PART VI

Chemical, fire and electrical safety

17. Hazardous chemicals

Workers in microbiological laboratories are not only exposed to pathogenic microorganisms, but also to chemical hazards. It is important that they have proper knowledge of the toxic effects of these chemicals, the routes of exposure and the hazards that may be associated with handling and storage (see Annex 5). Material safety data sheets or other chemical hazard information are available from chemical manufacturers and/or suppliers. These should be accessible in laboratories where these chemicals are used, e.g. as part of a safety or operations manual.

Routes of exposure

Exposure to hazardous chemicals may occur by:

1. Inhalation
2. Contact
3. Ingestion
4. Needle-sticks
5. Through broken skin.

Storage of chemicals

Only amounts of chemicals necessary for daily use should be stored in the laboratory. Bulk stocks should be kept in specially designated rooms or buildings.

Chemicals should not be stored in alphabetical order.

General rules regarding chemical incompatibilities

To avoid fire and/or explosions, substances in the left-hand column of Table 13 should be stored and handled so that they cannot come into contact with the corresponding substances in the right-hand column of the table.

Toxic effects of chemicals

Some chemicals adversely affect the health of those who handle them or inhale their vapours. Apart from overt poisons, a number of chemicals are known to have various toxic effects. The respiratory system, blood, lungs, liver, kidneys and the gastrointestinal system, as well as other organs and tissues may be adversely affected or seriously damaged. Some chemicals are known to be carcinogenic or teratogenic.

Table 13. **General rules for chemical incompatibilities**

SUBSTANCE CATEGORY	INCOMPATIBLE SUBSTANCES
Alkali metals, e.g. sodium, potassium, caesium and lithium	Carbon dioxide, chlorinated hydrocarbons, water
Halogens	Ammonia, acetylene, hydrocarbons
Acetic acid, hydrogen sulfide, aniline, hydrocarbons, sulfuric acid	Oxidizing agents, e.g. chromic acid, nitric acid, peroxides, permanganates

Some solvent vapours are toxic when inhaled. Apart from the more serious effects noted above, exposure may result in impairments that show no immediate discernible effects on health, but can include lack of coordination, drowsiness and similar symptoms, leading to an increased proneness to accidents.

Prolonged or repeated exposure to the liquid phase of many organic solvents can result in skin damage. This may be due to a defatting effect, but allergic and corrosive symptoms may also arise.

For detailed information on the toxic effects of chemicals see Annex 5.

Explosive chemicals

Azides, often used in antibacterial solutions, should not be allowed to come into contact with copper or lead (e.g. in waste pipes and plumbing), as they may explode violently when subjected even to a mild impact.

Ethers that have aged and dried to crystals are extremely unstable, and potentially explosive.

Perchloric acid, if allowed to dry on woodwork, brickwork or fabric, will explode and cause a fire on impact.

Picric acid and picrates are detonated by heat and impact.

Chemical spills

Most manufacturers of laboratory chemicals issue charts describing methods for dealing with spills. Spillage charts and spillage kits are also available commercially. Appropriate charts should be displayed in a prominent position in the laboratory. The following equipment should also be provided:

1. Chemical spill kits
2. Protective clothing, e.g. heavy-duty rubber gloves, overshoes or rubber boots, respirators
3. Scoops and dustpans
4. Forceps for picking up broken glass
5. Mops, cloths and paper towels
6. Buckets

7. Soda ash (sodium carbonate, Na_2CO_3) or sodium bicarbonate ($NaHCO_3$) for neutralizing acids and corrosive chemicals
8. Sand (to cover alkali spills)
9. Non-flammable detergent.

The following actions should be taken in the event of a significant chemical spill.

1. Notify the appropriate safety officer.
2. Evacuate non-essential personnel from the area.
3. Attend to persons who may have been contaminated.
4. If the spilled material is flammable, extinguish all open flames, turn off gas in the room and adjacent areas, open windows (if possible), and switch off electrical equipment that may spark.
5. Avoid breathing vapour from spilled material.
6. Establish exhaust ventilation if it is safe to do so.
7. Secure the necessary items (see above) to clean up the spill.

Compressed and liquefied gases

Information regarding storage of compressed and liquefied gases is given in Table 14.

Table 14. ***Storage of compressed and liquefied gases***

CONTAINER	STORAGE INFORMATION
Compressed gas cylinders and liquefied gas containers[a,b]	• Should be securely fixed (e.g. chained) to the wall or a solid bench so that they are not inadvertently dislodged. • Must be transported with their caps in place and supported on trolleys. • Should be stored in bulk in an appropriate facility at some distance from the laboratory. This area should be locked and appropriately identified. • Should not be placed near radiators, open flames other heat sources, sparking electrical equipment, or in direct sunlight.
Small, single-use gas cylinders[a,b]	• Must not be incinerated.

[a] The main high-pressure valve should be turned off when the equipment is not in use and when the room is unoccupied.
[b] Rooms where flammable gas cylinders are used and/or stored should be identified by warning notices on the doors.

For further information see references (*1*) and (*49–51*), and Annex 5.

18. Additional laboratory hazards

Laboratory personnel may confront hazards posed by forms of energy including fire, electricity, radiation and noise. Basic information about each of these is presented in this chapter.

Fire hazards

Close cooperation between safety officers and local fire prevention officers is essential. Apart from chemical hazards, the effects of fire on the possible dissemination of infectious material must be considered. This may determine whether it is best to extinguish or contain the fire.

The assistance of local fire prevention officers in the training of laboratory staff in fire prevention, immediate action in case of fire and the use of fire-fighting equipment is desirable.

Fire warnings, instructions and escape routes should be displayed prominently in each room and in corridors and hallways.

Common causes of fires in laboratories are:

1. Electrical circuit overloading
2. Poor electrical maintenance, e.g. poor and perished insulation on cables
3. Excessively long gas tubing or long electrical leads
4. Equipment unnecessarily left switched on
5. Equipment that was not designed for a laboratory environment
6. Open flames
7. Deteriorated gas tubing
8. Improper handling and storage of flammable or explosive materials
9. Improper segregation of incompatible chemicals
10. Sparking equipment near flammable substances and vapours
11. Improper or inadequate ventilation.

Fire-fighting equipment should be placed near room doors and at strategic points in corridors and hallways. This equipment may include hoses, buckets (of water or sand) and a fire extinguisher. Fire extinguishers should be regularly inspected and maintained, and their shelf-life kept up to date. Specific types and uses of fire extinguishers are shown in Table 15.

Table 15. ***Types and uses of fire extinguishers***

TYPE	USE FOR	DO NOT USE FOR
Water	Paper, wood, fabric	Electrical fires, flammable liquids, burning metals
Carbon dioxide (CO_2) extinguisher gases	Flammable liquids and gases, electrical fires	Alkali metals, paper
Dry powder	Flammable liquids and gases, alkali metals, electrical fires	Reusable equipment and instruments, as residues are very difficult to remove
Foam	Flammable liquids	Electrical fires

For further information see reference (*49*).

Electrical hazards

It is essential that all electrical installations and equipment are inspected and tested regularly, including earthing/grounding systems.

Circuit-breakers and earth-fault-interrupters should be installed in appropriate laboratory electrical circuits. Circuit-breakers do not protect people; they are intended to protect wiring from being overloaded with electrical current and hence to prevent fires. Earth-fault-interrupters are intended to protect people from electric shock.

All laboratory electrical equipment should be earthed/grounded, preferably through three-prong plugs.

All laboratory electrical equipment and wiring should conform to national electrical safety standards and codes.

Noise

The effect of excessive noise is insidious over time. Some types of laboratory equipment, such as certain laser systems, as well as facilities where animals are housed, can produce significant noise exposure to workers. Noise measurement surveys can be conducted to determine the noise hazard. Where warranted by data, engineering controls such as enclosures or barriers around noisy equipment or between noisy areas and other work areas, can be considered. Where noise levels cannot be abated and where laboratory personnel routinely experience excessive exposures, a hearing conservation programme that includes the use of hearing protection while working in hazardous noise and a medical monitoring programme to determine the effect of noise on the workers should be instituted.

Ionizing radiation

Radiological protection is concerned with protecting humans against the harmful effects of ionizing radiation, which include:

1. Somatic effects, e.g. clinical symptoms observable in exposed individuals. Somatic effects include radiation-induced cancers, e.g. leukaemia and bone, lung and skin cancers, the onset of which may occur many years after irradiation. Less severe somatic effects include minor skin damage, hair loss, blood deficiencies, gastrointestinal damage and cataract formation.
2. Hereditary effects, e.g. symptoms observed in the descendants of exposed individuals. The hereditary effects of radiation exposure to the gonads include chromosome damage or gene mutation. Irradiation of the germ cells in the gonads in high doses can also cause cell death, resulting in impaired fertility in both sexes or menstrual changes in women. Exposure of the developing fetus, particularly in weeks 8–15 of pregnancy, may increase the risk of congenital malformations, mental impairment or radiation-induced cancers in later life.

Principles of ionizing radiation protection

To limit the harmful effects of ionizing radiation, the use of radioisotopes should be controlled and should comply with relevant national standards. Protection from radiation is managed on the basis of four principles:

1. Minimizing the time of radiation exposure
2. Maximizing the distance from the radiation source
3. Shielding the radiation source
4. Substituting the use of radionuclides with non-radiometric techniques.

Protection activities include the following.

1. *Time*. The time of exposure experienced during manipulations of radioactive material can be reduced by:
   — Practising new and unfamiliar techniques without using the radionuclide until the techniques are mastered
   — Working with radionuclides in a deliberate and timely manner without rushing
   — Ensuring that all radioactive sources are returned to storage immediately after use
   — Removing radioactive waste from the laboratory at frequent intervals
   — Spending as little time as possible in the radiation area or laboratory
   — Exercising effective time management and planning of laboratory manipulations involving radioactive material.

   The less time spent in a radiation field, the smaller the received personal dose, as described in the equation:

   $$\textbf{Dose} = \textbf{Dose rate} \times \textbf{time}$$

2. *Distance*. The dose rate for most γ- and X-radiation varies as the inverse square of the distance from a point source:

   $$\textbf{Dose rate} = \textbf{Constant} \times \textbf{1/Distance}^2$$

Doubling the distance from a radiation source will result in reducing the exposure by one-fourth over the same period of time. Various devices and mechanical aids are used to increase the distance between the operator and the radiation source, e.g. long-handled tongs, forceps, clamps and remote pipetting aids. Note that a small increase in distance can result in significant decrease in the dose rate.

3. *Shielding*. Radiation energy-absorbing or attenuating shields placed between the source and the operator or other occupants of the laboratory will help limit their exposure. The choice and thickness of any shielding material depends on the penetrating ability (type and energy) of the radiation. A barrier of acrylic, wood or lightweight metal, thickness 1.3–1.5 cm, provides shielding against high-energy β particles, whereas high-density lead is needed to shield against high energy γ- and X-radiation.

4. *Substitution*. Radionuclide-based materials should not be used when other techniques are available. If substitution is not possible, then the radionuclide with the least penetrating power or energy should be used.

Safe practices for work with radionuclides

Rules for working with radioactive substances should include considerations in four areas:

1. Radiation area
2. Work-bench area
3. Radioactive waste area
4. Records and emergency response.

Some of the most important rules include the following:

1. *Radiation area*
   - Use radioactive substances only in dedicated areas.
   - Allow the presence of essential staff only.
   - Use personal protective equipment, including laboratory coats, safety spectacles and disposable gloves.
   - Monitor personal radiation exposures.

   Laboratories where radionuclides are used should be designed to simplify containment, cleaning and decontamination. The radionuclide work area should be located in a small room adjoining the main laboratory, or in a dedicated area within the laboratory away from other activities. Signs displaying the international radiation hazard symbol should be posted at the entrance to the radiation area (Figure 12).

2. *Work-bench area*
   - Use spill trays lined with disposable absorbent materials.
   - Limit radionuclide quantities.
   - Shield radiation sources in the radiation, work bench and radioactive waste areas.

Figure 12. ***International radiation hazard symbol***

— Mark radiation containers with the radiation symbol, including radionuclide identity, activity and assay date.
— Use radiation meters to monitor working areas, protective clothing and hands after completion of work.
— Use appropriately shielded transport containers.

3. *Radioactive waste area*
— Remove radioactive waste frequently from the working area.
— Maintain accurate records of use and disposal of radioactive materials.
— Screen dosimetry records for materials exceeding the dose limits.
— Establish and regularly exercise emergency response plans.
— In emergencies, assist injured persons first.
— Clean contaminated areas thoroughly.
— Request assistance from the safety office, if available.
— Write and keep incident reports.