working with chemicals in the laboratory.
- Contact lenses are not allowed.
- Use respiratory protection (dust mask or respirator) when appropriate.

2.3 Facilities & Equipment

All operators of laboratory equipment at Taibah University must be adequately instructed and trained in the safe use of laboratory equipment and the precautions to be taken when the equipment is used.

- All moving belts and pulleys must have safety guards.
- Keep up-to-date emergency phone numbers posted next to the phone.
- Have appropriate equipment and materials available for spill control; replace when necessary.
- Always keep up with housekeeping in the laboratory (floor must be dry at all times).
- Floors, walkways, hallways, and stairways must be kept clear at all times to eliminate slipping and tripping hazards.

- Access routes to emergency equipment (emergency showers and eyewash facilities, fire extinguishers, first aid kits) must be kept clear of obstruction.

  All laboratory equipment must accompany safe operating procedures.

2.4 Purchasing, Use and Disposal

- Label all chemicals accurately with date of receipt, or preparation, and initialed by the person responsible. Add pertinent precautionary information for handling.
- Never open a reagent container until the label has been read and completely understood.
- Unlabeled bottles (a special problem) must be identified to the extent that they can then be classified as hazardous or non-hazardous wastes.
- Incompatible and hazardous wastes are properly segregated in clearly marked containers affixed with workplace labels.
- Disposal of solvents meets all municipal, provincial, and federal regulations.
- Only order what you need.

2.5 Substitutions

- Where possible, reduce risks by using diluted substances instead of using concentrates.
- Use micro/semi-micro techniques instead of macro-techniques.
- Use films, videotapes, and other methods rather than experiments involving hazardous substances.
- Evaluate all substitutions before changing procedures.
- Always substitute a less toxic material when possible.

III. Chemical Hazards and the Workplace Hazardous Materials Information System

3.1 Introduction

Information regarding safety and health hazards of materials used in the work place can be obtained through the Workplace Hazardous Materials Information System. This system requires suppliers to provide safety information with their products and requires the University to educate and train everyone potentially exposed to hazardous materials.

This chapter will provide basic information about the key elements of Workplace Hazardous Materials Information System:

- **Labeling** – alerts workers to the identity and dangers of products and to the basic safety precautions;
- **Material Safety Data Sheets** (MSDS) – technical bulletins which provide detailed hazard and precautionary information; and
- **Worker education and training.**

3.2 Background

The purpose of Workplace Hazardous Materials Information System is to help reduce the likelihood of disease or injury in the workplace. It was developed through the collective efforts of labor, industry and federal, provincial and territorial regulatory agencies.

Provincial legislation, through amendments to occupational safety and health regulations, declares the responsibility of the employer to provide:

- Workplace labeling and identification;
- A material safety data sheet where the employer uses a controlled product;
- Worker education on controlled products.

3.3 Labels

All controlled products must be labeled according to the Workplace Hazardous Materials Information System regulations.

Labels must be replaced if they become illegible or damaged. Illegible labels can create first aid, handling, and disposal problems.

Two types of labels are required under the Workplace Hazardous Materials Information System:

- Supplier labels, produced by the supplier of the controlled product
- Workplace labels, produced by the employer for use in the workplace

Supplier labels

Supplier labels carry brief statements to inform workers about the risk posed by the chemical, precautionary measures they should take, and first aid measures in the event of injury. A supplier label is not meant to provide complete health and safety information about a product.

Seven items of information must be included within the distinctive hatched border:

1. Product Identifier: Identifies the product by its chemical name, common name, generic name, trade name, brand name, code name or code number.
2. Hazard Symbols: One or more of the eight Workplace Hazardous Materials Information System symbols indicating the hazard classes of the product.
3. Reference to MSDS: Indicates that an MSDS is available.
4. Supplier Information: Name of the supplier, manufacturer or distributor, preferably with the address and telephone number.
5. Risk Phrases: Short statements, which describe how the product can be harmful.
6. Precautionary Statements: Statements that describe essential precautions to take when using, storing, and disposing of the product.

Chemical identification and workplace labels

- If a chemical is transferred from the original container and is for use exclusively within the laboratory, or if the chemical is a controlled product undergoing analysis (e.g. a lab sample), the employer must ensure that the contents are clearly identified on the container.
- In cases where chemicals will not be used exclusively in the laboratory, employers must ensure that workplace labels are prepared and applied as required by Taibah University Regulations.
- If chemicals are transferred from the original container into another container or mixed with other chemicals to produce a different chemical, a workplace label must be generated and attached to the new container. Workplace labels must be placed on each container of hazardous waste handled or disposed of by the laboratory.

Workplace labels must include:

- The product identity
- Safe handling information
- Reference to material safety data sheet Labels must be replaced if they become illegible.

Other Identification requirements

Refrigerators and freezers need content identification and whether or not they are explosion-proof.

Chemical storage cabinets are required to have content identification signage with one of more of the Workplace Hazardous Materials Information System Hazardous Class symbols.

Cleaning baths and pipes require chemical name and/or Workplace Hazardous Materials Information System Hazardous Class identification.

3.4 Material Safety Data Sheets (MSDS)

Material safety data sheet (MSDS), is a technical bulletin which provides detailed hazard, precautionary and emergency information on a product. Workplace Hazardous Materials Information System provides minimum content requirements for data sheets:

- Product information
- Hazardous ingredients
- Physical data
- Fire and explosion hazard
- Reactivity data
- Toxicological properties (health effects)
- Preventive measures
- First aid measures

Preparation information with date of preparation, name and phone number of persons or corporate departments to be contacted for additional information

Suppliers

Suppliers must develop or obtain an MSDS for each controlled product they sell or import. Information must be current and prepared not more than three years before sale or importation. A copy of the MSDS must be sent to the purchaser at the time of first purchase. Purchasers may request data sheets in either or both of the official languages. An MSDS is a technical bulletin, which provides detailed hazard, precautionary and emergency information on a product.

Employers

Employers at Taibah University must ensure that MSDS are received for all controlled products supplied to the workplace. The employer must contact the supplier for an updated sheet when the data sheet at the workplace is more than three years old.

If the employer produces a controlled product for use at the workplace, the employer must develop an MSDS to accompany workplace labeling for it. Such data may be in the language of choice at the workplace.

Copies of supplier and employer MSDS must be accessible to employees, close to their work areas and available during each work shift. MSDS may be hard copies or available on a computer if the employer takes all reasonable steps to keep the system in active working order (e.g. if the power goes out, the system is still accessible). Workers must know how to access MSDS, and must be educated in the content required on the data sheet and the applicable information in it

3.5 Worker Education and Training

Workplace Hazardous Materials Information System education is required for anyone who:

- Stores, handles, uses or disposes of a controlled product or supervises workers performing those duties;
- Serve as emergency personnel;
- Performs maintenance or cleaning in the vicinity and may be exposed to spills or other accidental releases of controlled products; or
- Works near the controlled product such that their health and safety could be at risk during normal storage, handling, use or disposal, during maintenance operations or in emergencies.

The Taibah University establishes education and training programs for workers including:

- How Workplace Hazardous Materials Information System is implemented;
- The hazards of controlled products;
- Procedures for the safe storage, handling, use and disposal of a controlled product
- Emergency procedures addressing spill or release of controlled products.

Training must ensure that workers are able to apply hazard information to protect their own health and safety.

Training and education programs must be reviewed at least once a year, if conditions at the workplace change or new hazard information on the product changes the known risk to workers.

IV. Chemicals Hazards and Handling

4.1 Introduction

Chemical hazards are defined under Workplace Hazardous Materials Information System according to one of six hazard categories:
(A) Compressed gases
(B) Flammable and combustible materials
(C) Oxidizing materials
(D) Toxic materials
(E) Corrosive materials
(F) Dangerously reactive materials.

Workplace Hazardous Materials Information System regulations require employers to educate workers in the safe handling, use and storage of these products in the workplace.

Hazard Symbol & Definition	Associated Hazards	Handling Information
Class A - Compressed Gas 	• an explosion hazard because the gas is being held in a cylinder under pressure • container can explode if heated in a fire • container may explode if dropped	• do not drop cylinder • keep cylinder away from potential sources of ignition • store containers in a designated area • secure in an upright position
Class B - Combustible and Flammable Materials 	• the material burns or represents a fire hazard • may burn at relatively low temperatures; flammables will ignite at lower temperatures than combustibles • may burst into flame spontaneously in air, or release flammable gas on contact with water • may cause fire when exposed to heat, sparks, flames or friction	• keep away from heat sources and oxidizing materials • never smoke in vicinity • store in cool, fire-proof area, as designated by supervisor
Class C – Oxidizing Materials 	• poses fire/explosion risk in presence of Class B materials • may cause fire, react violently or cause explosion in the presence of combustible materials such as wood and solvents • may react violently with reducing agents • may burn skin and eyes upon contact	• keep away from Class B materials • store in designated area • keep away from ignition sources • never smoke in vicinity • wear eye, face, and hand protection, and protective clothing

Class D - Division 1 **Poisonous and Infectious Materials Causing Immediate and Serious Toxic Effects** 	• potentially fatal substances • may be fatal or cause permanent damage if inhaled, swallowed or absorbed into body • may burn eyes or skin upon contact	• handle with extreme caution • avoid contact with skin or eyes; wear appropriate personal protective equipment and clothing • avoid inhaling; work in well-ventilated area and/or wear respiratory protection • wash and shower thoroughly after each use • store in designated areas only
Class D - Division 2 **Causing Other Toxic Effects** 	• not immediately dangerous to health • may cause death or permanent damage as a result of repeated exposures over time • may be skin or eye irritant or sensitizer • may cause cancer • may cause reproductive or teratogenic effects	• avoid eye, skin contact by using appropriate personal protective equipment and clothing • avoid inhaling; work in well-ventilated area and/or wear respiratory protection • store in designated areas
Class D - Division 3 Biohazardous and Infectious Materials 	• may cause a serious disease resulting in illness or death	• take every precaution to avoid contamination • handle only when wearing necessary protective equipment • handle in designated areas only where appropriate engineering controls are in place
Class E - Corrosive Materials 	• causes severe eye and skin irritation upon contact • causes severe tissue damage with prolonged contact • may be harmful if inhaled • may damage metal	• keep containers tightly closed • avoid skin and eye contact by wearing eye, face and hand protection and protective clothing • avoid inhaling; work in well-ventilated area and/or wear respiratory protection

Class F - Dangerously Reactive Materials 	• unstable; may react with water to release toxic or flammable gas • may explode as a result of shock, friction or increase in temperature • may undergo vigorous polymerization	• keep away from heat • open containers carefully; do not drop • store material in designated cool, flame-proof area

4.2 Class A- Compressed Gases and Cryogenic Materials

i. Definition

Class A - compressed gases include compressed gases, dissolved gases or gases liquefied by compression or refrigeration within reinforced metal cylinders. This includes cryogenic liquids that are hundreds of degrees below zero Celsius, thereby representing an extreme cold hazard. There are four sub-groups of compressed gases: Compressed gas (O_2, helium, argon); compressed liquid (chlorine, CO_2); dissolved gas in liquid (acetylene in acetone), and cryogenic liquids (N_2, O_2).

ii. Hazards

Compressed gases present a physical danger resulting from the sudden, out-of-control release of these materials from their containers. This release is associated with a concomitant discharge of energy due to great expansion in volume of the material leaving the cylinder (i.e. the energy released is akin to a jettisoned rocket that is capable of bursting through walls or any other objects in its way). The rapid diffusion of compressed gas can increase the exposure radius, increasing the potential for acute exposure and damage (corrosive or toxic gases). The release of compressed gas can also cause asphyxiation through the displacement of oxygen in the air. Compressed gases may be flammable, pyrophoric, toxic, corrosive, oxidizer, or reactive; their additional hazards will depend on the chemical nature

Cryogenic Liquids:

Most cryogenic liquids, such as liquid nitrogen, can cause frostbite to the skin. A few cryogenic liquids, such as hydrogen, propane and liquefied natural gas, are flammable. When handling these materials, the appropriate hand and eye protection against cold hazards as well as chemical hazards must be used.

iii. Handling

The following are basic precautions should be implemented when handling compressed gas cylinders:

- Chain or strap in upright position
- Protective cap in place while being moved
- Use cart to move
- Do not empty (not less than 30 psi)
- Cylinder valves closed when not in use

Compressed Gas Cylinders – Pressure Regulators

Pressure regulators are used in a system using compressed gas to reduce pressure from high-pressure sources, such as gas cylinders or gas supply pipelines, to a safe working pressure range. The pressure regulator should be attached to a cylinder without forcing the threads. A poor fit may indicate that the regulator is not intended for use on the gas chosen.

Take additional precautions when working with cryogenic liquids:

- Use proper Personal Protective Equipment
    - Wear clothing that cover arms & legs
    - Wear cryogenic gloves under sleeves
    - Wear safety glasses and face shield
    - Wear non-slip closed shoes and apron
- Use specially designed storage, transport, and dispensing containers
- When working indoors, make sure the dispensing area is adequately ventilated

Insulated vacuum jacketed pressure vessels are equipped with safety relief valve and rupture disk to protect from pressure build up, check them regularly.

When transporting large volume of cryogenic liquids in an elevator, whenever possible, send the cryogen container in an elevator without any passengers, and ensure that no passengers get on the elevator while the cryogen is being transported. In a power failure, a passenger could be trapped in the confined space of an elevator with the cryogen. Excessive amounts of the cryogen could vaporize and displace the oxygen

4.3 Class B- Flammable and Combustible Materials

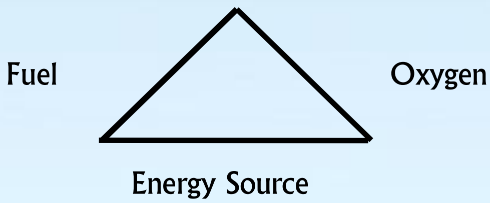
i. Definitions

Class B - flammable and combustible materials are substances that form vapours that can burn or explode. Vapour pressure is the pressure that is exerted by a saturated vapour above its own liquid in a closed container. It is reported in mm Hg, and it is positively correlated with temperature.

Examples of substances that are included in this classification are:

- Flammable gases
- Flammable liquids
- Combustible liquids
- Flammable solids
- Flammable aerosols
- Reactive flammables (spontaneously combustible in air, or materials that react with water to produce a flammable gas)

There are three elements that must be present in order for a fire to result. One way of pictorially describing this phenomenon is the —Fire Triangle||. Removing any of the three components will extinguish a fire.



ii. Hazards

May readily burn or explode if placed near heat, sparks, or open flames.

Flammable liquids give off vapours that, in most cases, are heavier than air and can travel long distances until reaching a source of ignition such as an open flame, hot surfaces, static sparks, etc. at which time a fire or explosion could result. These vapours can also be carcinogenic or otherwise harmful to one's health, and should generally be used in a fume hood.

Flammable liquids pose many serious problems. The misuse of a small amount can have a disastrous effect. As liquids, they can flow and thus any spillage will increase the fire hazard. Burning flammable liquids will likewise flow and spread the fire.

iii. Handling

Keep away from heat, sparks, and open flames. Keep the minimum quantity in the work area. Store the chemicals away from oxidizers. Label containers FLAMMABLE. Ensure sprinklers and fire extinguishers are available and working. Safe handling practices must be strictly followed in handling and transferring of all flammable liquids.Grounding of containers used for transferring flammable solvents is required to eliminate static charge build-up.

4.4 Class C- Oxidizing Materials

i. Definition

Class C – oxidizing materials are substances that readily yield oxygen or its equivalent to stimulate the combustion (oxidation) of organic matter. Chromic acid and chromates, nitric acid and nitrates, perchloric acid and perchlorates, permanganates, peroxides and bleach (hypochlorite) are all examples of oxidizing reagents. Oxidizers are incompatible with reducing agents (which usually contain hydrogen), such as hydrides, bisulfites and thiosulfates, and with flammable and combustible materials such as solvents, Varsol and acetic acid.

Nitric and perchloric acids are both strongly oxidizing acids. They will act rapidly on exposed skin through a denaturing mechanism. Nitric and perchloric acids will also act explosively with organic compounds and reducing agents.

ii. Hazards

Oxidizing materials can cause fire without an ignition source when mixed with flammable or combustible materials. These materials can also increase the speed and intensity of a fire.

And cause generally non-combustible materials to burn rapidly. Oxidizing materials may react with other chemicals to produce toxic gases as well.

iii. Handling

Oxidizing materials should be used in an area free of combustible, flammable and reducing materials. Minimum amounts of oxidizing material should be left out of storage when in use. Oxidizing materials that contain peroxidizable compounds must have a label, and must be tested regularly to ensure that a build-up of peroxide has not occurred.

4.5 Class D- Toxic Material

i. Definition

A toxic chemical is any substance that may cause damage to structure or disturbance to function when it is ingested, inhaled or absorbed, or when applied to, injected into or developed within the body, in relatively small amounts, by its chemical action.

Class D – toxic and infectious materials comprise 3 subdivisions. D1 materials are those causing immediate and serious toxic effects including coma and death. D2 materials are those that cause effects over a longer period of time. These materials can be carcinogenic (causing cancer), teratogenic (causing birth defects), mutagenic (causing mutation in DNA), irritating or sensitizing, bringing about chronic effects. D3 materials are those classified as biohazardous and will not be discussed here.

ii. Routes of Entry

Skin and Eyes

a. Interaction
   - Skin acts as a barrier
   - Reaction with a chemical may cause local irritation or tissue destruction
   - A chemical may penetrate the skin and react with tissue proteins causing allergic sensitivity
   - A chemical may penetrate the skin and enter the blood stream, especially through broken skin
   - Fat soluble solvents readily penetrate the skin
   - Eyes are especially vulnerable to chemical exposure

b. Symptoms of Exposure
   - Dry, whitened skin
   - Redness, swelling
   - Rash, blisters, itching

c. Protection
   - Protect hands against cuts
   - Wear the appropriate gloves, remove gloves before touching uncontaminated surfaces
   - Protect eyes with safety glasses, goggles, or face shield

Respiratory Tract

a. Interaction
   - Route of entry for gases, vapours, and small particulates

- Absorption of gases and vapors in the respiratory tract depends on
    - Vapor pressure of the material
    - Concentration in inhaled air
    - Chemical properties

b. Symptoms of Exposure
    - Headache
    - Eye, nose, and throat irritation
    - Increased mucus in the nose and throat
    - Narcotic effects (headache, confusion, dizziness, collapse)
    - Asphyxiation through displacement of oxygen or blocking transport or utilization of oxygen (e.g. carbon monoxide, hydrogen sulfide)

c. Protection
    - Engineering controls such as fume hoods, general and local exhaust systems, and biosafety cabinets
    - When engineering controls are not available, use respirators to eliminate exposure from inhaled particulates, vapors, gases or fumes

<u>Gastrointestinal Tract</u>

a. Interaction
    - Ingestion of toxic substances can occur accidentally through poor hygiene practices or use of contaminated laboratory glassware for food or drink

b. Symptoms
    - Mouth and throat discomfort
    - Gastrointestinal discomfort
    - Coma, death

c. Protection
    - Do NOT pipette by mouth
    - Do NOT store food items in lab glassware bin or lab refrigerator
    - Do NOT eat or drink in the lab
    - Wash hands after working with chemicals, before leaving the lab and before eating

<u>Injection</u>

a. Interaction
    - Occurs through mishaps with hypodermic needles and broken glassware

b. Symptoms
    - May be local or systemic

c. Protection
    - Wear protective gloves when feasible
    - Use forceps or broom and dustpan for cleaning up broken glass

iii. Dose

The dose is the amount of chemical that actually enters the body. It can be determined by the concentration of the chemical and frequency and duration of exposure.

iv. Duration of exposure

Acute Exposure

- Usually single, short term exposure
- Acute toxicity results from the potential for a chemical to cause harm after a single, short exposure.
- Effects appear quickly
- Effects often reversible

Chronic Exposure

- Repeated exposure
- Chronic toxicity is the potential for a chemical to cause harm following repeated exposure over weeks, months or years
- Effects take time to appear
- Usually irreversible effects
- e.g. mercury and carbon tetrachloride are cumulative poisons requiring special work and clean-up procedures

v. Effects of Toxic Chemicals

The effect of toxic chemicals can be local or systemic and will depend on individual worker susceptibility.

Local effects

- Area in contact with the chemical (e.g. acid, base burns)

Systemic effects

- Affects tissues and organs that are far removed from the site of contact
- Chemical enters body and is distributed via blood
  e.g. methanol inhalation or ingestion can cause permanent eye damage

Individual Susceptibility

- Important factors include general health, heredity, diet, age, and sex

The properties of the chemicals being used must be determined prior to use by reading labels and Material Safety Data Sheets.

Any substance has the potential for being toxic depending on:

- The amount or dose;
- Duration of exposure;
- The route of entry; and
- Susceptibility of the individual being exposed.

vi. Exposure Limits

Definitions:

- "8-hour TWA limit" means the time weighted average (TWA) concentration of a substance in air which may not be exceeded over a normal 8 hour work period;
- "ACGIH" means the American Conference of Governmental Industrial Hygienists publication entitled Threshold Limit Values and Biological Exposure Indices as amended from time to time, or
- "Short-term exposure limit" or "STEL" means the time weighted average (TWA) concentration of a substance in air which may not be exceeded over any 15 minute

period, limited to no more than 4 such periods in an 8 hour work shift with at least one hour between any 2 successive 15 minute excursion periods;

- —Ceiling limit" means the concentration of a substance in air which may not be exceeded at any time during the work period;
- ACGIH L endnote- —L‖ is defined as —exposure by all routes should be carefully controlled to levels as low as possible.‖ Examples of these highly toxic substances include benzo(a)pyrene, polytetrafluoroethylene decomposition products, and rosin core solder thermal decomposition products.

Workers must not be exposed to a substance concentration that exceeds the ceiling limit, short-term exposure limit, or 8-hour TWA limit prescribed by ACGIH.

If a TWA, STEL or other exposure limit is not available, there are other toxicity measures:

- LD50: "Lethal Dose— the amount of a material given at once, which causes the death of 50% of a group of test animals (units in mg/kg)
  - Extremely Toxic -1 or less (a drop)
  - Highly Toxic- 1-50 (4 ml)
  - Moderately Toxic- 50-500 (30 ml)
  - Slightly Toxic 500- 5000 (600 ml)
  - Practically Non-toxic- 5000 and above

- LC50: for inhalation experiments, the concentration of the chemical in air that kills 50% of the test animals in a given time (usually four hours) (units in ppm)
  - Extremely Toxic -10 or less
  - Highly Toxic- 10-100
  - Moderately Toxic- 100-1000
  - Slightly Toxic 1000- 10000
  - Practically Non-toxic- 10000 and above

Delayed effects:

If a substance identified as any of the following is present in the workplace, it must be replaced if practical, with a material, which reduces the risk to workers:

(a) **ACGIH A1**- Confirmed human carcinogen or **ACGIH A2**- Suspected human carcinogen, or **IARC 1**- Human carcinogen, **IARC 2A**- Probable human carcinogen or **IARC 2B** - Possible human carcinogen, or **NTP**- Known to be Human Carcinogen (KC) or **NTP**- Reasonably Anticipated Human Carcinogen (RAC).

(b) **ACGIH reproductive toxin**- a substance that has the potential for an adverse reproductive effect, including effects on both female and male reproductive organs, tissues, or cells; effects on fertility; effects on the embryo or fetus; effects that have been demonstrated to cause developmental abnormalities; tumour-causing effects; and effects on the newborn.

(c) **ACGIH sensitizer**- This critical health effect refers to the potential for a substance to produce sensitization as confirmed by human or animal data. Depending on the substance, workers can become sensitized to the substance through the respiratory system, the skin, or the eyes. Sensitization often involves a response by the body's immune system. Initially, there may be little or no response to a sensitizing substance. However, after a person is sensitized, subsequent exposure may cause severe reactions even at low exposure concentrations, including at levels below the exposure limit.

IARC- International Agency for Research on Cancer

ACGIH- American Conference of Governmental Industrial Hygienists

NTP- National Toxicology Program

4.6 Class E- Corrosive Materials

i. Definition

Class E - corrosive substances are materials that, upon contact, cause visible destruction of, or irreversible alteration to tissue or metal. The eyes are especially sensitive to permanent damage by corrosive substances.

ii. Hazards

Large quantities of corrosive chemicals are used routinely in manufacturing and laboratory procedures. Many household chemicals are corrosive in nature and deserve the same respect and care.

Corrosives comprise both acids and bases (caustics). The pH of a solution describes the degree of acidity or alkalinity of a solution, on a scale of 0 to 14. Materials with pH 7 are considered neutral and non-corrosive; those below 7 are acidic and those above 7 are caustic or basic. The further away from pH 7 that a substance is, the more corrosive it is.

iii. Handling

When mixed together, acids and bases will react vigorously with each other through an exothermic (heat releasing) neutralization reaction. Proper handling and usage of corrosives require protective clothing to prevent skin, eye, or lung exposure. Serious burns and eye or lung damage can result from contact with corrosive materials.

Exposure requires immediate action to wash away the material away with copious amounts of water. Thick, oily corrosive liquids such as sulphuric acid and 40% sodium hydroxide are especially hazardous as it is difficult for water to quickly penetrate and dissolve these materials. Washing, in this situation, may include wiping off the oily layer with a cloth while keeping the affected body part in the water stream. Proper and prompt decontamination can prevent or minimize serious injury.

Volatile corrosive materials, such as concentrated ammonium hydroxide or hydrochloric acid, should be handled in the fume hood. Personal protective equipment, such as splash goggles, rubber gloves, substantial shoes and a lab coat or rubber apron, should always be worn when handling corrosive materials.

Acids

The common inorganic acids include hydrochloric, nitric, sulphuric, and phosphoric acids. Phenols and the halogens, such as bromine and chlorine are also acidic in nature. All hydrogen halides are acids that are serious respiratory and skin hazards.

Sulphuric acid is a very strong dehydrating acid. When preparing aqueous solutions of this oxoacid and other concentrated acids, **always add acid to water**, very slowly. The reaction is extremely exothermic, producing a rapid increase in temperature during mixing. Continual stirring of the solution as well as the use of —distilled water|| ice for cooling (substitute for water) is recommended.

Hydrogen fluoride presents a special hazard. Both the gas and liquid form are highly toxic and able to penetrate deeply into the tissues and bone. Symptoms (pain) of contact with hydrogen fluoride solutions (eg. Hydrofluoric Acid) may be delayed with serious burns resulting. When skin is exposed to hydrogen fluoride solutions, flush with water for at least 15 minutes, apply calcium gluconate gel after washing with water, and in all cases of exposure, seek medical attention.

Bases (caustics)

The most common bases found in laboratories are the alkali metal hydroxides, ammonium hydroxide and organic amines. The alkali metal hydroxides are especially destructive to the skin. The skin has a slippery feel when exposed to these materials because the hydroxyl radicals bond to the skin's peptides (saponification). Since the pain of exposure is delayed, it is extremely important that the skin be washed thoroughly for at least 15 minutes after exposure to these alkali solutions. The vapours from ammonium hydroxide (ammonia) present serious respiratory hazards.

4.7 Class F- Dangerously Reactive Materials

i. Definition

Class F - Dangerously reactive materials are substances that:

a) undergo vigorous polymerization, decomposition or condensation;
b) become self-reactive under conditions of shock, or increase in pressure or temperature; or
c) react vigorously with water to release poisonous gas.
d) spontaneously combust in air (pyrophoric)

ii. Hazards and Handling

a) Quantities of explosive and highly reactive material available in the work area must be restricted to amounts immediately required for the work day;
b) If the nature of the laboratory work suggests that explosions or implosions may result, the laboratory apparatus or equipment involved in such work must be adequately shielded; Subsequently, the operators must be provided with and must wear suitable protective devices; and
c) Wherever practicable, the work must be safely isolated from workers by distance.

Acid halides, such as acetyl chloride or phosphoryl chloride, react violently with water. Lithium aluminium hydride and butyl lithium spontaneously combust in air. Some organic monomers, such as butadiene, will self-polymerize in air. Read labels and material safety data sheets carefully to determine reactivity and compatibility characteristics of the chemicals being used.

Potentially Explosive chemicals –can release tremendous amounts of destructive energy rapidly. If not handled properly, these chemicals can pose a serious threat to the health and safety of laboratory personnel, emergency responders, building occupants, chemical waste handlers, and disposal companies.

Most chemicals that are used in research and teaching laboratories are stable and non-explosive at the time of purchase. Over time, some chemicals can oxidize, become contaminated, dry out, or otherwise destabilize to become Potentially Explosive Chemicals (PEC) (e.g., isopropyl ether, sodium amide, and picric acid).

4.8 Special Hazardous Chemicals

Organic Peroxides

i. Definition

Organic peroxides are a particular group of oxidizing materials that are often unstable in nature. They can be among the most hazardous materials handled in laboratories. They are low power explosives, which are sensitive, to varying degrees, to heat or shock. Often they are products of room temperature oxidation of a variety of organic ethers, alkenes, certain alcohols, potassium and other materials. Organic peroxides are especially dangerous when dried.

Peroxide inhibitors are usually added to compounds that readily form explosive peroxides; however, they may not be sufficient to control peroxide formation once the container has been opened. Any peroxidizable compound must have this label attached to the container. The label should be updated every 3-12 months depending on the chemical.

ii. Precautions

If ether peroxidation is visibly evident as a viscous layer in the bottom of the container or crystals around the cap, **do not handle the container**. If the container is more than 2 years old, and has not been opened or tested within the past 12 months, do not open the container.

iii. Peroxide Testing Program

Certain ethers such as di-isopropyl ether form peroxides more rapidly than most others and should be handled with particular care. Purchases of large quantities and long term storage are not recommended.

There are several methods for the detection of peroxides, two of which are described below.

<u>Test Strips</u>

The simplest method for testing for the presence of peroxides in materials can be done using peroxide test strips available from local laboratory supply houses (e.g. E M Quant from Anachemia Scientific).

<u>Chemical Testing</u>

To 1 mL of the ether to be tested, add a solution of 100 mg of potassium iodide in 1 mL of glacial acetic acid. A pale yellow colour indicates a low concentration (0.001 to 0.0005 %) of peroxides, and a bright yellow or brown colour indicates a high (> 0.1%) and hazardous concentration of peroxides. This chemical test is more sensitive than the test strips, as it will detect dialkyl peroxides as well as hydroperoxides.

It should be remembered that these tests are valid only for relatively simple chemicals. Complicated organic structures may also act as oxidizing agents and therefore appear to give positive tests for peroxides. There are no testing methods for peroxides of potassium metal.

iv. Handling and Removal of Peroxides

If peroxides are detected, the solvent should be treated prior to use or being sent for disposal.

Picric Acid

Dry **picric acid** is a highly explosive material that is widely used as a DNA marker. Solid picric acid must be stored with at least 10% moisture content and **regular inspections** must be made to ensure that the minimum **moisture content is maintained.** Solutions of picric acid must not be allowed to accumulate and dry around cap threads||. It is important to: dispose of old stocks; order minimum amounts; and check current stocks routinely to ensure solid material has not dried out.

Perchloric Acid

Regulation specifically refers to the use of **perchloric acid**. Perchloric acid must be used in a special wash-down fume hood made of a non-combustible material (usually stainless steel). The use of the hood must be posted and no combustibles are permitted to be stored in the same hood. **No more than 6.4 kg of perchloric acid may be stored in a laboratory.** Stored perchloric acid **must be inspected monthly**, and if any discoloration is noted it must be disposed of immediately and in a safe manner. Anhydrous perchloric acid may only be used if freshly made; any unused portions must be disposed of safely at the end of the procedure and not kept for more than one day.

V. Hazard Controls

5.1 Introduction

At Taibah University there are many types of laboratories, each with very different hazards, however common control measures can be implemented to prevent accidents, injuries, and disease. The following process can be used to address common laboratory health and safety hazards:

5.1.1 Identify and assess hazards

Supervisors are required to identify hazards and conduct a hazard assessment before any equipment, machinery, or work process is used or started. Potential hazards include exposure to chemicals, heat, noise, vibration, violence, and ergonomic problems. The hazard assessment should be done in consultation with a health and safety committee member or, if there is no committee, a person who is familiar with the job process.

5.1.2 Implement control measures

Once the hazards have been identified and assessed, it is necessary to control these chemical hazards used in the laboratory. There are four types of controls for minimizing or eliminating hazards:

- Substituting with less hazardous material
- Engineering controls
- Administrative controls

- **Personal protective equipment**

Elimination of a hazardous product or substitution with a less hazardous product represents the best solution. Engineering controls are the next best choice for controlling hazardous materials. They do not require continual monitoring and are more likely to be used; however, they do require regular maintenance and are more expensive to implement. The next type of control is administrative and it includes written procedures, training, supervision and scheduling of activities. The use of personal protective equipment represents the least effective type of control; its effectiveness is limited by the dependence on individuals wearing it, and its discomfort.

5.2 Engineer Controls

5.2.1 Laboratory Fume Hoods

Fume hoods protect workers from hazardous exposure to airborne contaminants by capturing fumes, dusts, vapours and gases generated inside the hood and discharging them safely.

i. Work Practices

- Conduct all operations, which generate air-born contaminants, inside a fume hood.
- Always wear appropriate eye protection and a lab coat when working near a fume hood.
- If the hood is used for long-term experiments, post the name and phone number of the person in charge, experiment title and potential hazards.
- Keep your head outside the face of the hood with the sash lower than your face.
- Keep apparatus at least 15 cm from the face of the hood to minimize turbulence at entrance to hood as this can cause some of the contaminants to be swirled out of the hood.
- Avoid blocking the rear ventilation slot. Material stored at the back of the hood should be stored on an elevated shelf so that the slot airflow is not impeded.
- Avoid storing chemicals or gas cylinders inside the hood. Hazardous chemicals should be stored in approved safety cabinets.
- Do not place electrical receptacles or other ignition sources inside the hood when flammable liquids or gases are present. No permanent electrical receptacles are permitted in the hood (current design criteria).
- Avoid cross drafts at the face of the hood. Minimize foot traffic past the hood and position windows and supply air diffusers to direct air away from the hood.
- Do not raise the sash higher than the labeled height as this will reduce the hood efficiency.
- Leave the sash lowered when the experiment is unattended.
- Keep the bypass grill clean.

ii. Fume Hood Airflow Failure Response

The abrupt and complete loss of airflow to a laboratory fume hood may create significant hazards or cause injury to maintenance and laboratory staff. The purpose of this procedure is to ensure that the hazards associated with hood system failure are minimized.

Fume hood users need to develop a plan of action to follow if the fume hood fails. This planned procedure should include the following steps:

If Fume Hood Air Flow Stops:

- Note pressure gauge reading, if one is provided.
- Shut off experiments, turn off heat, relieve system pressure.
- Seal containers; remove compressed gas cylinders from the hood.
- Ensure no other lab equipment is vented into the hood.
- Place ―Do Not Use; Hood Out of Order‖ sign on the fume hood.
- Where radioisotopes are used, contact the Radiation
- Advise your departmental administrator

iii. Fume Hood Maintenance

Fume hood maintenance is a planned, annual procedure. Depending on the nature of the work involved (e.g. whether the actual fume cupboard is included or whether the fume hood system has leaks or not) there are standard procedures that must be performed by fume hood users prior to work being done by maintenance personnel.

There are three levels of fume hood maintenance; they differ with respect to the type of work or maintenance being done and consequently with respect to the activities to be assumed by the fume hood user. For all fume hood shutdowns, the following is required:

- Containers capped; gas cylinders removed
- Heat sources closed
- Hood monitored for radioactivity & decontaminated as required
- No equipment is venting into hood.

The table below summarizes the main differences between Level II & III.

Type of Work or Maintenance	User's Responsibilities
II. Work done outside hood, but within ductwork	All chemicals removed from hood
III. Work done within hood	Everything is removed from hood

5.3 Personal Protective Equipment

Personal protective equipment is an individual's means of protecting themselves from hazards in the laboratory. Wherever possible, engineering controls should be installed to make the workplace safe.

PPE needs and selection must be determined based on assessment of exposure hazard, the available control measures and the need for further controls. PPE must be selected and used in accordance with recognized standards, and provide effective protection. Personal protective equipment must be provided by employer if it is required to perform an operation safely. Hazards must be assessed before the proper PPE can be chosen.

The basic PPE to be used in laboratory where chemicals are used is consist of: lab coat, safety glasses, appropriate gloves, long pants, closed-toe and -heel shoes.

The type of PPE that is required will depend on the particular hazards of the materials, equipment and procedures being used and may include: safety headgear, eye and face protection, limb and body protection, and foot wear. In addition respiratory protection may be required if the safe exposure limits are to be exceeded and ear protection should be used in environment where noise level TWA exceed 85 dB.

i. Eye Protection

The type of eye protection that is required in a laboratory depends on the materials and operations in use. Proper eye protection includes safety glasses, safety goggles, and face shields. Eye protection will be required when there is hazard from:

- flying particles (dust)
- liquid chemicals (acids and caustics)
- gases and vapors
- and injurious light (UV or IR radiation)

The following guidelines should be considered when determining the type of eye protection that is required. The same rules apply to those working near or visiting hazardous areas.

1) Contact lenses are not recommended when working with volatile chemicals. They must be worn with safety glasses and supervisors must be aware of who is wearing them.
2) Shatterproof prescription eyeglasses do not provide adequate splash protection. Splash goggles, with sealed sides and top, must be worn when handling corrosive, toxic or irritating liquids and there is a splash risk.
3) Face shields and explosion-proof shields must be used where necessary; i.e. use when there is a risk of explosion, splashing or combustion with high or low temperature or during pressure reactions or procedures.

ii. Gloves

There are several glove types available depending on the potential hazard of concern. Hand protection will be required when there is a risk of: chemical burns, hazardous material skin absorption. When work involves: sharp objects, material cutting, or extreme temperature

No single glove material will protect against all chemicals. Different glove materials interact differently with different types of chemicals. It is therefore important to match the right glove material to the type of chemical(s) being used. Natural rubber latex gloves may be suitable for dilute aqueous solutions; however, oils, greases and many organic solvents will easily permeate the latex material. Nitrile gloves may be used against oils and greases but are generally unsatisfactory for use against aromatic or halogenated solvents.

Suppliers and manufacturers sometimes publish chemical compatibility charts or refer to the MSDS to help identify the most suitable glove type for specific applications.

General guidelines for chemical resistant glove selection are included below. Due to variations between manufacturers, the final choice must be dependent on their specific characteristics and recommendations.

Leather, Canvas or Metal Mesh Gloves - Sturdy gloves made from metal mesh, leather or canvas provide protection against cuts and burns. Leather or canvass gloves also protect against sustained heat.

Fabric gloves protect against dirt, slivers, chafing and abrasions. They do not provide sufficient protection for use with rough, sharp or heavy materials. Adding a plastic coating will strengthen some fabric gloves.

Chemical- and Liquid-Resistant Gloves

Chemical-resistant gloves are made with different kinds of rubber: natural, butyl, neoprene, nitrile and fluorocarbon (viton); or various kinds of plastic: polyvinyl chloride

(PVC), polyvinyl alcohol and polyethylene. These materials can be blended or laminated for better performance. As a general rule, the thicker the glove material, the greater the chemical resistance but thick gloves may impair grip and dexterity, having a negative impact on safety.

Some examples of chemical-resistant gloves include:

Butyl gloves are made of a synthetic rubber and protect against a wide variety of chemicals, such as peroxide, rocket fuels, highly corrosive acids (nitric acid, sulfuric acid, hydrofluoric acid and red-fuming nitric acid), strong bases, alcohols, aldehydes, ketones, esters and nitro compounds. Butyl gloves also resist oxidation, ozone corrosion and abrasion, and remain flexible at low temperatures. Butyl rubber does not perform well with aliphatic and aromatic hydrocarbons and halogenated solvents.

Natural (latex) rubber gloves are comfortable to wear, which makes them a popular general-purpose glove. They feature outstanding tensile strength, elasticity and temperature resistance. In addition to resisting abrasions caused by grinding and polishing, these gloves protect workers' hands from most water solutions of acids, alkalis, salts and ketones. Latex gloves have caused allergic reactions in some individuals and may not be appropriate for all employees. Hypoallergenic gloves, glove liners and powderless gloves are possible alternatives for workers who are allergic to latex gloves.

Neoprene gloves are made of synthetic rubber and offer good pliability, finger dexterity, high density and tear resistance. They protect against hydraulic fluids, gasoline, alcohols, organic acids and alkalis. They generally have chemical and wear resistance properties superior to those made of natural rubber.

Nitrile gloves are made of a copolymer and provide protection from chlorinated solvents such as trichloroethylene and perchloroethylene. Although intended for jobs requiring dexterity and sensitivity, nitrile gloves stand up to heavy use even after prolonged exposure to substances that cause other gloves to deteriorate. They offer protection when working with oils, greases, acids, caustics and alcohols but are generally not recommended for use with strong oxidizing agents, aromatic solvents, ketones and acetates.

A visual inspection of gloves should be done before each use to ensure that they are not torn, punctured or made ineffective in any way. Gloves that are discolored or stiff may also indicate deficiencies caused by excessive use or degradation from chemical exposure.

Any gloves with impaired protective ability should be discarded and replaced. Reuse of chemical-resistant gloves should be evaluated carefully, taking into consideration the absorptive qualities of the gloves. A decision to reuse chemically-exposed gloves should take into consideration the toxicity of the chemicals involved and factors such as duration of exposure, storage and temperature.

iii. Protective Clothing

Lab coats must be worn in laboratories at all times as per WorkSafeBC Regulations. Additional protection such as aprons and specialized suits may be required when handling corrosive, toxic, or other harmful materials. It is important to choose the material best suited for the work being done. Lab coats and coveralls should be made of a tough fire-resistant fabric with proper fasteners and long enough to protect the legs. Aprons should be chemical-resistant, fire-resistant and washable. Avoid flammable fabrics such as polyester. Bare legs are not allowed when handling hazardous materials.

iv. Footwear

Shoes must be worn in the laboratory; they must cover the entire foot and be made of a substantial material, such as leather. Open-toed shoes and sandals must not be worn by laboratory workers who work with or near chemical hazards. Workers performing spill clean up require chemical-resistant footwear. Workers who frequently change gas cylinders are at increased risk of injury from cylinders falling on their toes, therefore hard-toed shoes are recommended for this task.

v. Respiratory Protection

In general, it should not be necessary for laboratory workers to wear respiratory protection. Workers must know the limitations of the respirator and be properly fit-tested for the use of them. Use of respirators should be considered to control exposure **only** after engineering and administrative controls have been considered. These types of controls include ventilation (e.g. fume hoods), enclosing the process, substitution of less hazardous products, rescheduling of work procedures, etc.

A **respirator program** is required to ensure that respirators used by employees provide effective protection against airborne contaminants. It should also define employer, supervisor and employee's respective responsibilities.

VI. Chemical Storage and Segregation

6.1 Inventory

An annual inventory of hazardous materials is required. An inventory must be maintained which identifies all hazardous substances at the workplace in quantities that may endanger workers in an emergency including controlled products covered by WHMIS, explosives, pesticides, radioactive materials, hazardous wastes, and consumer products. The inventory must identify the nature, location, and approximate quantity of all such substances, and the location of MSDSs.

Annual inventories serve as a reminder to:

- Check chemicals with limited shelf life;
- Remove surplus and old chemicals;
- Correct incompatible storage;
- Know what you have; and
- Cleanup containers & shelves.

Develop a system for locating your chemicals and finding information about them such as:

- Computer database system
- Cardex system

A good system should:

- Direct you quickly to the chemical;
- Be easy to use;
- Be easy to maintain; and
- Be updated annually.

Laboratories are not storerooms, particularly with respect to chemicals and solvents. Chemicals in laboratories should be stored in areas away from experimental activities, and limited to the requirements of 12 months or less. Excess stock should be kept in a proper chemical storage facility.

Order in small amounts; don't stockpile chemicals. It is often false economy to order 1 kg of a material because it is cheaper than ordering 100 g of the same product. The materials end up:

- Taking up valuable space;
- Presenting a greater potential hazard;
- Eventually becoming a disposal problem, and costing the generator more to dispose of the material.

6.2 General Rules for Safe Storage

Chemical storage, whether in a laboratory or central storeroom, should be under the supervision of a qualified person; storerooms must have adequate security. Specialized cabinets should be used for specific groups of compatible substances.

- Do not overcrowd shelves.
- Store solvents in a proper flammable liquid cabinet and keep door closed.
- Use appropriate containers for solvents and waste.
- Store highly toxic or controlled materials in a secure (locked) cupboard.
- Store in central, properly ventilated area that includes forced ventilation from floor to ceiling and with exhaust above roof level.
- Store working quantities (small containers that are used daily or frequently) on bench side shelving
- Shelving should be accessible with chemicals at eye level or lower; no high shelf chemical storage.
- Avoid floor chemical storage (even temporary).
- Shelf assemblies are firmly secured to walls.
- Provide anti-roll lips on all shelves.
- All chemical containers must be sealed, intact, properly labeled and made of compatible material
- Regularly vent materials capable of building up pressure; e.g. formic acid, nitric acid, and hydrogen peroxide
- Do not store chemicals in fume hoods unless the fume hoods are used exclusively for this purpose and are labeled as a storage area only

6.3 Chemical Segregation for Storage

Each chemical must be evaluated to determine where and how it should be stored. Manufacturers' recommendations should be followed. As a general rule, flammable or combustible liquids, toxic chemicals, explosive chemicals, oxidizing agents, corrosive chemicals, water-sensitive chemicals, and compressed gases should be segregated from each other. They must be stored in such a way that they will not mix with each other if a container leaks or breaks.

It is important to segregate chemicals for storage in a compatible manner. Two segregation storage systems are provided below:

i. Storage segregation based on WHMIS Hazard Classes

- Sort according to the 6 WHMIS categories described below.
- Prioritize the separation process in the following order:

FLAMMABLE & COMBUSTIBLE MATERIALS DANGEROUSLY REACTIVE
OXIDIZING MATERIALS
CORROSIVE MATERIALS
COMPRESSED GASES HIGHLY TOXIC

ii. Segregation for storage

Class	Flammable gases	Non-flammable /non toxic	Toxic/ corrosive gases	Flammable liquids	Flammable solids	Substances subject to spontaneous ignition	Water reactive	Oxidizing substances	Organic Peroxides	Poisonous Substance	Corrosives
Flammable gases	-	P	X	P	P	A	DS	X	X	X	X
Non-flammable /non toxic	P	-	P	P	P	P	P	P	P	P	P
Toxic/ corrosive gases	X	P	-	X	A	A	DS	A	X	DS	A
Flammable liquids	P	P	X	-	P	A	A	X	X	DS	A
Flammable solids	P	P	A	P	-	A	DS	X	X	DS	A
Substances subject to spontaneous ignition	A	P	A	A	A	-	DS	X	X	DS	A
Water reactive	DS	P	DS	A	DS	DS	-	X	X	DS	X
Oxidizing substances	X	P	A	X	X	X		-	X	A	X
Organic Peroxides	X	P	X	X	X	X	X	X	-	X	X
Poisonous Substance	X	P	DS	DS	DS	DS	DS	A	X	-	A
Corrosives	X	P	A	A	A	A	A	X	X	A	-

P Permitted; items may be stored together.
X Incompatible items; do not store together in same storage facility. A
Incompatible items; separate by minimum of 1 meter distance.
DS Defer to Material Safety Data Sheet.

6.4 Storage Guidelines of Specific Hazard Classes

i. Compressed Gases

- Protect cylinders from excessive variations in temperature, ignition sources, and direct contact with the ground.
- Label empty cylinders and store them separately from other cylinders.
- Use smallest, returnable size containers and quantities
- Keep all compressed gas cylinders upright and fully secured against falling
    - Individually chain or strap compressed gas cylinders.
    - Store lecture bottles upright and chain, or secure in a proper holder.
- Store in central, properly ventilated area that includes forced ventilation from floor to ceiling and with exhaust above roof level.
- Storage according to compatibility
- If flammable gasses are stored indoors, the room must have a 2-hour fire separation with entry from the exterior. Natural ventilation to outside wall must exist, and the room must have no other purpose.
- Separate flammable gases from oxidizing gases with noncombustible partitions.
- If pressure testing is required, indicate on the cylinder when it was pressure-tested.
- Routily check hazard gases for leaks
- Store hazardous gases with poor warning properties in exhausted enclosures

ii. Flammable Liquids

Flammable liquids should be stored in a dry, cool well-ventilated area, preferably a flammable materials storage cabinet or room.

a) Laboratory Storage

Flammable liquids should be stored:

- Storage cabinets must be conspicuously labeled to indicate that they contain flammable liquids.
- No combustible material is permitted in storage rooms.
- Do not store in or adjacent to exits, elevators, or routes that provide access to exits.
- If flammable liquids are to be stored cold, the refrigerators and freezers must meet explosion proof standards.
- the maximum volume of flammable and combustible liquid allowed outside a flammable safety cabinet is 10L including not more than 5L of flammable liquids
- Flammable liquid safety cans of up to 25L can be used for flammable liquid storage out side safety cabinet
- In listed approved metal safety cans which meet the fire code requirements that are equipped with a flash arrestor and self-closing lid.
- In appropriate 5 litre waste solvent containers that are capped when not in active use.

b) Flammable Liquid Cabinets

An approved flammable liquid storage cabinet may be used when quantities of flammables are near or exceed 25 litres. An approved flammable liquid storage cabinet must be listed by an acceptable testing agency and approved by the local Fire Department.

Flammable liquid cabinets provide:

- A safe means of storage over a short period of time.
- A time-saving method of storage by locating cabinets in, or adjacent to work areas which reduces the frequency of trips to the drum storage or dispensing facility.

Flammable liquids cabinets must:

- Be closed at all times, with door latches operable.
- Have vents that are either plugged or vented directly to the outside.
- Be either wood (must meet specifications of fire code) or metal.
- Be suitably placed; ie. not located near an exit door or blocking access to an exit route.
- May have to be in a room which has a second exit depending on the quantity and hazards of flammable liquids in the room.
- Contain no more than 500 litres maximum of flammable and combustible liquids of which no more than 250 litres may be flammable.
- Be no more than one (1) per fire compartment, unless approved by the local Fire Department.

c) Flammable Liquid Storage Rooms

A properly designed flammable liquids room must satisfy many requirements, e.g. location, ventilation, electrical equipment. fire protection, etc. It must also meet the needs of the user, e.g. adequate size, conveniently located, etc.

The flammable liquids storage room should be easily accessible to fire fighting; i.e. located in corners of buildings over window openings and doors all providing sufficient entry. Explosion venting can then be incorporated into the exterior walls.

Specific guidelines for flammable liquid storage rooms include the maximum number of litres per square metre of floor space, maximum room size with and without a sprinkler system (or other automatic extinguishing system) and the fire resistance rating of the interior walls.

d) Refrigerator Storage

Refrigerators must be approved for storage of flammable liquids (explosion- proof), or acceptably tested and approved. A number of refrigerators have exploded due to flammable vapours.

iii. Toxic Materials

- Store in secured area.
- For carcinogen and reproductive toxins secondary containment is recommended.

iv. Corrosive Acids and Bases

- Store acids and bases separately.
- Store in dedicated corrosive cabinets.
- Store oxidizing acids (eg. nitric acid) away from organic acids (e.g. acetic acid).
- Store hydrofluoric and perchloric acids in secondary containers made from compatible materials.
- Safety showers and eye wash facilities must be within easy access.
- Protective equipment must be inspected regularly to insure proper working order, especially in corrosive atmospheres.

v. Reactive Chemicals

- Store in cool, dry area away from normal work areas and protected from shock, vibration, incompatible chemicals, elevated temperatures, and rapid temperature changes
- Store as required according to the nature of their individual hazards e.g. metal hydrides; some hydrogenation catalysts; picric acid; dinitrophenol; trinitrotoluene
- For air reactive chemicals use a glove box or fill the head space of the container with an inert gas before sealing the container.
- Water sensitive chemicals
    - Store in cool, dry areas designed to prevent accidental contact with water and other incompatible substances.
    - Storage construction should be fire-resistant.
    - Protect chemicals from water from sprinkler systems.
- Secondary containment is recommended.

vi. Oxidizers and Peroxidizable Compounds

Store oxidizers separate from flammable or combustible materials and reducing agents
e.g. nitrates; chromates; permanganates; chlorates; peroxides

All peroxidizable compounds should be stored away from heat and light (which catalyse the peroxidation reaction) and reducing agents, and protected from physical damage and ignition sources.

An inventory of all peroxidizable material is required. These substances must be inspected and tested for peroxides regularly after the container is opened. A simple test procedure for detection of peroxides in substances such as alkali metals, alkali metal alkoxides, amides or organometallics is not available.

VII. Chemical Laboratory Emergency Response

7.1 Introduction

Report all incidents, accidents and hazardous conditions to your supervisor and to the Department of Risk Management Services Use the Incident/Accident Report Forms to report all fires, injuries, chemical exposures and spills.

All buildings/ departments at Taibah University must have

- a local safety committee
- an emergency response plan
- a posted emergency evacuation plan
- an emergency meeting location
- a building emergency director
- floor wardens for each floor or area
- first aid as required by Taibah University

Emergency Procedures must be posted in the workplace at appropriate sites such as next to the elevator, entrances to stairwells and in areas where hazardous materials, equipment or processes are located. Emergency procedures should include response measures for responding to fires, explosions, first aid and life-threatening injuries, and hazardous materials exposures and spills.

7.2 Fire Safety Procedures

Where fire is involved, the procedure is to:

- Activate the fire alarm, alert others, and move everyone away from the area of the fire, closing doors behind you.
- Use the stairway, proceeding down to the ground floor, never up. Never use elevators if fire is suspected.
- Use a fire extinguisher only if it is safe, i.e. there is a means of exiting if the fire cannot be controlled; or leave area.
- Use the stairway, proceeding down to the ground floor, never up. Never use elevators if fire is suspected.
- Return to workplace only when authorized by fire warden or fire safety director.
- Once outside, proceed to the predetermined area so that a head count can be taken. Find out the location of your predetermined area before a fire occurs

i. General Guidelines for Buildings

Work and storage areas must be kept clean and free of accumulations of combustibles not essential to operations. Access to buildings must be maintained for fire fighters.

A fire safety emergency and evacuation plan and procedures must be developed.
a) The plan will include:

- sounding the alarm
- notifying the fire department
- instructing personnel on procedures to follow
- when alarm sounds, confine/control and extinguish fire if safe, evacuate building.
- scheduling of fire drills and inspections.

b) Fire exit rules include:
- Access to exits and exits must be kept clear.
- Corridors and stairwells must be kept free of obstructions and combustibles.
- Fire doors must not be wedged open.
- Some labs have 2 exits - know their location.

i. Fire Extinguishment
Portable extinguishers must be provided and maintained. Occupants should know:
- Where they are;
- How to use them – consider taking a hands-on fire extinguisher training course from the local fire department;
- Not to block access to them – do not use them for hanging lab coats; and

It is important that the appropriate fire extinguisher be used on a particular fire. The table below describes the 4 different types of extinguishers and the types of fires they are meant for.

Class	Type of Fire
A	Ordinary combustibles: wood, cloth, paper, rubber, many plastics
B	Flammable liquids: e.g. gasoline, oil, grease, tar, oil-based paint, lacquer
C	Live electrical equipment
D	Combustible metals

7.3 Treatment of Injuries

In the event of personal injury, the treatment of the injury must take precedence.
- For minor injures when first aid is required contact your local/departmental first aid attendant

7.4 Spill Clean-Up Procedures
There are various steps that laboratory personnel can take in the event of a laboratory spill. The laboratory worker may be able to respond to a small contained lab spill.
Laboratory workers should never put themselves in harms way. If there is any doubt about the safety of the individual in the lab.
It is essential to know what chemicals are involved, the quantity of the spill, and the exact location of the spill. The safety of everyone in the laboratory and everyone else in the building is foremost important
In order to place your laboratory in a position to be able to handle a small spill, preplanning is necessary. Laboratories must have a minimum amount of personal protective equipment (PPE) and appropriate clean-up materials present prior to an incident. The minimum PPE needed includes:
a. goggles
b. lab coats
c. rubber booties
d. a spill cart

7.5 Safety Showers and Eye Wash Stations

Emergency showers and eye washes should be available to all laboratory personnel who work with large quantities of hazardous materials. Plant Operations personnel are responsible for the annual testing of showers.
Laboratory supervisors are responsible for ensuring that eye washes are flushed weekly to clear them of particulate that could damage eyes during emergency use.
Safety showers provide an effective means of treatment in the event that chemicals are spilled or splashed onto the skin or clothing. Safety shower facilities should be installed wherever corrosive chemicals are used (e.g. acids or alkalis) and must be readily available to all personnel.
Safety showers should be in a clearly marked location. The facility should be no more than 100 feet, or 10 seconds, away from every lab work bench. Laboratory workers should be able to locate the shower(s) with their eyes closed (emergency situations may leave victims temporarily blind). Safety showers are operated by grasping a ring chain or triangular rod.

VIII. Equipment Safety

It is vital that laboratory personnel understand how to correctly and safely use the apparatus that is needed in any given experiment. This includes the use of basic types of glassware, distillation, filtration and low pressure apparatus as well as more expensive and sophisticated instruments such as gas and liquid chromatographs and spectrometers. Laboratory equipment that presents a physical hazard to workers must be adequately safeguarded, shielded, or isolated by location.

Awareness of potential hazards in the use of all types of equipment must be recognized and the appropriate procedures in place. This includes emergency procedures for responding to utility shutdowns and interruptions requiring evacuation. Equipment must be properly maintained in order for it to operate safely and correctly. Broken or chipped glassware or leaking hoses should not be used, especially with low pressure systems.
Written procedures are required wherever the equipment, process or materials used are potentially hazardous.

A log book should be used for all potentially hazardous equipment. Advise co-workers of potential hazards. Post emergency procedures with name and phone number of contact person. Prior to the start of all new projects, tasks, or processes, a hazard assessment should be done.

IX. Safe Experiment Design

9.1 Introduction

A comprehensive experimental design process is an essential step in running safe laboratory operation. This process should review the potential hazards associated with each experiment over its life cycle. It is instrumental in maintaining safe laboratory operations, minimizing exposure to potential hazards, minimizing waste generation and ensuring regulatory compliance.

In this process, the whole range of experimental steps should be considered. From the development of clear experiment goals and objectives, through acquisition, setup and handling of materials and equipment, detailed assessment of chemicals and reactions, all the way to storage and disposal practices, each step should be examined to determine safety issues and environmental concerns.

Detailed information related to potential hazards identified and safety measures to be implemented should be incorporated to the experimental protocol and be an integral part of it!

9.2 Responsibility

Principal Investigators and supervisors are responsible for ensuring that effective pre-experiment review is implemented for each laboratory protocol prepared by a lab worker.

9.3 Procedure

1. State the goals and objectives of your experiment
2. Consider and state all the fundamental steps of the experiment
3. Perform hazard assessment for each step of the experiment or process.

   Consider the following elements:

i) Hazard evaluation of materials and chemicals to be used:
Complete hazard assessment for all materials and products associated with experiment. If risks are determined to be unacceptable, redesign the experiment, minimize quantities, reduce concentrations, reduce volume or use less hazardous chemical alternatives. Consider the chemical amount, volume, flow rate, physical properties, and the potential for exposure. Address emergency response for unexpected events. Special attention should be given to new materials produced whose physical properties and toxicity are unknown.

ii) Management of chemicals and equipment:

Include provisions for acquiring and storing chemical reagents and equipment, proper equipment set up, handling and operation, inventory management, source reduction, material sharing, monitoring of reactive chemicals, compound shelf life, and storage incompatibility. Consider the potential impact of loss of air, water or power, on your experiment. Assess additional equipment hazard (noise, radiation, electrical hazard, ergonomics).

iii) Working with chemicals:

Include steps such as sample preparation, equipment assembly and commissioning, equipment startup and calibration, product isolation and characterization, storage and disposal of materials after work is completed. Special consideration should be given to planning unattended operations, introduction of new equipment, and significant process scale up.

iv) Types of reactions:

Know the chemistry of your reactions. Be prepared for exothermic reactions, runaway reactions, bumping, pressure build up, generation of hazardous gases or interaction between incompatible materials. Know the physical conditions required for the reaction (e.g. high pressure, vacuum, extremely cold temperature, high temperature, high voltage) and conditions that may develop over the course of the reaction. Consider the potential associated hazards.

v) Equipment, area cleaning and decontamination:
Develop a procedure for equipment and area decontamination. Make sure you are using the proper decontamination procedures and cleaning materials and know how to properly dispose of any residue or waste. Special caution should be taken with reactive materials (air/moisture/water reactive) and when cleaning with solvents. Review compatibility information of cleaning and decontamination agents.

vi) Proper disposal and deactivation procedures:

Consider waste minimization and recycling of materials. Evaluate the properties of all waste products to be generated by the experiment and develop written disposal instructions for each waste stream. Consider the amount and frequency of waste generated and methods to neutralize the waste or render it non-hazardous. Have a procedure in place to deal with unstable waste or wastes that require special storage and handling. Review the compatibility of materials being accumulated. Minimize the generation of multi-hazard waste. Minimize the release of hazardous chemicals to the environment. Do not use the fume hood to dispose of volatile hazardous materials (use filters, scrubbers or other control equipment). Do not discharge hazardous chemicals into the sewer system.

vii) Provide a contingency plan to deal with the unexpected:

Be prepared for emergencies. Include information regarding emergency response in each procedure: the location and type of spill control equipment and materials; the location and type of fire extinguisher required (D type for combustible metals) the type and location of antidotes to special hazardous chemicals (HF, cyanide)

viii) Laboratory facilities:
Assess the area proposed for the experiment. Identify any potential hazards. Consider the location of equipment relative to the location of emergency response facilities. Work with hazardous materials should be carried out in the fume hood, glove box or biosafety cabinets. Special needs for bench space, ventilation or shielding may affect experimental planning and should be stated.

ix) Personal protective equipment (PPE) and industrial hygiene monitoring:

Review the need for PPE and determine the type of PPE required for each step of the experiment. Incorporate this information to your protocol. Work with certain materials may require industrial hygiene monitoring or a special occupational health review.

X. Laboratory Inspections

At Taibah University University, various individuals, groups, and regulatory agencies conduct inspections. Safety Committees Services also conduct annual inspections of fire extinguishers and other fire-safety issues such as storage of flammable liquids and condition of fire exits.

Taibah University General requirements state that:

Every employer must ensure that regular inspections are made of all workplaces, including buildings, equipment, work methods and practices, at intervals that will prevent the development of unsafe working conditions.

Any deficiencies found during regular inspection by committee members should be reported immediately to the supervisor. If corrective action is not taken to the satisfaction of the committee, the item should be included on the agenda for consideration at the next meeting.

X. Laboratory Biosafety

11.1. Introduction

Throughout this manual, references are made to the relative hazards of infective microorganisms by risk group (WHO Risk Groups 1, 2, 3 and 4). **This risk group classification is to be used for laboratory work only.** Table 1 describes the risk groups.

*Table 1. **Classification of infective microorganisms by risk group***

Risk Group 1 *(no or low individual and community risk)*
A microorganism that is unlikely to cause human or animal disease.

Risk Group 2 *(moderate individual risk, low community risk)*
A pathogen that can cause human or animal disease but is unlikely to be a serious hazard to laboratory workers, the community, livestock or the environment. Laboratory exposures may cause serious infection, but effective treatment and preventive measures are available and the risk of spread of infection is limited.

Risk Group 3 *(high individual risk, low community risk)*
A pathogen that usually causes serious human or animal disease but does not ordinarily spread from one infected individual to another. Effective treatment and preventive measures are available.

Risk Group 4 *(high individual and community risk)*
A pathogen that usually causes serious human or animal disease and that can be readily transmitted from one individual to another, directly or indirectly. Effective treatment and preventive measures are not usually available.

Laboratory facilities are designated as basic – Biosafety Level 1, basic – Biosafety Level 2, containment – Biosafety Level 3, and maximum containment – Biosafety Level 4. Biosafety level designations are based on a composite of the design features, construction, containment facilities, equipment, practices and operational procedures required for working with agents from the various risk groups. Table 2 relates but **does not "equate"** risk groups to the biosafety level of laboratories designed to work with organisms in each risk group.

Countries (regions) should draw up a national (regional) classification of microorganisms, by risk group, taking into account:

Table 2. ***Relation of risk groups to biosafety levels, practices and equipment***

RISK GROUP	BIOSAFETY LEVEL	LABORATORY TYPE	LABORATORY PRACTICES	SAFETY EQUIPMENT
1	Basic – Biosafety Level 1	Basic teaching, research	GMT	None; open bench work
2	Basic – Biosafety Level 2	Primary health services; diagnostic services, research	GMT plus protective clothing, biohazard sign	Open bench plus BSC for potential aerosols
3	Containment – Biosafety Level 3	Special diagnostic services, research	As Level 2 plus special clothing, controlled access, directional airflow	BSC and/or other primary devices for all activities
4	Maximum containment – Biosafety Level 4	Dangerous pathogen units	As Level 3 plus airlock entry, shower exit, special waste disposal	Class III BSC, or positive pressure suits in conjunction with Class II BSCs, double-ended autoclave (through the wall), filtered air

BSC, biological safety cabinet; GMT, good microbiological techniques (see Part IV of this manual)

1. Pathogenicity of the organism.
2. Mode of transmission and host range of the organism. These may be influenced by existing levels of immunity in the local population, density and movement of the host population, presence of appropriate vectors, and standards of environ-mental hygiene.
3. Local availability of effective preventive measures. These may include: prophylaxis by immunization or administration of antisera (passive immunization); sanitary measures, e.g. food and water hygiene; control of animal reservoirs or arthropod vectors.
4. Local availability of effective treatment. This includes passive immunization, postexposure vaccination and use of antimicrobials, antivirals and chemo-therapeutic agents, and should take into consideration the possibility of the emergence of drug-resistant strains.

The assignment of an agent to a biosafety level for laboratory work must be based on a risk assessment. Such an assessment will take the risk group as well as other factors into consideration in establishing the appropriate biosafety level. For example, an agent that is assigned to Risk Group 2 may generally require Biosafety Level 2 facilities, equipment, practices and procedures for safe conduct of work. However, if particular experiments require the generation of high-concentration aerosols, then Biosafety

*Table 3. **Summary of biosafety level requirements***

	BIOSAFETY LEVEL			
	1	**2**	**3**	**4**
Isolation[a] of laboratory	No	No	Yes	Yes
Room sealable for decontamination	No	No	Yes	Yes
Ventilation:				
— inward airflow	No	Desirable	Yes	Yes
— controlled ventilating system	No	Desirable	Yes	Yes
— HEPA-filtered air exhaust	No	No	Yes/No[b]	Yes
Double-door entry	No	No	Yes	Yes
Airlock	No	No	No	Yes
Airlock with shower	No	No	No	Yes
Anteroom	No	No	Yes	—
Anteroom with shower	No	No	Yes/No[c]	No
Effluent treatment	No	No	Yes/No[c]	Yes
Autoclave:				
— on site	No	Desirable	Yes	Yes
— in laboratory room	No	No	Desirable	Yes
— double-ended	No	No	Desirable	Yes
Biological safety cabinets	No	Desirable	Yes	Yes
Personnel safety monitoring capability[d]	No	No	Desirable	Yes

[a] Environmental and functional isolation from general traffic. [b] Dependent on location of exhaust (see Chapter 4).
[c] Dependent on agent(s) used in the laboratory.
[d] For example, window, closed-circuit television, two-way communication.

Thus, the assignment of a biosafety level takes into consideration the organism (pathogenic agent) used, the facilities available, and the equipment practices and procedures required to conduct work safely in the laboratory.

11.2. Microbiological risk assessment

The backbone of the practice of biosafety is risk assessment. While there are many tools available to assist in the assessment of risk for a given procedure or experiment, the most important component is professional judgement. Risk assessments should be performed by the individuals most familiar with the specific characteristics of the organisms being considered for use, the equipment and procedures to be employed, animal models that may be used, and the containment equipment and facilities available. The laboratory director or principal investigator is responsible for ensuring that adequate and timely risk assessments are performed, and for working closely with the institution's safety committee and biosafety personnel to ensure that appropriate equipment and facilities are available to support the work being considered. Once performed, risk assessments should be reviewed routinely and revised when necessary, taking into consideration the acquisition of new data having a bearing on the degree of risk and other relevant new information from the scientific literature.

One of the most helpful tools available for performing a microbiological risk assessment is the listing of risk groups for microbiological agents. However, simple reference to the risk grouping for a particular agent is insufficient in the conduct of a risk assessment. Other factors that should be considered, as appropriate, include:

1. Pathogenicity of the agent and infectious dose
2. Potential outcome of exposure
3. Natural route of infection
4. Other routes of infection, resulting from laboratory manipulations (parenteral, airborne, ingestion)
5. Stability of the agent in the environment
6. Concentration of the agent and volume of concentrated material to be manipulated
7. Presence of a suitable host (human or animal)
8. Information available from animal studies and reports of laboratory-acquired infections or clinical reports
9. Laboratory activity planned (sonication, aerosolization, centrifugation, etc.).

10. Any genetic manipulation of the organism that may extend the host range of the agent or alter the agent's sensitivity to known, effective treatment regimens
Local availability of effective prophylaxis or therapeutic intervention
On the basis of the information ascertained during the risk assessment, a biosafety level can be assigned to the planned work, appropriate personal protective equipment selected, and standard operating procedures (SOPs) incorporating other safety interventions developed to ensure the safest possible conduct of the work.

Specimens for which there is limited information

The risk assessment procedure described above works well when there is adequate information available. However, there are situations when the information is insufficient to perform an appropriate risk assessment, for example, with clinical specimens or epidemiological samples collected in the field. In these cases, it is prudent to take a cautious approach to specimen manipulation.

1. Standard precautions (*2*) should always be followed, and barrier protections applied (gloves, gowns, eye protection), whenever samples are obtained from patients.
2. Basic containment – Biosafety Level 2 practices and procedures should be the minimum requirement for handling specimens.
3. Transport of specimens should follow national and/or international rules and regulations.

Some information may be available to assist in determining the risk of handling these specimens:

1. Medical data on the patient
2. Epidemiological data (morbidity and mortality data, suspected route of trans-mission, other outbreak investigation data)
3. Information on the geographical origin of the specimen.

In the case of outbreaks of disease of unknown etiology, appropriate ad hoc guidelines may be generated and posted by national competent authorities and/or WHO on the World Wide Web (as was the case during the 2003 emergence of the severe acute respiratory syndrome (SARS)) to indicate how specimens should be consigned for shipment and the biosafety level at which they should be analysed.

11.3. Basic laboratories –Biosafety Levels 1 and 2

For the purposes of this manual, the guidance and recommendations given as minimum requirements pertaining to laboratories of all biosafety levels are directed at microorganisms in Risk Groups 1–4. Although some of the precautions may appear to be unnecessary for some organisms in Risk Group 1, they are desirable for training purposes to promote good (i.e. safe) microbiological techniques (GMT).

Diagnostic and health-care laboratories (public health, clinical or hospital-based) must all be designed for Biosafety Level 2 or above. As no laboratory has complete control over the specimens it receives, laboratory workers may be exposed to organisms in higher risk groups than anticipated. This possibility must be recognized in the development of safety plans and policies. In some countries, accreditation of clinical laboratories is required. Globally, standard precautions (*2*) should always be adopted and practised.

The guidelines for basic laboratories – Biosafety Levels 1 and 2 presented here are comprehensive and detailed, as they are fundamental to laboratories of all biosafety levels. The guidelines for containment laboratories – Biosafety Level 3 and maximum containment laboratories – Biosafety Level 4 that follow (Chapters 4 and 5) are modifications of and additions to these guidelines, designed for work with the more dangerous (hazardous) pathogens.

Code of practice

This code is a listing of the most essential laboratory practices and procedures that are basic to GMT. In many laboratories and national laboratory programmes, this code may be used to develop written practices and procedures for safe laboratory operations.

Each laboratory should adopt a safety or operations manual that identifies known and potential hazards, and specifies practices and procedures to eliminate or minimize such hazards. GMT are fundamental to laboratory safety. Specialized laboratory equipment is a supplement to but can never replace appropriate procedures. The most important concepts are listed below.

Access

1. The international biohazard warning symbol and sign (Figure 1) must be displayed on the doors of the rooms where microorganisms of Risk Group 2 or higher risk groups are handled.
2. Only authorized persons should be allowed to enter the laboratory working areas.
3. Laboratory doors should be kept closed.
4. Children should not be authorized or allowed to enter laboratory working areas.
5. Access to animal houses should be specially authorized.
6. No animals should be admitted other than those involved in the work of the laboratory.

Personal protection

1. Laboratory coveralls, gowns or uniforms must be worn at all times for work in the laboratory.
2. Appropriate gloves must be worn for all procedures that may involve direct or accidental contact with blood, body fluids and other potentially infectious materials or infected animals. After use, gloves should be removed aseptically and hands must then be washed.

Personnel must wash their hands after handling infectious materials and animals, and before they leave the laboratory working area.

4. Safety glasses, face shields (visors) or other protective devices must be worn when it is necessary to protect the eyes and face from splashes, impacting objects and sources of artificial ultraviolet radiation.
5. It is prohibited to wear protective laboratory clothing outside the laboratory, e.g. in canteens, coffee rooms, offices, libraries, staff rooms and toilets.
6. Open-toed footwear must not be worn in laboratories.
7. Eating, drinking, smoking, applying cosmetics and handling contact lenses is prohibited in the laboratory working areas.
8. Storing human foods or drinks anywhere in the laboratory working areas is prohibited.
9. Protective laboratory clothing that has been used in the laboratory must not be stored in the same lockers or cupboards as street clothing.

Procedures

1. Pipetting by mouth must be strictly forbidden.
2. Materials must not be placed in the mouth. Labels must not be licked.
3. All technical procedures should be performed in a way that minimizes the formation of aerosols and droplets.
4. The use of hypodermic needles and syringes should be limited. They must not be used as substitutes for pipetting devices or for any purpose other than parenteral injection or aspiration of fluids from laboratory animals.
5. All spills, accidents and overt or potential exposures to infectious materials must be reported to the laboratory supervisor. A written record of such accidents and incidents should be maintained.
6. A written procedure for the clean-up of all spills must be developed and followed.
7. Contaminated liquids must be decontaminated (chemically or physically) before discharge to the sanitary sewer. An effluent treatment system may be required, depending on the risk assessment for the agent(s) being handled.
8. Written documents that are expected to be removed from the laboratory need to be protected from contamination while in the laboratory.

Laboratory working areas

1. The laboratory should be kept neat, clean and free of materials that are not pertinent to the work.
2. Work surfaces must be decontaminated after any spill of potentially dangerous material and at the end of the working day.
3. All contaminated materials, specimens and cultures must be decontaminated before disposal or cleaning for reuse.
4. Packing and transportation must follow applicable national and/or international regulations.

When windows can be opened, they should be fitted with arthropod-proof screens.

Biosafety management

1. It is the responsibility of the laboratory director (the person who has immediate responsibility for the laboratory) to ensure the development and adoption of a biosafety management plan and a safety or operations manual.
2. The laboratory supervisor (reporting to the laboratory director) should ensure that regular training in laboratory safety is provided.
3. Personnel should be advised of special hazards, and required to read the safety or operations manual and follow standard practices and procedures. The laboratory supervisor should make sure that all personnel understand these. A copy of the safety or operations manual should be available in the laboratory.
4. There should be an arthropod and rodent control programme.
5. Appropriate medical evaluation, surveillance and treatment should be provided for all personnel in case of need, and adequate medical records should be maintained.

Laboratory design and facilities

In designing a laboratory and assigning certain types of work to it, special attention should be paid to conditions that are known to pose safety problems. These include:

1. Formation of aerosols
2. Work with large volumes and/or high concentrations of microorganisms
3. Overcrowding and too much equipment
4. Infestation with rodents and arthropods
5. Unauthorized entrance
6. Workflow: use of specific samples and reagents.

Design features

1. Ample space must be provided for the safe conduct of laboratory work and for cleaning and maintenance.
2. Walls, ceilings and floors should be smooth, easy to clean, impermeable to liquids and resistant to the chemicals and disinfectants normally used in the laboratory. Floors should be slip-resistant.
3. Bench tops should be impervious to water and resistant to disinfectants, acids, alkalis, organic solvents and moderate heat.
4. Illumination should be adequate for all activities. Undesirable reflections and glare should be avoided.
5. Laboratory furniture should be sturdy. Open spaces between and under benches, cabinets and equipment should be accessible for cleaning.
6. Storage space must be adequate to hold supplies for immediate use and thus prevent clutter on bench tops and in aisles. Additional long-term storage space, conveniently located outside the laboratory working areas, should also be provided.
7. Space and facilities should be provided for the safe handling and storage of solvents, radioactive materials, and compressed and liquefied gases.
8. Facilities for storing outer garments and personal items should be provided outside the laboratory working areas.
9. Facilities for eating and drinking and for rest should be provided outside the laboratory working areas.
10. Hand-washing basins, with running water if possible, should be provided in each laboratory room, preferably near the exit door.
11. Doors should have vision panels, appropriate fire ratings, and preferably be self-closing.
12. At Biosafety Level 2, an autoclave or other means of decontamination should be available in appropriate proximity to the laboratory.
13. Safety systems should cover fire, electrical emergencies, emergency shower and eyewash facilities.
14. First-aid areas or rooms suitably equipped and readily accessible should be available

15. In the planning of new facilities, consideration should be given to the provision of mechanical ventilation systems that provide an inward flow of air without recirculation. If there is no mechanical ventilation, windows should be able to be opened and should be fitted with arthropod-proof screens.

16. A dependable supply of good quality water is essential. There should be no cross-connections between sources of laboratory and drinking-water supplies. An anti-backflow device should be fitted to protect the public water system.

17. There should be a reliable and adequate electricity supply and emergency lighting to permit safe exit. A stand-by generator is desirable for the support of essential equipment, such as incubators, biological safety cabinets, freezers, etc., and for the ventilation of animal cages.

18. There should be a reliable and adequate supply of gas. Good maintenance of the installation is mandatory.

Laboratories and animal houses are occasionally the targets of vandals. Physical and fire security must be considered. Strong doors, screened windows and restricted issue of keys are compulsory. Other measures should be considered and applied, as appropriate, to augment security

Laboratory equipment

Together with good procedures and practices, the use of safety equipment will help to reduce risks when dealing with biosafety hazards. This section deals with basic principles related to equipment suitable for laboratories of all biosafety levels. Requirements for laboratory equipment pertinent to higher biosafety levels are dealt with in the relevant chapters.

The laboratory director should, after consultation with the biosafety officer and safety committee (if designated), ensure that adequate equipment is provided and that it is used properly. Equipment should be selected to take account of certain general principles, i.e. it should be:

1. Designed to prevent or limit contact between the operator and the infectious material
2. Constructed of materials that are impermeable to liquids, resistant to corrosion and meet structural requirements
3. Fabricated to be free of burrs, sharp edges and unguarded moving parts
4. Designed, constructed and installed to facilitate simple operation and provide for ease of maintenance, cleaning, decontamination and certification testing; glassware and other breakable materials should be avoided, whenever possible.

Detailed performance and construction specifications may need to be consulted to ensure that the equipment possesses the necessary safety features.

Essential biosafety equipment

1. Pipetting aids – to avoid mouth pipetting. Many different designs are available.
2. Biological safety cabinets, to be used whenever:
   - infectious materials are handled; such materials may be centrifuged in the open laboratory if sealed centrifuge safety cups are used and if they are loaded and unloaded in a biological safety cabinet

— there is an increased risk of airborne infection

— procedures with a high potential for producing aerosols are used; these may include centrifugation, grinding, blending, vigorous shaking or mixing, sonic disruption, opening of containers of infectious materials whose internal pressure may be different from the ambient pressure, intranasal inoculation of animals, and harvesting of infectious tissues from animals and eggs.

3. Plastic disposable transfer loops. Alternatively, electric transfer loop incinerators may be used inside the biological safety cabinet to reduce aerosol production
4. Screw-capped tubes and bottles.
5. Autoclaves or other appropriate means to decontaminate infectious materials.
6. Plastic disposable Pasteur pipettes, whenever available, to avoid glass.
7. Equipment such as autoclaves and biological safety cabinets must be validated with appropriate methods before being taken into use. Recertification should take place at regular intervals, according to the manufacturer's instructions.

Health and medical surveillance

The employing authority, through the laboratory director, is responsible for ensuring that there is adequate surveillance of the health of laboratory personnel. The objective of such surveillance is to monitor for occupationally acquired diseases. Appropriate activities to achieve these objectives are:

1. Provision of active or passive immunization where indicated
2. Facilitation of the early detection of laboratory-acquired infections
3. Exclusion of highly susceptible individuals (e.g. pregnant women or immuno-compromised individuals) from highly hazardous laboratory work
4. Provision of effective personal protective equipment and procedures.

Guidelines for the surveillance of laboratory workers handling microorganisms at Biosafety Level 1

Historical evidence indicates that the microorganisms handled at this level are unlikely to cause human disease or animal disease of veterinary importance. Ideally, however, all laboratory workers should undergo a pre-employment health check at which their medical history is recorded. Prompt reporting of illnesses or laboratory accidents is desirable and all staff members should be made aware of the importance of maintaining GMT.

Guidelines for the surveillance of laboratory workers handling microorganisms at Biosafety Level 2

1. A pre-employment or preplacement health check is necessary. The person's medical history should be recorded and a targeted occupational health assessment performed.
2. Records of illness and absence should be kept by the laboratory management.
3. Women of childbearing age should be made aware of the risk to an unborn child of occupational exposure to certain microorganisms, e.g. rubella virus. The precise steps taken to protect the fetus will vary, depending on the microorganisms to which the women may be exposed.

Training

Human error and poor technique can compromise the best of safeguards to protect the laboratory worker. Thus, a safety-conscious staff, well informed about the recognition and control of laboratory hazards, is key to the prevention of laboratory

acquired infections, incidents and accidents. For this reason, continuous in-service training in safety measures is essential. An effective safety programme begins with the laboratory managers, who should ensure that safe laboratory practices and procedures are integrated into the basic training of employees. Training in safety measures should be an integral part of new employees' introduction to the laboratory. Employees should be introduced to the code of practice and to local guidelines, including the safety or operations manual. Measures to assure that employees have read and understood the guidelines, such as signature pages, should be adopted. Laboratory supervisors play the key role in training their immediate staff in good laboratory techniques. The biosafety officer can assist in training and with the development of training aids and documentation.

Staff training should always include information on safe methods for highly hazardous procedures that are commonly encountered by all laboratory personnel and which involve:

1. Inhalation risks (i.e. aerosol production) when using loops, streaking agar plates, pipetting, making smears, opening cultures, taking blood/serum samples, centrifuging, etc.
2. Ingestion risks when handling specimens, smears and cultures
3. Risks of percutaneous exposures when using syringes and needles
4. Bites and scratches when handling animals
5. Handling of blood and other potentially hazardous pathological materials
6. Decontamination and disposal of infectious material.

Waste handling

Waste is anything that is to be discarded.

In laboratories, decontamination of wastes and their ultimate disposal are closely interrelated. In terms of daily use, few if any contaminated materials will require actual removal from the laboratory or destruction. Most glassware, instruments and laboratory clothing will be reused or recycled. The overriding principle is that all infectious materials should be decontaminated, autoclaved or incinerated within the laboratory.

The principal questions to be asked before discharge of any objects or materials from laboratories that deal with potentially infectious microorganisms or animal tissues are:

1. Have the objects or materials been effectively decontaminated or disinfected by an approved procedure?
2. If not, have they been packaged in an approved manner for immediate on-site incineration or transfer to another facility with incineration capacity?

Does the disposal of the decontaminated objects or materials involve any additional potential hazards, biological or otherwise, to those who carry out the immediate disposal procedures or who might come into contact with discarded items outside the facility?

Decontamination

Steam autoclaving is the preferred method for all decontamination processes. Materials for decontamination and disposal should be placed in containers, e.g. autoclavable plastic bags, that are colour-coded according to whether the contents are to be autoclaved and/or incinerated. Alternative methods may be envisaged only if they remove and/or kill microorganisms.

Handling and disposal procedures for contaminated materials and wastes

An identification and separation system for infectious materials and their containers should be adopted. National and international regulations must be followed. Categories should include:

1. Non-contaminated (non-infectious) waste that can be reused or recycled or disposed of as general, "household" waste
2. Contaminated (infectious) "sharps" – hypodermic needles, scalpels, knives and broken glass; these should always be collected in puncture-proof containers fitted with covers and treated as infectious
3. Contaminated material for decontamination by autoclaving and thereafter washing and reuse or recycling
4. Contaminated material for autoclaving and disposal
5. Contaminated material for direct incineration.

Sharps

After use, hypodermic needles should not be recapped, clipped or removed from disposable syringes. The complete assembly should be placed in a sharps disposal container. Disposable syringes, used alone or with needles, should be placed in sharps disposal containers and incinerated, with prior autoclaving if required.

Sharps disposal containers must be puncture-proof/-resistant and must not be filled to capacity. When they are three-quarters full they should be placed in "infectious waste" containers and incinerated, with prior autoclaving if laboratory practice requires it. Sharps disposal containers must not be discarded in landfills.

Contaminated (potentially infectious) materials for autoclaving and reuse

No precleaning should be attempted of any contaminated (potentially infectious) materials to be autoclaved and reused. Any necessary cleaning or repair must be done only after autoclaving or disinfection.

Contaminated (potentially infectious) materials for disposal

Apart from sharps, which are dealt with above, all contaminated (potentially infectious) materials should be autoclaved in leakproof containers, e.g. autoclavable, colour-coded plastic bags, before disposal. After autoclaving, the material may be placed in transfer containers for transport to the incinerator. If possible, materials deriving from health-care activities should not be discarded in landfills even after decontamination

11.4. Laboratory animal facilities

Those who use animals for experimental and diagnostic purposes have a moral obligation to take every care to avoid causing them unnecessary pain or suffering. The animals must be provided with comfortable, hygienic housing and adequate wholesome food and water. At the end of the experiment they must be dealt with in a humane manner.

For security reasons, the animal house should be an independent, detached unit. If it adjoins a laboratory, the design should provide for its isolation from the public parts of the laboratory should such need arise, and for its decontamination and disinfestation.

Table 4. ***Animal facility containment levels: summary of practices and safety equipment***

RISK GROUP	CONTAINMENT LEVEL	LABORATORY PRACTICES AND SAFETY EQUIPMENT
1	ABSL-1	Limited access, protective clothing and gloves.
2	ABSL-2	ABSL-1 practices plus: hazard warning signs. Class I or II BSCs for activities that produce aerosols. Decontamination of waste and cages before washing.
3	ABSL-3	ABSL-2 practices plus: controlled access. BSCs and special protective clothing for all activities.
4	ABSL-4	ABSL-3 plus: strictly limited access. Clothing change before entering. Class III BSCs or positive pressure suits. Shower on exit.

ABSL, animal facility Biosafety Level; BSCs, biological safety cabinets

Animal facilities, like laboratories, may be designated according to a risk assessment and the risk group of the microorganisms under investigation, as Animal facility Biosafety Level 1, 2, 3 or 4.

With respect to agents to be used in the animal laboratory, factors for consideration include:

1. The normal route of transmission
2. The volumes and concentrations to be used
3. The route of inoculation
4. Whether and by what route these agents may be excreted.

With respect to animals to be used in the animal laboratory, factors for consideration include:

1. The nature of the animals, i.e. their aggressiveness and tendency to bite and scratch
2. Their natural ecto- and endoparasites
3. The zoonotic diseases to which they are susceptible
4. The possible dissemination of allergens.

As with laboratories, the requirements for design features, equipment and precautions increase in stringency according to the animal biosafety level. These are described below and summarized in Table 4. These guidelines are additive, so that each higher level incorporates the standards of the lower levels.

Animal facility – Biosafety Level 1

This is suitable for the maintenance of most stock animals after quarantine (except nonhuman primates, regarding which national authorities should be consulted), and for animals that are deliberately inoculated with agents in Risk Group 1. GMT are required. The animal facility director must establish policies, procedures and protocols for all operations, and for access to the vivarium. An appropriate medical surveillance programme for the staff must be instituted. A safety or operations manual must be prepared and adopted.

Animal facility – Biosafety Level 2

This is suitable for work with animals that are deliberately inoculated with micro-organisms in Risk Group 2. The following safety precautions apply:

1. All the requirements for animal facilities – Biosafety Level 1 must be met.
2. Biohazard warning signs should be posted on doors and other appropriate places.
3. The facility must be designed for easy cleaning and housekeeping.
4. Doors must open inwards and be self-closing.
5. Heating, ventilation and lighting must be adequate.
6. If mechanical ventilation is provided, the airflow must be inwards. Exhaust air is discharged to the outside and should not be recirculated to any part of the building.
7. Access must be restricted to authorized persons.
8. No animals should be admitted other than those for experimental use.
9. There should be an arthropod and rodent control programme.
10. Windows, if present, must be secure, resistant to breakage and, if able to be opened, must be fitted with arthropod-proof screens.

After use, work surfaces must be decontaminated with effective disinfectants

12. Biological safety cabinets (Classes I or II) or isolator cages with dedicated air supplies and HEPA-filtered exhaust air must be provided for work that may involve the generation of aerosols.
13. An autoclave must be available on site or in appropriate proximity to the animal facility.
14. Animal bedding materials must be removed in a manner that minimizes the generation of aerosols and dust.
15. All waste materials and bedding must be decontaminated before disposal.
16. Use of sharp instruments should be restricted whenever possible. Sharps should always be collected in puncture-proof/-resistant containers fitted with covers and treated as infectious.
17. Material for autoclaving or incineration must be transported safely, in closed containers.
18. Animal cages must be decontaminated after use.
19. Animal carcasses should be incinerated.
20. Protective clothing and equipment must be worn in the facility, and removed on leaving.
21. Hand-washing facilities must be provided. Staff must wash their hands before leaving the animal facility.

22. All injuries, however minor, must be treated appropriately, reported and recorded.

23. Eating, drinking, smoking and application of cosmetics must be forbidden in the facility.

24. All personnel must receive appropriate training.

Animal facility – Biosafety Level 3

This is suitable for work with animals that are deliberately inoculated with agents in Risk Group 3, or when otherwise indicated by a risk assessment. All systems, practices and procedures need to be reviewed and recertified annually. The following safety precautions apply:

1. All the requirements for animal facilities – Biosafety Levels 1 and 2 must be met.
2. Access must be strictly controlled.
3. The facility must be separated from other laboratory and animal house areas by a room with a double-door entrance forming an anteroom.
4. Hand-washing facilities must be provided in the anteroom.
5. Showers should be provided in the anteroom.
6. There must be mechanical ventilation to ensure a continuous airflow through all the rooms. Exhaust air must pass through HEPA filters before being discharged to the atmosphere without recirculation. The system must be designed to prevent accidental reverse flow and positive pressurization in any part of the animal house.

An autoclave must be available at a location convenient for the animal house where the biohazard is contained. Infectious waste should be autoclaved before it is moved to other areas of the facility

11.5. Biological safety cabinets

Biological safety cabinets (BSCs) are designed to protect the operator, the laboratory environment and work materials from exposure to infectious aerosols and splashes that may be generated when manipulating materials containing infectious agents, such as primary cultures, stocks and diagnostic specimens. Aerosol particles are created by any activity that imparts energy into a liquid or semiliquid material, such as shaking, pouring, stirring or dropping liquid onto a surface or into another liquid. Other laboratory activities, such as streaking agar plates, inoculating cell culture flasks with a pipette, using a multichannel pipette to dispense liquid suspensions of infectious agents into microculture plates, homogenizing and vortexing infectious materials, and centrifugation of infectious liquids, or working with animals, can generate infectious aerosols. Aerosol particles of less than 5 μm in diameter and small droplets of 5–100 μm in diameter are not visible to the naked eye. The laboratory worker is generally not aware that such particles are being generated and may be inhaled or may cross-contaminate work surface materials. BSCs, when properly used, have been shown to be highly effective in reducing laboratory-acquired infections and cross-contaminations of cultures due to aerosol exposures. BSCs also protect the environment.

Over the years the basic design of BSCs has undergone several modifications. A major change was the addition of a high-efficiency particulate air (HEPA) filter to the exhaust system. The HEPA filter traps 99.97% of particles of 0.3 μm in diameter and 99.99% of particles of greater or smaller size. This enables the HEPA filter to effectively trap all known infectious agents and ensure that only microbe-free exhaust air is discharged from the cabinet. A second design modification was to direct HEPA-filtered air over the work surface, providing protection of work surface materials from contamination. This feature is often referred to as product protection. These basic design concepts have led to the evolution of three classes of BSCs. The type of protection provided by each is set out in Table 3.

Note. Horizontal and vertical outflow cabinets ("clean-air work stations") are **not** biological safety cabinets and should not be used as such.

Table 4. ***Selection of a biological safety cabinet (BSC), by type of protection needed***

TYPE OF PROTECTION	BSC SELECTION
Personnel protection, microorganisms in Risk Groups 1–3	Class I, Class II, Class III
Personnel protection, microorganisms in Risk Group 4, glove-box laboratory	Class III
Personnel protection, microorganisms in Risk Group 4, suit laboratory	Class I, Class II
Product protection	Class II, Class III only if laminar flow included
Volatile radionuclide/chemical protection, minute amounts	Class IIB1, Class IIA2 vented to the outside
Volatile radionuclide/chemical protection	Class I, Class IIB2, Class III

Selection of a biological safety cabinet

A BSC should be selected primarily in accordance with the type of protection needed: product protection; personnel protection against Risk Group 1–4 microorganisms; personnel protection against exposure to radionuclides and volatile toxic chemicals; or a combination of these. Table 8 shows which BSCs are recommended for each type of protection.

Volatile or toxic chemicals should not be used in BSCs that recirculate exhaust air to the room, i.e. Class I BSCs that are not ducted to building exhaust systems, or Class IIA1 or Class IIA2 cabinets. Class IIB1 BSCs are acceptable for work with minute amounts of volatile chemicals and radionuclides. A Class IIB2 BSC, also called a total exhaust cabinet, is necessary when significant amounts of radionuclides and volatile chemicals are expected to be used.

XII. References

1. University of British Columbia Laboratory Chemical Safety Manual 2002
2. Canadian Centre for Occupational Health and Safety (CCOHS)
3. WorkSafe BC Laboratory Safety Hand Book
4. WorkSafe BC WHMIS Instructor's Manual
5. Transport Canada TDG Regulations
6. Prudent Practices in the Laboratory: Handling and Disposal of Chemicals (1995), National Research Council.
7. IARC Classifications of Carcinogenic Agents
8. NTP 11th Report on Carcinogens
9. WHO Laboratory Biosafety Manual