CHAPTER 33

Safety in Biomedical and Other Laboratories

WILLIAM E. GRIZZLE,[1] WALTER BELL,[1] JERRY FREDENBURGH[2]
[1]*Department of Pathology, University of Alabama at Birmingham, Birmingham, AL;*
[2]*Richard Allan Scientific, Kalamazoo, MI, USA*

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33.1 INTRODUCTION

The safe operation of a laboratory requires attention to many issues and details that are complex and depend on the activities of the specific laboratory. For example, if a laboratory works with human samples, then depending on the location of the laboratory, complex national regulations related to safety precautions may need to be followed. For example, in the United States, regulations specify approaches necessary to protect employees from laboratory chemicals, and blood borne pathogens. In contrast, if no radioactive material is stored or used in a laboratory, a safety plan dealing with radiological safety may be unnecessary for that laboratory. Clearly, issues related to fire, electrical, and physical safety affect all laboratories. However, complex, extensive, or detailed regulations related to these areas of safety primarily are promulgated by regional and local governments. Thus, each laboratory should determine which areas of safety affect it and develop a safety program to protect its employees from all laboratory hazards to which they are exposed. This includes determining the local, regional, national, and international regulations related to safety that apply to any given laboratory and/or organization.

The approaches to safety discussed in this chapter are based upon regulations governing safety in the United States. Nevertheless, the approaches to safety discussed can be generalized to biological laboratories located internationally.

Operating a biological laboratory safely is difficult, and no single source of information will provide all the information necessary to develop an adequate safety program/plan. Therefore, the limited approaches and information presented in this chapter are only a starting point; this starting point is not static in that new issues related to laboratory safety are developing almost daily. The authors do not maintain that these approaches and information presented here are adequate to ensure the safety of laboratory personnel or to ensure that a laboratory is able to meet regulatory or accreditation standards in safety.

33.2 INTERNATIONAL, NATIONAL, REGIONAL, AND LOCAL SAFETY REGULATIONS

In developing safety plans for a laboratory, there are more aids available than in other areas of laboratory operation because of the extensive national, regional, and local regulations that must be met in order to protect the health and safety of employees. Along with these regulations, many national, regional, and local governmental organizations provide guidance concerning how to meet specific regulations related to safety. For example, the web-based aids to understanding the regulations of the United States and some other countries concerning safety are listed in Table 33.1. Table 33.2 contains general informational resources that may aid in developing a safety program, and several reviews devoted to safety issues have been published in the scientific literature (Grizzle and Polt, 1988; Sewell, 1995; Richmond *et al.*, 1996; Beekmann and Doebbeling, 1997; Cardo and Bell, 1997; Padhye *et al.*, 1998; Grizzle and Fredenburgh, 2001). Laboratories outside the United States will also find many of these educational aids to be very useful in developing safety programs.

TABLE 33.1 Internet resources on safety.

Web site	Organization	Topics
General Safety		
http://www.osha.gov	Occupational Safety and Health Administration, Department of Labor, USA	Current regulations; regulations under development; technical information; prevention information, training information; links
http://www.rmlibrary.com/db/lawosha.htm		Occupational safety laws of all 50 states
http://www.med.virginia.edu	University of Virginia, International Health Care Worker Safety Center	Surveillance data
http://www.medcntr/centers/epinet	Exposure Prevention Information Network (EpiNet)	Surveillance information
http://www.cap.org	College of American Pathologists	General and technical information; lab management
http://www.lbl.gov/ehs/pub3000	Berkeley Lab Health and Safety	Health and safety manual
http://www.nccls.org	National Committee for Clinical Laboratory Standards	General and technical information; forums; links
Biosafety		
http://www.cdc.gov	Centers for Disease Control and Prevention, Atlanta, GA	Surveillance data; prevention information, technical information; links. Proposed guidelines for working safety with *M. tuberculosis*
http://www.cdc.gov/ncidod	National Center for Infectious Diseases	General and technical information; case information, teaching materials; research and resources
http://www.fda.gov/cber	Food and Drug Administration, Center for Biologics Evaluation and Research	Information on recalls, withdrawals; and safety issues concerning biologics
http://www.absa.org	American Biological Safety Association	Technical information
http://www.ace.osrt.edu	National Antimicrobial Information Network of Oregon State University and the EPA	Technical information on disinfectants; links
http://www.maaf.gov.uk	Ministry of Agriculture, Fisheries and Food, UK	Surveillance data on BSE in Europe; technical information; links
http://www.cjd.ed.ac.uk	UK Surveillance Unit for CJD	Surveillance data on vCJD; technical information; links
Chemical safety		
http://www.cdc.gov/niosh/database.html	National Institute for Occupational Safety and Health (NIOSH)	Databases and information resource links and publications
http://www.ilo.org/public/english/protection/safework/cis/products/icsc/dtasht/index.htm	International Occupational Safety and Health Information Center	Chemical database; International Chemical Safety Cards (ICSC)
http://response.restoration.noaa.gov/chemaids/react.html	Chemical Reactivity Worksheet	Chemical database of reactivity of substances or mixtures of substances
http://www.cdc.gov/niosh/chem-inx.html	Master Index of Occupational Health Guidelines for Chemical Hazards (NIOSH)	Guidelines for chemical hazards of specific chemicals

TABLE 33.1 Internet resources on safety.—Cont'd

Web site	Organization	Topics
Electrical safety		
http://ehssun.lbl.gov/ehsdiv/pub3000/CH08.html	Berkeley Laboratory Health and Safety	Electrical safety program
http://www.princeton.edu/~ehs/labmanual/sec7-7.html	Princeton University	Laboratory electrical safety program
http://www.ehs.uconn.edu/Word%20Docs/Electrical%20Safety%20in%20the%20Lab.pdf	University of Connecticut Environmental Health and Safety	Electrical safety in the laboratory
Fire safety		
http://ehssun.lbl.gov/ehsdiv/pub3000/CH12.html	Berkeley Laboratory Health and Safety	Fire prevention and protection program
http://www.ehs.stonybrook.edu/policy/LabFireSafetyHazardAssessment.pdf	Stony Brook Environmental Health and Safety	Laboratory fire safety hazard assessment and work practices
Radiological safety		
http://ehssun.lbl.gov/ehsdiv/pub3000/CH21.html	Berkeley Laboratory Health and Safety	Radiation safety program
http://www.jmu.edu/safetyplan/radiology/advisorycommittee.shtml	James Madison University	Radiation protection program

TABLE 33.2 Books and reference material on safety.

- Block, S. S., ed. (1991). *Disinfection, Sterilization, and Preservation*, 4e. Lea and Febiger, Philadelphia, PA
- Bloom, B. R., ed. (1994). *Tuberculosis, Pathogenesis, Protection and Control*. American Society for Microbiology Press, Washington, DC, pp. 85–110
- Centers for Disease Control/National Institutes of Health. (1999). *Biosafety in Microbiological and Biomedical Laboratories*, 4e. US Government Printing Office: US Department of Health and Human Services, Public Health Service, CDC and NIH, Washington, DC (available online from CDC)
- Fleming, D. O., Richardson, J. H., Tulis, J. J., and Vesley, D., eds. (1995). *Laboratory Safety: Principles and Practices*, 2e. American Society for Microbiology, Washington, DC
- Fredenburgh, J. L., and Grizzle, W. E. *Safety and Compliance in the Histology Laboratory: Biohazards to Toxic Chemicals* (available only at workshops)
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- Lieberman, D. F., ed. (1995). *Biohazards Management Handbook*. Marcel Dekker, New York. *Biosafety in the Laboratory: Prudent Practices for the Handling and Disposal of Infectious Materials*. (1989) National Academy Press, Washington, DC
- Miller, B. M., ed. (1986). *Laboratory Safety Principles and Practices*. American Society for Microbiology, Washington, DC
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- Richmond, J. Y., ed. (2000) *Anthology of Biosafety: I. Perspectives on Laboratory Design*. American Biological Safety Association
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- Richmond, J. Y., ed. (2000). *Anthology of Biosafety: III. Application of Principles*. American Biological Safety Association
- Wald, P. H., and Stave, G., eds. (1994). *Physical and Biological Hazards of the Workplace*. Van Nostrand Reinhold, New York. *Preventing Occupational Disease and Injury*. (1991) American Public Health Association, Washington, DC

33.3 GENERAL CONSIDERATIONS IN LABORATORY SAFETY

Safety plans should be developed and used to prevent or to minimize injuries to employees in the work environment. In order to develop an effective safety plan, the likelihood and source of specific injuries for each employee must be identified. The sources and likelihood of specific injuries depend upon the procedures/activities that employees perform (i.e., their jobs) as well as the locations in which the employees are likely to spend time. For example, though secretarial or office personnel usually would not be expected to be exposed to chemical hazards, chemical exposure might occur if the secretary/office personnel pick up material to be typed, filed, or transferred in a room in which chemicals are utilized and fumes or surface contaminations with chemicals are present. Thus, safety plans need to be specific for the individual. Similarly, the environment around the work area from the standpoint of dangers it might impose on employees should be considered.

Each person and their supervisor should identify potential sources of injury and how the likelihood of injury from these sources can be minimized via changes in procedures or engineering changes, which would include the use of safety equipment or the improvement of ventilation within a specific area.

33.4 Training in Safety

Training in safety has the same areas of focus as concerns in safety. Of the general areas of safety training, requirements for training in biohazards, chemical hazards, and radiological hazards are the most demanding.

Training in each area of safety should be given to employees before they begin their work in the laboratory. The training should be updated periodically for all employees according to governing regulations. In the United States, training of employees in safety must be updated annually. Training should be led by knowledgeable trainers in a language that is appropriate for the employees being trained. The training should be at a level that is appropriate for the educational background of each employee and for the risks to which each employee may be exposed. Thus there may be a need for different levels of training in safety based upon the needs and requirements of specific employees. Records of employee training should be maintained according to regulations; in the United States they must be kept for at least three years.

33.5 Safety Infrastructure

The Chief Executive Officer (CEO) of each institution has total responsibility for the safe operation of all components of the institution; depending on the country, the CEO may be subject to civil and criminal penalties depending on safety violations and the extent of any injuries resulting form safety violations/problems.

The CEO usually appoints a safety committee (SC), which is responsible for the overall safety plan of the institution, for periodic monitoring of the success of the safety plan (SP), for changing the safety plan to correct problems with safety, and for training in safety. The SC appoints a safety officer to administer the safety program. While a working safety infrastructure is important, the responsibility for safe operation of an organization falls primarily on each and every employee. Very large organizations that have many separate large divisions may have separate divisional safety committees and safety officers. This is especially true when specific hazards are limited to only one division. For example, a large clinical laboratory that is part of a university may sometimes have a separate safety committee, safety officer, and safety plan. Usually the administrator responsible for areas with increased safety concerns appoint these separate safety officers.

The safety officer is responsible for day-to-day issues related to safety; the safety officer establishes a training program in safety, monitors and maintains compliance with the overall safety program, evaluates safety incidents and injuries, and recommends to the safety committee changes to the safety program to prevent recurrence of incidents and injuries. Evaluations by the safety officer of safety incidents and actions to prevent recurrence are submitted to the safety committee, which evaluates needed changes to the safety plan. In the day-to-day operations of the safety program, the safety officer works closely with area supervisors to ensure local safety.

Biomedical laboratories are potentially very dangerous working environments compared to other working environments because of the many existing potential dangers. Not only are there biohazards associated with specimens of human and/or animal tissues but also with cell lines or cellular components developed or produced from humans, animals, and animal tissues as well as micro-organisms. The type of laboratory may limit the type of biohazards to which employees are exposed. Similarly, it is the rare biomedical laboratory that does not contain a wide variety of chemicals—some may be potential carcinogens and allergens such as formaldehyde; others may be teratogens, toxins, and irritants; some may be flammable/explosive. Similarly, each biomedical laboratory will have physical hazards, electrical hazards, and fire hazards. Also, many laboratories will use some type of radioactivity, and all forms of radioactivity are dangerous.

If a laboratory operates within safety infrastructure as described, the safety officer together with the laboratory supervisor(s) will monitor safety in the laboratory. If such an infrastructure does not exist at a specific organization, it may be necessary to establish mini-infrastructure in safety that follows the safety outlines described previously.

Specifically, a senior technologist needs to be appointed as a safety officer and this person will be responsible for developing a safety plan and for training of laboratory personnel in safety.

The safety plan plus the general details of the safety requirements and national regulations related to safety should be available to all employees. Providing specific actions and details to ensure safety in laboratories, especially those handling human and/or animal tissues, chemicals, and radioactivity, are beyond the scope of this chapter. Multiple books and articles are devoted to specific safety information, which are appropriate for safety training and for establishing or improving a safety program.

33.5.1 Biological Safety

Animal and especially all human tissues are inherently dangerous and must be handled with universal precautions (Grizzle and Fredenburgh, 2001). All employees of organizations handling or processing tissues must be educated in the dangers of tissues as well as governmental regulations that apply to handling or being exposed to human and animal tissues. Similarly, those transferring tissues to other individuals or laboratories should require that anyone who receives the tissues as well as all those at the receiving site who may handle or contact the tissues are educated in the potential dangers of human tissue (e.g., cuts, sticks, splashes, oral, and respiratory transmissions). They must also be familiar with applicable governmental regulations related to exposure to human tissues.

All human tissues and to a lesser extent animal tissues, whether fixed, paraffin embedded, fresh-frozen, or freeze-dried should be considered as biohazardous. As the extent of alteration of tissue increases (e.g., fresh → frozen → fixed → paraffin embedded), the risks from various infective agents usually are reduced. However, certain agents such as prions (e.g., the infective agents for Creutzfeldt-Jacob Disease, Mad Cow Disease, Deer/Elk Wasting Disease, Scappie) may still be infective even when tissues are fixed and processed to paraffin blocks. Also, spores of certain bacteria such as anthrax in animal tissues (e.g., pelts) as well as specific soils may be infective for decades. Thus, all human and animal tissues independent of their physiochemical state should be treated with universal precautions; that is, they should be handled as if infected with agents that may be pathogenic to humans (Grizzle and Fredenburgh, 2001).

Other biological hazards in laboratories may include systems for transfecting cells with specific genetic products. Biological hazards may result when the transfection system includes self-replicating viral vectors. The safety of such systems should be always considered.

Similarly, with the advent of international travel, newly identified infectious agents frequently spread rapidly through populations. An example is Severe Acute Respiratory Syndrome (SARS), which developed in China and spread rapidly to multiple countries; and monkey pox and West Nile Virus, which have been acquired in or transferred to North America from exotic pets. Similarly, with the possibility of bioterrorism, agents that may be encountered very rarely such as anthrax and small pox could represent agents to which laboratory personnel are exposed. When there is notice of a "new" disease which may be studied and diagnosed or to which employees may be exposed, a plan to deal with this condition should be developed. These laboratory safety issues are in addition to those prescribed for the usual pathogens potentially encountered in a laboratory dealing with human tissues.

In the United States, the major federal regulation (29CFR Part 1910.1030 Occupational Exposure to Bloodborne Pathogens) addresses requirements for laboratories to protect against bloodborne pathogens. Any laboratory that deals with human tissues may need to meet the requirements of this regulation. The development of a safety program in biohazards is outlined in Table 33.3.

General approaches to biosafety include identifying potential hazards without regard to standard operational procedures (SOPs) or to the use of safety equipment. After potential hazards/dangers are identified, SOPs should be modified to reduce the likelihood of injuries from biohazards. SOPs should include requirements for frequent washing of hands, for using safety equipment, for providing employees with hepatitis B vaccinations, and for related preventive medical support. Similarly, all employees should be trained with respect to minimizing biohazards. Medical support should be provided when employees are injured and work practices should be changed based on the analysis of safety incidents to prevent future injuries. The safety plan

TABLE 33.3 The key steps in developing a biosafety program.

1. Identify requirements related to biohazard safety promulgated by governmental and laboratory accrediting organizations and likely sources of up-to-date information regarding biosafety. Use this information in developing or updating an overall safety program and in training programs related to biohazards.
2. Develop the organizational infrastructure necessary to develop and maintain a safety program.
3. Identify risks and general issues of biosafety in the laboratory; this includes identification of work activities and the safety issues of each activity as well as risks in various working spaces.
4. Develop written guidelines to ensure biosafety based on published information, federal, state, and local regulations as well as local and consultant experience. These guidelines should be reviewed and updated periodically and modified as soon as possible to correct any identified problems. Maintain records of personnel safety incidents.
5. Develop and implement a training program of which a major focus is biosafety and maintain records of employee training.

should be evaluated yearly and improved to prevent the recurrence of injuries. Clear, detailed records of these approaches to biosafety should be maintained.

Most laboratories that handle human tissues for research will at some time be queried as to whether or not an individual from whom tissues were obtained is infected with HIV, Hepatitis B, C, or D, West Nile Virus, Creutzfeldt-Jakob prions, and so on. This query may be prior to use of the tissues and/or after an employee is exposed to infection by the tissue. Organizations that provide tissues for research usually will not have permission to test patients and/or their tissue for such agents. In addition, a negative test does not insure safety of the tissues for that pathogen, and for some pathogens there are no tests available. Thus, recipients of tissue specimens must agree to educate employees as to the dangers of tissues with which they come into contact, and not to test tissues for human pathogens. When an employee is exposed (cut or stick) to human biohazards immediate medical care is necessary. If the hepatitis B titer is low, a revaccination should be considered. Also, treatment with hyperimmune gamma globulin might be warranted. After acute medical care and appropriate medical advice is provided, the employee is then monitored for evidence of those human pathogens for which testing is available.

In addition to considering biological dangers associated with human tissues and materials that may be used within the laboratory, some biohazardous conditions may develop within the laboratory independent of the use of human or animal tissues. For example, the ventilation system, cooling system, condensation drains, drains of sinks, animal debris, bedding, incubators, cell culture or other growth media, refrigerators/freezers, and/or unconsumed food may develop colonization with fungal species or other biohazardous agents that especially may affect laboratory personnel who may have compromised immune systems (e.g., employees with HIV infections or those taking immunosuppressive agents such as steroids for asthma or arthritis or chemotherapeutic drugs for cancer). Also, some common fungi such as Cryptococcus may affect apparently healthy individuals. These same agents via circulating spores also may compromise biological experiments. Therefore, all biological laboratories should maintain strict standards of cleanliness, for example, with periodic decontamination of the drains of sinks and prohibition of use of food and drinking material in the laboratory. Material and debris should be cleared from the laboratory.

33.5.2 Chemical Safety

There are several federal regulations related to chemical safety that may affect repositories. These include Occupational Exposure to Hazardous Chemicals in Laboratories (29CFR 1910.1450), the Hazard Communication Standard (29 CFR 1910.1200), and the Formaldehyde Standard (29 CFR 1910.1048). Most repositories must abide by the Occupational Exposure to Hazardous Chemicals in Laboratories law (29CFR 1910.1450). This law mandates that employers develop a written chemical hygiene plan; it is the core of the standard. The chemical hygiene plan must be capable of protecting employees from hazardous chemicals in the laboratory and capable of keeping chemical exposures below the action level or in its absence the permissible exposure limit (PEL). Table 33.4 outlines the designated elements that a chemical hygiene plan must include. Laboratories dealing with fixed tissues should also understand the Formaldehyde Standard.

Most laboratories deal with relatively small amounts of most chemicals; nevertheless, even small amounts of specific chemicals may be very dangerous. Tiny amounts of some chemicals may be toxic or may be carcinogens or teratogens. Similarly ether, especially old ether that has oxidized after opening, or picric acid that has dried out, may constitute explosive hazards. Combinations of chemicals may also cause spontaneous combustion as well as accelerated heating, which may cause boiling and splashing, or even explosions. Personnel should avoid direct contact with even small quantities of carcinogens, teratogens, and/or highly toxic agents such as cyanides.

All chemicals used in repositories should have material safety data sheets (MSDS) available for reference for

TABLE 33.4 Mandated elements of a chemical hygiene SOP plan relevant to safety and health must be developed, and the following procedures need to be addressed.

1. A written emergency plan to address chemical spills. The plan should include consideration of prevention, containment, clean-up, waste disposal, and disposal of chemically contaminated materials used during the clean-up.
2. A policy to monitor the effectiveness of ventilation and to minimize exposure to potentially dangerous vapors.
3. A policy in reference to ventilation failure, evacuation, medical care, reporting of chemical exposure incidents, and chemical safety drills.
4. Policies prohibiting eating, drinking, smoking, gum chewing, and application of cosmetics in the laboratory.
5. Policies to prohibit storing food and/or beverages in storage areas or laboratory refrigerators.
6. Mouth pipetting and mouth suctioning for starting a siphon must be prohibited.
7. Personal protection should be mandated; all persons including visitors must wear appropriate eye protection. Suitable gloves should be worn where there is a potential for contact with toxic chemicals. Gloves should be inspected before using and washed before removing. The use of contact lenses in the laboratory should be avoided.
8. After handling hazardous materials, hands and other possible areas of exposed skin should be washed.

employees who potentially will come into contact with these chemicals. MSDS sheets are prepared by the manufacturer and are available from the manufacturer of the chemical. The MSDS lists the various hazards of the specific chemical to which the MSDS apply. This includes toxicity, explosive potential, and categories of danger (e.g., strong oxidizers). The MSDS also specifies procedures to minimize toxic exposures as well as contact information so that additional information on the chemical can be obtained rapidly.

Even though the dangers of most chemicals are identified in MSDS, combinations of chemicals that may be serious hazards may not be specified clearly. It may be obvious that concentrated strong acids (HCl) should never be combined directly with concentrated bases, especially strong bases (e.g., NaOH) without dilution and extreme care; however, mixing strong oxidizes (e.g., potassium permanganate) with materials with high carbon content (e.g., ethylene glycol) may cause spontaneous fires and such mixes also should be approached with great care. These are just a few of the examples that should be included in the educational program in chemical safety.

When individuals work with chemicals, the chemical safety plan should ensure that potential injuries are avoided by proper work procedures, by proper clothing and safety equipment, and by extensive education. Such approaches to chemical safety are regulated in the United States by the Department of Labor and are addressed by laws such as the Occupational Exposure to Hazardous Chemicals in Laboratories (29CFR1910.1450) and the Hazard Communication Standard (29CFR1910.1200).

There also are special laws that address particularly dangerous chemicals such as formaldehyde (the Formaldehyde Standard 29CFR1910.1048). This law has specific safety requirements for the preparation and use of formaldehyde.

Although laboratories outside the United States may be governed by separate regulations, the previously mentioned laws may provide aids in developing a chemical safety program. Also, MSDS are international and understanding such sheets is a great step in laboratory safety.

33.5.3 Electrical Safety

Electrical injuries can be avoided by ensuring that all equipment is grounded. This is ensured by testing all equipment when first purchased, and yearly thereafter. Similarly, all electrical base plugs must be in good condition and grounded. Electrical work should be done with great care, ensuring that all areas are protected by removal of fuses and with written warnings at the fuse box. Frequently personal electrical appliances such as radios, hairdryers, and so on, may be ignored when testing for grounding, and represent significant dangers. Also, great care should be taken with electrical appliances/equipment around water sources, especially sinks and bathrooms/showers.

33.5.4 Fire Safety

Fire safety can be evaluated by arranging an inspection by the local fire department. Prior to such inspections and at least yearly, fire drills should be practiced and emergency exit pathways should be posted at all room exits. Obviously, emergency exits should never be blocked, obstructed, or locked, and hallways must not be obstructed or cluttered. Similarly, access to fire blankets, showers, and fire equipment must not be impeded.

Flammable agents should be stored appropriately including storage of large amounts of flammable agents only in fire cabinets if more than several quarts of flammable agents are stored in one area. Fire cabinets or areas where small amounts of flammable chemicals are stored should not be located near the exits of rooms/areas.

Smoking should be regulated carefully; similarly, furniture, rugs, and equipment should be constructed of nonflammable material. Regulations for types of doors to serve as fire barriers should be followed as should fire requirements for construction of buildings that house specific activities (e.g., laboratories).

33.5.5 Physical Safety

The physical safety of employees is a safety consideration that must be taken into account in all organizations and for all employees. Physical safety ranges from preventing falls to ensuring employees are not physically injured or intimidated by other individuals, either employees or nonemployees. Much of a plan for ensuring physical safety involves careful maintenance of the physical plant and facilities. Tears in rugs, broken steps, and water, soap, paraffin, and other slippery substances on floors, and inappropriate use of ladders or chairs as ladders, all may lead to unnecessary falls. Similarly, unrestrained gas cylinders, unbalanced file cabinets, and inadequately secured shelves all can lead to injuries via falling or moving agents or structures. Also, included in causes of physical injuries include repetitive action injuries and back injuries secondary to inappropriate lifting as well as temperature burns both cold (e.g., liquid nitrogen) and hot.

Great care should be taken with the overall security of the workplace; this includes limiting access to the workplace by unauthorized personnel. There should be no tolerance of threats to employees, especially by other employees. The protection of employee safety from others may extend outside the direct work environment to areas surrounding the workplace, including parking areas.

Physical injuries that are more difficult to avoid include minor cuts (e.g., paper), bumps, and strains due to inattentive actions. However, such minor injuries should not be compounded by exposure, for example of broken skin, to biohazards. The other hazards that can be prevented or ameliorated (use of gloves to avoid burns) should be addressed in the overall safety program.

33.5.6 Radiological Safety

Laboratories that purchase, store, and/or use radioactive material should have a radiological safety plan. For laboratories requiring a radiological safety plan, the personnel who utilize or come into contact with radioactive material require extensive training as well as the availability of specific equipment to monitor for the extent of radiation and radioactive contamination. As with other areas of safety, the training must be periodically updated and should be appropriate for language and education of personnel. Everyone who has access to the areas where radiation is used or stored should have appropriate training. Depending on the danger of the radioisotopes used, some employees, usually those with professional degrees, may hold a local license to use specific isotopes, and these licensed personnel are responsible for the direction and supervision of all employees who work under their supervision and all spaces to which they are assigned.

Although radiation safety is a very specialized area, it can be generalized (see Table 33.5). Surveys of all laboratory areas, which can detect types of radioactive material being used in the laboratory, should be performed periodically. Gamma survey meters are an aid indicating contamination by strong β and γ emitters but periodic surveys of work, floor, and storage areas using swipes are critical to laboratory safety. Contamination can be easily spread throughout a building and even to the homes of laboratory personnel.

TABLE 33.5 Essential elements of a radiological safety program.

1. Train in radiological hazards all personnel who have access to areas where radioactivity is used and/or stored and update training periodically.
2. Monitor usage of radioactivity and maintain accurate records as to the usage, disposal, and inventory of radioactive nuclides.
3. Develop a plan to prevent and to minimize radioactive contamination.
4. Develop a plan to survey periodically for radioactive contamination all areas of the laboratory.
5. Monitor radiation exposure of all employees exposed to radiation.
6. Develop a plan to minimize the exposure of all personnel to radiation using appropriate shielding, safety equipment, and optimal procedures.
7. Develop a plan to ensure safe and secure storage of radioactive material.
8. Develop a plan to contain and clean up major radioactive spills.
9. Record and evaluate all incidents involving radioactivity.
10. Maintain careful records of all aspects of radiological safety plan.

When occupying unsurveyed laboratory space or using unsurveyed equipment (e.g., refrigerators and freezers), these should be certified as radiation free before occupancy or use.

Personnel should be shielded from exposure to radiation. This is especially important for strong β and γ emitters (e.g., ^{32}P, ^{60}Co). Not only does this require shielding but also appropriate laboratory clothing and safety equipment. Contamination is avoided by quickly and effectively containing all radioactive spills and cleaning up all spills or release of radioactivity.

33.6 CONCLUSIONS

The safe operation of a laboratory depends upon all employees working to maintain a safe working environment. This requires establishing a safety infrastructure including developing and monitoring of an effective safety plan and training as to the safety hazards associated with special types of laboratory work, such as biohazards, chemical hazards, and radiation hazards. All laboratories should consider issues in physical, electrical, and fire safety. Laboratory safety can be maintained with the careful evaluation of all safety incidents and modification of the safety plan to prevent similar incidents.

NOTE:

At the time of this publication, a U.S. regulation for protection from tuberculosis is no longer being developed.

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