2. Facilities and safety

2-1: Overview

Role in quality management system

The laboratory work space and facilities must be such that the workload can be performed without compromising the quality of work and the safety of the laboratory staff, other health care personnel, patients and the community.

This chapter will describe essential elements for laboratory design and safety that prevent and control exposure to physical, chemical and biological hazards.

This chapter addresses pathogens and chemicals of moderate or low-level risk, rather than highly dangerous substances. As a general rule, all diagnostic laboratories should be designed and organized for biosafety level 2 or above.

Importance of safety

A laboratory safety programme is important in order to protect the lives of employees and patients, to protect laboratory equipment and facilities, and to protect the environment.

Neglecting laboratory safety is very costly. Secondary effects of a laboratory accident are:

- loss of reputation
- loss of customers / loss of income
- negative effect on staff retention
- increased costs—litigation, insurance.

Responsibilities

Ensuring quality and safety during laboratory processes is a major concern for laboratory managers. Often, the laboratories they manage are designed by architects and/or administrators who have little knowledge of specific laboratory needs, making the job of the manager more difficult.

As a **laboratory director**, it is important to:

- actively participate in the design and planning stages of new laboratory facilities;
- assess all potential risks and apply basic concepts of organization in order to provide a proper and safe environment for conducting laboratory activities, including services to patients;
- consider the organization of the laboratory when developing new activities or new diagnostic techniques in the laboratory.

As a **quality manager (or designated safety officer)**, it is necessary to:

- develop a complete and thorough description of basic safety rules and organization, and ensure that personnel are trained in their specific duties when new activities or techniques are introduced into the laboratory;
- know the basics of safety and biosafety management issues when working with chemicals and pathogens of moderate or low level of risk;
- know how to perform an extensive risk assessment when developing new activities in the laboratory;
- conduct laboratory safety audits.

As a **laboratorian,** it is important to:

- be aware of basic safety rules and processes;
- understand the basics of safety and biosafety management issues when working with toxic chemicals, biological samples and physical hazards, and when interacting with patients.

Everyone in the laboratory is responsible for quality and safety.

2-2: Laboratory design

Access

When designing a laboratory or organizing workflow, ensure that patients and patient samples do not have common pathways. Circulation paths should be designed in such a way that contact between the public and biological materials can occur only in the rooms where patient samples are collected. The reception desk where incoming patients register should be located as close as possible to the entry door.

Access to rooms where manipulation or analysis of samples takes place, or where hazardous chemicals or other materials are stored, must be restricted to authorized persons, usually laboratory technical staff and maintenance staff. Restriction of access may be accomplished using signs on doors, locks when appropriate and staff identification badges.

Circulation pathways

To identify where improvements in laboratory design may be needed in order to prevent or reduce risks of cross-contamination, follow the path of the sample as it moves through the laboratory during the pre-examination, examination and post-examination phases of testing. Pathways to assess include:

- Sample collection areas—a laboratory layout with both the reception and the sample collection room located at the entrance saves time and energy.
- Sample processing areas—here, samples are centrifuged as needed, allocated for different examinations and dispersed to the appropriate sections of the laboratory for analysis. If possible, the sample processing area should be separated from, but nearby, the testing areas.
- Start with changes that can be easily accomplished and have the biggest impact.
- Circulation pathways of biological samples between different sections of the laboratory—These pathways should be assessed for the purpose of minimizing contamination risks. If possible, circulation pathways of clean and dirty laboratory materials should never cross, and circulation pathways of contaminated waste should be isolated.
- Post-examination pathways—After the analysis of the samples, the results must be accurately recorded, properly filed, and delivered on time to the right person. Communication systems appropriate to the size and complexity of the laboratory, including the efficient and reliable transferring of messages, should be part of the laboratory design.

For the most efficient design, all related services should be located in close proximity.

2-3: Geographic or spatial organization

Distribution of activities

When organizing laboratory work space, divide the laboratory into areas with different access control in order to separate patients from biological samples. Where samples are actually processed, plan for spatial organization that ensures the best service.

For optimal organization of the laboratory, consider:

- Delineation of laboratory activities—Care should be taken to either group related activities in a single room, or to clearly delineate bench space for specific activities. Measures must be taken to prevent cross-contamination of samples.
- Location of service rooms—Service rooms to accommodate autoclaves, sinks for cleaning glassware, preparation and sterilization of culture media, and so on, should be located in a central area to minimize distances and facilitate circulation paths of materials, samples and goods. A responsible staff member should be designated to oversee cleaning and maintenance of the service rooms.
- Location of activities with specific requirements, such as:
  - molecular biology—needs to be located in a separate space, with at least two rooms, so that preparation of DNA extracts is not performed in the same room as where the subsequent steps (preparation of reagent mixes and DNA amplification) are performed;
  - fluorescence microscopy—requires a dark room with proper ventilation which must not be used for storage of stock materials and other chemicals;
  - ultraviolet illumination systems for DNA gel photography—requires a dark room and appropriate eye protection equipment.

Spatial provision for equipment

The laboratory director and safety officer must consider special needs for equipment when designing laboratory space. Some things to consider are:

- Access to equipment for entry and maintenance—Make sure that there are no physical restrictions for access, such as door and elevator size, that could pose a problem for the delivery and maintenance of new machines and equipment.
- Power supply—Consider the need for a stable power supply for sensitive equipment and a backup power supply or emergency generator for times when the laboratory's primary power source is down.
- Managing disposal of liquids from equipment—Disposal of liquid reagents, by-products and wastes from laboratory equipment and procedures is a major concern for laboratories. When placing equipment in the laboratory, be sure to consider how liquid wastes will be handled. It is important to be aware of, and comply with, local and national requirements for liquid waste disposal, in order to prevent contamination of community sewage systems with pathogens or toxic chemicals.

2-4: Physical aspects of premises and rooms

Facilities

The laboratory must be designed to ensure proper ventilation throughout, with an active ventilation system and adequate space for circulation of people, laboratory carts and trolleys.

Rooms should have a high ceiling to ensure proper ventilation, and walls and ceilings should be painted with washable, glossy paint or coated with a material suitable for cleaning and disinfection. The floor must also be easy to clean and disinfect, and have no edges between the walls and floor.

Work benches

Laboratory work benches should be constructed of materials that are durable and easy to disinfect. If the laboratory's budget allows, ceramic tiles are good materials to use for benchtops, as they are easy to clean and are resistant to deterioration from harsh disinfectants and aggressive cleaning products. However, be aware that the grout between them can sometimes harbour contaminating microorganisms, so must be disinfected regularly.

Wood should not be used, as it is not easy to clean or disinfect, and will deteriorate over time when repeatedly exposed to disinfectants and detergents. Wood also support the growth of contaminants when wet or damaged.

The disadvantage of using steel for benchtops is that steel will rust when washed with chlorine.

It is advisable to organize work benches according to the type of analysis that is performed, with adequate space for benchtop equipment and enough space to place a standard operating procedure while in use and display job aids. In areas where microbiology procedures are performed, work benches should be separated according to the different types of samples or pathogens that are analyzed, in order to minimize risks of cross-contamination.

Cleaning

It is very important that all areas of the laboratory are cleaned and maintained on a regular basis. Examples of areas that need daily attention are:

- Benchtops—clean and disinfect benchtops after completing examinations, and after any spills of samples or reagents. This responsibility is generally assigned to the technical staff performing the tests.
- Floors—these are usually cleaned by cleaning staff, unless restricted access allows only technical staff to disinfect the floors at the end of the day.

Other areas of the laboratory should be scheduled for cleaning on a weekly or monthly basis, depending on laboratory conditions. For example, ceilings and walls may require cleaning weekly, whereas items such as refrigerators and storage areas might be scheduled for a monthly cleaning.

Cleaning and disinfection of laboratory areas should be recorded, including the date and name of the person performing the maintenance.

2-5: Safety management programme

Developing a laboratory safety programme

Often, the responsibility for developing a safety programme and organizing appropriate safety measures for the laboratory is assigned to a laboratory safety officer. In smaller laboratories, the responsibility for laboratory safety may fall to the laboratory manager or even to the quality officer. The steps for designing a safety management programme include:

- developing a manual to provide written procedures for safety and biosafety in the laboratory;
- organizing safety training and exercises that teach staff to be aware of potential hazards and how to apply safety practices and techniques—training should include information about universal precautions, infection control, chemical and radiation safety, how to use personal protective equipment (PPE), how to dispose of hazardous waste, and what to do in case of emergencies;
- setting up a process to conduct risk assessments—this process should include initial risk assessments, as well as ongoing laboratory safety audits to look for potential safety problems.

General safety equipment

The safety officer should be assigned responsibility for ensuring that there is an adequate supply of appropriate equipment for safety and biosafety, such as:

- PPE
- fire extinguishers and fire blankets
- appropriate storage and cabinets for flammable and toxic chemicals
- eye washers and emergency shower
- waste disposal supplies and equipment
- first aid equipment.

Standard safety practices

Policies should be put in place that outline the safety practices to be followed in the laboratory. Standard laboratory safety practices include:

- limiting or restricting access to the laboratory;
- washing hands after handling infectious or hazardous materials and animals, after removing gloves, and before leaving the laboratory;
- prohibiting eating, drinking, smoking, handling contact lenses, and applying cosmetics in work areas;
- prohibiting mouth pipetting;
- using techniques that minimize aerosol or splash production when performing procedures—biosafety cabinets should be used whenever there is a potential for aerosol or splash creation, or when high concentrations or large volumes of infectious agents are used;

- preventing inhalation exposure by using chemical fume hoods or other containment devices for vapours, gases, aerosols, fumes, dusts or powders;
- properly storing chemicals according to recognized compatibilities—chemicals posing special hazards or risks should be limited to the minimum quantities required to meet short-term needs and stored under appropriately safe conditions (i.e. flammables in flammable storage cabinets)—chemicals should not be stored on the floor or in chemical fume hoods;
- securing compressed gas cylinders at all times;
- decontaminating work surfaces daily;
- decontaminating all cultures, stocks and other regulated wastes before disposal via autoclave, chemical disinfection, incinerator or other approved method;
- implementing and maintaining an insect and rodent control programme;
- using PPE such as gloves, masks, goggles, face shields and laboratory coats when working in the laboratory;
- prohibiting sandals and open-toed shoes to be worn while working in the laboratory;
- disposing of chemical, biological and other wastes according to laboratory policies.

Procedures and exercises

Monthly and yearly exercises must be organized for fire drills and laboratory evacuation procedures. This is an occasion for the safety officer to emphasize risks to laboratory staff and to review with them the specific procedures for evacuation, handling of incidents and basic security precautions.

Waste management

Laboratory waste management is a critical issue. All potentially harmful and dangerous materials (including liquids and radioactive materials) must be treated in a specific way before disposing. Separate waste containers should be used depending on the nature of the waste, and must be clearly identified by a colour code. Specific attention should be given to the management of potentially harmful contaminated waste such as sharps, needles or broken glassware. Sharps containers must be available on work benches so they are conveniently accessible to staff.

Internationally recognized labels

Many labels that give warnings and instructions for safety precautions are internationally recognized. A list of websites that provide these labels can be found in the references and resources section.

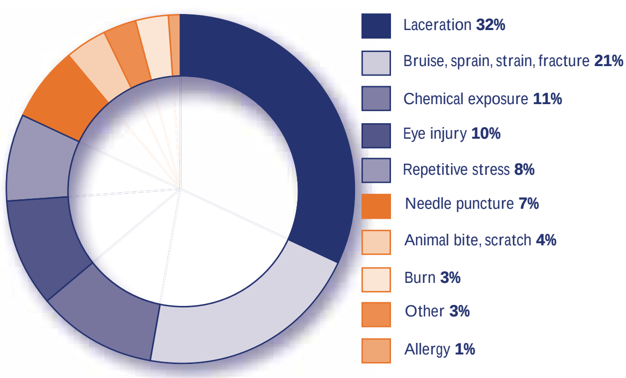
2-6: Identification of risks

Laboratories are hazardous environments

Laboratory workers encounter a significant number of risks, which vary with the types of activities and analyses that are performed.

Risk assessment is compulsory in order for the laboratory director to manage and reduce risks to laboratory employees. Assistance from a safety officer is needed to appreciate potential risks and incorporate appropriate preventive measures. It is important to develop safety procedures that describe what to do in case of accidents, injuries or contamination. In addition, it is important to keep a record of staff exposures to hazards, actions taken when this occurs, and procedures put into place to prevent future occurrences.

The outcome of a study of physical risks encountered by laboratory staff that was conducted by the Howard Hughes Medical Institute Office of Laboratory Safety is shown in the chart. This study only addressed physical risks, but personnel contamination and infection have been reported in many instances, and recent reports on laboratory-acquired infection leading to severe acute respiratory syndrome (SARS) show that the risks are never reduced to zero, even in high-confinement facilities.



Physical hazards

Laboratory equipment is a significant source of potential injury to laboratory staff, thus making training in specific safety procedures imperative. Examples of equipment in which safety training and precautions are important include autoclaves, centrifuges, compressed gas cylinders and fume hoods. Many laboratory instruments pose a danger of electrical shock, and some equipment can emit dangerous microwaves or radiation if not properly used or maintained.

Storage of compressed gases in the laboratory requires precautions unique to the unusual containers in which these materials are kept, and the high pressures they are subject to. Cylinders are kept chained to the wall so that they cannot fall over. The safety cap must be secured over the valve of the cylinder whenever it is moved or taken out of service.

Needles and sharps

Needles, broken glass and other sharps need to be handled and disposed of appropriately to prevent risks of infection to laboratory and housekeeping (custodial) staff. Instructions for proper disposal of sharps are:

- Avoid needle recapping. If recapping is crucial, the correct procedure is for the person doing the recapping to keep one hand behind the back of the needle, and use the other hand to scoop the cover onto the needle.
- Put sharps in a puncture-resistant, leak-proof sharps container. Label the container "Sharps". If the sharps are not biohazardous, deface any biohazard markings or symbols. Seal the container tightly.

Laboratory glassware and plasticware are not considered to be sharps for disposal purposes. Laboratory glassware and plasticware include any item that could puncture regular waste bags and therefore endanger waste handlers. Laboratory glass must be placed in cardboard boxes for safety during transport through the building. Any cardboard box may be used, provided it is sturdy and of a size that will not weigh more than 40 pounds when full.

Contaminated laboratory glass must be appropriately decontaminated prior to disposal.

Never use boxes for the disposal of:

- sharps
- biohazardous materials that have not been autoclaved
- liquid wastes
- chemically contaminated laboratory glassware or plasticware
- chemical containers that cannot be disposed of as regular solid waste.

Chemical hazards

Exposure to toxic chemicals poses a real threat to the health and safety of laboratory staff. There are three main routes by which chemicals enter the body.

- Inhalation—this is the major route of entry when working with solvents; there is great rapidity of absorption when fumes are inhaled.
- Absorption through skin—this may produce systemic poisoning; the condition of the skin determines the rate of absorption. Examples of chemicals with these risks are organic lead, solvents such as xylene and methylene chloride, organophosphate, pesticides and cyanides.
- Ingestion—accidental ingestion is generally due to poor hygiene practices, such as eating or smoking in the laboratory.

To prevent or reduce incidents caused by exposure to toxic chemicals, all chemicals, including solutions and chemicals transferred from their original containers, should be labelled with their common names, concentrations and hazards. Additional information, such as the date received, date opened and date of expiration, should also be recorded.

It is crucial that chemicals are stored properly. Store corrosive, toxic and highly reactive chemicals in a well-ventilated area, and store chemicals that can ignite at room temperature in a flammables cabinet.

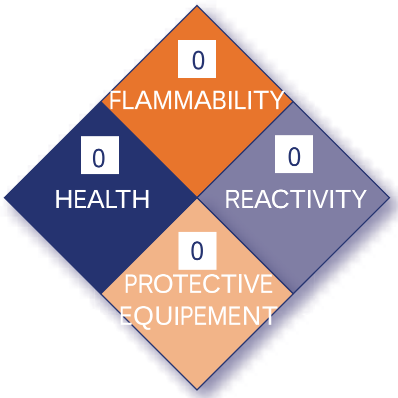
Radiochemicals require special precautions, and dedicated benches with specific bench covers for manipulation of radiolabelled elements are needed. Specific storage areas for radioactive materials are needed. These must provide appropriate protection (Plexiglas™, lead) and specific waste containers, depending on the chemical nature of waste and radioactive elements.

Material safety data sheet

The material safety data sheet (MSDS) is a technical bulletin providing detailed hazard and precautionary information.[1] Businesses are required to provide to their customers the MSDS for all chemicals they manufacture or distribute. Laboratories need to heed precautions listed in the MSDS in order to ensure the chemicals they use are handled and stored safely.

The MSDS provides:

- product information;
- fire and explosion precautions;
- toxicology;
- health effects;
- recommended PPE;
- storage recommendations;
- leaks and spills—recommended actions;
- waste disposal recommendations;
- first aid.



The MSDS should be:

- available to all employees prior to use of hazardous materials;
- kept close to where the hazardous material is used and located.

Biological hazards

Laboratory-acquired infections are not infrequent in medical laboratories. The following tables show the most frequently reported infections acquired in laboratories in the United States of America from 1979 to 1999.[2]

1 ISO 15190:2003. *Medical laboratories—requirements for safety*. Geneva: International Organization for Standardization, 2003.

2 Harding AL, Brandt Byers K. Epidemiology of laboratory-associated infections. In: Fleming, DO, Hunt DL, eds. *Biological safety: principles and practices*. Washington, DC, ASM Press, 2000, 35–54.

Disease or agent	No. of cases
Mycobacterium tuberculosis	223
Q fever	176
Hantavirus	169
Hepatitis B	84
Brucella sp.	81
Salmonella sp.	66
Shigella sp.	56
Hepatitis non-A, non-B	28
Cryptosporidium sp.	27
Total	910

Disease	Probable source	Maximum distance from source	No. infected
Brucellosis	Centrifugation	Basement to 3rd floor	94
Coccidioidomycosis	Culture transfer, solid media	2 building floors	13
Coxsackie virus infection	Spilled tube of infected mouse tissue on floor	5 feet estimated	2
Murine typhus	Intranasal inoculation of mice	6 feet estimated	6
Tularemia	20 petri plates dropped	70 feet	5
Venezuelan encephalitis	9 lyophilized ampoules dropped	4th floor stairs to 3rd or 5th floor	24

Aerosols are the main sources of contamination within diagnostic laboratories; contamination can occur over very long distances. This is why the major target of containment systems is the blockage of aerosol diffusion inside and outside the laboratory. Diagnostic laboratories of physical containment level 2, where activities concern only pathogens of moderate risks, must have appropriate ventilation. Higher containment level laboratories or working cabinets must ensure a continuous inward airflow, as well as absolute filtration of exhausted air, to avoid aerosol dissemination outside the working area or the whole laboratory.[1]

1 Reitman M, Wedum AG. Microbiological safety. *Public Health Reports,* 1956, 71(7):659–665.

2-7: Personal protective equipment

Basic information

The major routes by which laboratory staff acquire work-related infections are:

- percutaneous inoculation
- contact between mucous membranes and contaminated material
- accidental ingestion.

To reduce the risk of these occurrences, it is imperative that staff have access to PPE, be trained in how to properly use it, and habitually use the PPE while working in the laboratory. Approved goggles, face shields, splatter guards, masks, or other eye and face protection should be worn when handling infectious or other hazardous materials outside the biosafety cabinet.

Hand protection

Gloves should be worn in all instances, and should be available to laboratory staff on a routine basis. Effective use of gloves relies on two simple practices.

1. Remove gloves when leaving the working area to prevent contamination of other areas such as the telephone, door handles and pens.
2. Never reuse gloves. Do not attempt to wash or decontaminate gloves—they will develop microcracks, become more porous and lose their protective properties. After use, gloves **must** be disposed of in the contaminated waste.

Face protection

Goggles—The projection of droplets is a frequent occurrence when opening patient sample containers. Protection of eyes with goggles is strongly recommended as a routine procedure to prevent contact with these droplets.

Another way to protect eyes and other mucous membranes from projection is to manipulate the specimen tubes behind a screen (glass or Plexiglas™) or face shield. This equipment should be compulsory when manipulating dangerous liquids, such as liquid nitrogen or some solvents.

Contact lenses do not offer protection from splashes. Additional eye protection must be worn with contact lenses.

Masks—Masks serve as a barrier when splashes or sprays occur. Furthermore, in order to reduce laboratory workers' respiratory exposure to airborne highly dangerous pathogens, it is recommended to use fit-tested particulate respirators with adequate filtering (e.g. EU FFP2, US NIOSH-certified N95) during specimen collection or handling.

Body protection

Laboratory coats are compulsory in all instances in the physical containment level 2 laboratory. Be aware of the composition of fabrics, as some might be highly flammable.

A disposable laboratory coat is compulsory in physical containment level 3 laboratories or in specific instances such as sample collection when highly dangerous pathogens can be involved, such as suspected cases of H5N1 avian influenza or SARS.

2-8: Emergency management and first aid

Emergencies

Laboratories need to have procedures in place for how staff should deal with accidents and emergencies. General written procedures for first aid should be developed and made available to all staff so they know the first things to do, and who to call or notify in case of minor cuts and bruises, major wounds or skin contamination.

Chemical spills

A chemical spill is considered to be **minor** only if the person who spilled it is familiar with the chemical, knows the associated hazards and knows how to clean up the spill safely. The recommended steps for dealing with a minor spill include:

- alert coworkers, then clean up spill;
- follow procedures for disposal of materials used to clean up spill;
- absorb free liquids with an appropriate absorbent, as follows
  - caustic liquids—use polypropylene pads or diatomaceous earth
  - oxidizing acids—use diatomaceous earth
  - mineral acids—use baking soda or polypropylene pads
  - flammable liquids—use polypropylene pads;
- neutralize residues and decontaminate the area.

Anything beyond a minor spill and that requires help from outside of the laboratory group constitutes a **major** spill. Steps to deal with major spills include alerting coworkers, moving to a safe location and calling authorities to report the situation.

Biological spills

When **surfaces are contaminated** by biological spills, the appropriate actions to take are:

1. Define/isolate the contaminated area.
2. Alert coworkers.
3. Put on appropriate PPE.
4. Remove glass/lumps with forceps or scoop.
5. Apply absorbent towel(s) to the spill; remove bulk and reapply if needed.
6. Apply disinfectant to towel surface.
7. Allow adequate contact time (20 minutes).
8. Remove towel, mop up, and clean the surface with alcohol or soap and water.
9. Properly dispose of materials.
10. Notify the supervisor, safety officer, and other appropriate authorities.

Disinfectant: For most spills, use a 1:50 solution (1 g/l chlorine) of household bleach (sodium hypochlorite solution containing 50 g/l chlorine).

For spills containing large amounts of organic material, use a 1:10 solution (5 g/l chlorine) of household bleach, or an approved mycobactericidal.[1] Suggested sources of mycobactericidals are registered with the United States of America Environmental Protection Agency (http://www.epa.gov/oppad001/chemregindex.htm).

Alcohols are not recommended as surface decontaminating agents because they evaporate quickly, thus decreasing contact time.

If **laboratory personnel become contaminated** with biological hazards due to splashes or spills, immediate steps to take include:

1. Clean exposed skin or body surface with soap and water, eyewash (for eye exposures) or saline (for mouth exposures).
2. Apply first aid and treat as an emergency.
3. Notify supervisor, safety officer, or security desk (after hours).
4. Follow appropriate reporting procedures.
5. Report to physician for treatment or counselling.

Laboratory fires

Laboratory personnel need to be alert for conditions that might pose a risk for fires. Keep in mind that liquids with low flash points may ignite if they are near heat sources such as hotplates, steam lines or equipment that might produce a spark or heat.

A small laboratory fire is considered to be one that is extinguishable within 1–2 minutes. The appropriate action to take is to cover the fire with an inverted beaker or wet paper towels. If this fails, use a fire extinguisher. For large fires, call the appropriate local authorities, usually the fire department and the police department.

Laboratories should have the appropriate class of extinguisher for the fire hazards in the laboratory. In general, a class BC or class ABC extinguisher is appropriate. Fire extinguishers must be inspected annually and replaced as needed. Laboratory personnel should be trained in the various classes of fires and basic fire extinguisher use in annual laboratory safety and hazardous waste management training.

All laboratory personnel must learn how to operate a portable fire extinguisher.

1 See World Health Organization. *Laboratory biosafety manual,* 3rd ed. Geneva, WHO, 2004

2-9: Summary

Summary

When designing a laboratory or organizing workflow, ensure that patients and patient samples do not have common pathways. To identify where improvements in laboratory design may be needed in order to prevent or reduce risks of cross-contamination, follow the path of the sample as it moves through the laboratory during the pre-examination, examination and post-examination phases of testing.

The design of laboratory work areas should ensure proper ventilation and surfaces that can be cleaned and disinfected.

In establishing a safety management programme, it is important to appoint a responsible supervisor. The laboratory should have a safety manual that establishes policy and describes standard procedures for handling safety and emergency issues. Personnel need to be trained in how to apply safety practices and techniques, and to be aware of potential hazards.

Key message

Neglecting laboratory safety is costly. It jeopardizes the lives and health of employees and patients, laboratory reputation, equipment and facilities.