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Safety Management in Chinese University Biochemical Laboratories: A Strategic Approach

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Abstract: This article examines safety management in Chinese university biochemical laboratories, emphasizing the need for improved safety awareness and standardized practices. The study analyzes challenges such as inadequate safety consciousness among researchers, risks associated with chemical reagents, and equipment-related hazards. Comparative insights are drawn from international safety management systems, particularly those in Australian universities. The research proposes solutions including the establishment of a laboratory admission system, strict management of chemical reagents, and the standardization of experimental instrument usage. The findings underscore the importance of rigorous safety protocols and preventive measures to mitigate accidents in university biochemical laboratories.

Keywords: Biochemical laboratory safety; University research laboratories; Hazard management

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1. Introduction

University biochemical laboratories are crucial sites for conducting biochemical experimental teaching and research projects, serving as essential bases for talent cultivation. These laboratories house a large number of instruments and equipment and extensively use various hazardous chemicals, narcotic drugs, bacteria, and other biological materials. The experimental operations often involve high temperatures, high pressures, and high-speed centrifugation, all of which can lead to complex and varied safety risks, making the safety management of biochemical laboratories more intricate [1].

Laboratory safety management is not only a prerequisite and guarantee for the normal conduct of teaching, research, and service work in universities but also constitutes an important aspect of university campus construction. In recent years, with the continuous expansion of university laboratories, the variety of experimental instruments, equipment, and consumables has also increased, underscoring the significance of laboratory safety management.

In May 2019, the Ministry of Education of China issued the "Opinions on Strengthening Laboratory Safety Work in Universities," which emphasized the need for the education system to establish a concept of safe development. It is crucial to learn from past safety accidents and significantly enhance the safety management capabilities and standards of university laboratories, ensuring the safety and stability of the campus and the life safety of teachers and students. Therefore, universities should strengthen the safety management of scientific research laboratories, and institutionalize, concretize, and normalize safety work to ensure the personal safety of teachers and students and the property safety of the institute [2].

2. Issues in Chinese biochemistry laboratories

2.1. Weak safety awareness among research personnel

With the expansion of universities and the increasing number of undergraduates and postgraduates utilizing research laboratories, there has been a rise in personnel turnover, leading to increased safety pressures in these laboratories. Currently, most universities emphasize teaching and research performance indicators, neglecting laboratory safety assessment indicators. This situation has fostered a mindset among university teachers that prioritizes research activities while overlooking safety management.

Simultaneously, some universities lack necessary laboratory safety education and emergency response training for teachers and students. Many researchers have a scant understanding of basic safety knowledge and exhibit weak safety awareness. For instance, some students lack proper protective awareness and the ability to handle emergencies. They conduct chemical experiments without wearing lab coats or safety goggles, are unaware of the location of fire extinguishers and other firefighting equipment nearby, and do not know how to use them.

Furthermore, some researchers with indifferent safety consciousness handle toxic volatile reagents (like acetic acid, chloroform, and methanol) outside fume hoods, touch nucleic acid dyes without protective gloves during DNA gel electrophoresis, dispose of volatile or toxic waste liquids directly in sinks, and carelessly throw biological solid waste into regular trash bins.

2.2. Safety hazards associated with chemical reagents used in experiments

In biochemical teaching experiments, reagents that are flammable, explosive, corrosive, volatile, toxic, or teratogenic are frequently employed. For instance, during the extraction and identification of nucleic acids from animal tissues, the use of strong acids like trichloroacetic acid for protein precipitation and concentrated sulfuric acid for nucleic acid identification can pose burn risks due to improper handling by students. Chloroform, utilized for RNA extraction from tissues and cells, exhibits strong volatility and significant hepatotoxicity. Barbiturates, used in serum protein acetate cellulose membrane electrophoresis, have central inhibitory effects and are harmful to the human body. Ethidium bromide, employed in agarose gel electrophoresis for plasmid DNA identification, is a highly sensitive fluorescent dye and is generally considered a strong mutagen that can insert into DNA molecules, causing base mismatches. Acrylamide and bis-acrylamide, used in polyacrylamide gel electrophoresis for protein separation, are neurotoxic and can be absorbed through the skin and respiratory tract. If students do not pay attention to personal protection during experiments, they may easily jeopardize their health. Improper storage of flammable and volatile reagents can lead to serious accidents such as fires or explosions. Additionally, the careless disposal of these harmful waste liquids can cause severe environmental damage.

Beyond teaching experiments, the hazardous chemicals used in research laboratories involve a broader and more complex range of flammable, explosive, volatile, toxic, and teratogenic substances compared to those used in teaching laboratories. The variety of instruments and equipment is wider, with more dangerous devices and large-scale instruments being used more frequently and for longer periods. Some imported equipment is also highly expensive. Biological materials are more complex, encompassing various bacteria, viruses, clinical pathological specimens, transgenic animals, various pathological animal models, and constructed plasmids. All these factors amplify the safety hazards and management difficulties in laboratories [3].

2.3. Safety hazards of experimental instruments and equipment

Biochemical laboratories are equipped with a variety of instruments, including autoclaves, laminar flow hoods, high-speed centrifuges, constant temperature water baths, electrophoresis apparatus, electric stoves, gas cylinders, and micropipettes. These instruments and equipment come with strict operating procedures, and failure to adhere to these can easily result in equipment damage and serious safety incidents.

For instance, students using centrifuges may, in an attempt to save time, neglect precise sample balancing, relying instead on visual inspection of the scale lines or improperly positioning samples. This can cause the rotor to tilt and, in severe cases, detach, leading to potential injury. When using an electrophoresis apparatus, removing the gel without disconnecting the power can pose the risk of electric shock. Operating a laminar flow hood without first turning off the UV sterilization lamp may result in prolonged exposure to UV light, causing retinal detachment and skin burns. Additionally, the simultaneous use of multiple high-power electrical appliances in teaching laboratories with aging electrical circuits can lead to overloading and electrical risks in the laboratory.

2.4. Irrational internal division of laboratory spaces

Many university laboratories in China are overcrowded, with numerous people and limited space. Instruments, equipment, and consumables fill these laboratories, most of which lack a separate preparation room. Laboratory coats are often hung in the study area or inside the laboratory itself, and there is no clear division of areas for washing. Activities such as washing hands, general laboratory equipment cleaning, and the cleaning of contaminated laboratory equipment often take place at the same sink. In some cases, study areas are located within the laboratory, increasing safety risks [4].

3. Suggestions for Chinese biochemical laboratories

3.1. Enhance safety awareness among research personnel and establish a laboratory admission system

Using Western Sydney University in Australia as a benchmark, the university employs a robust Work Health and Safety Management System. It has established a dedicated Work Health and Safety Unit (WHSU), staffed by a professional team responsible for managing work health and safety, emergency management, and workers' compensation. This department, guided by the New South Wales Work Health and Safety Act and the specific needs of the university's research and teaching, has developed tailored policies, regulations, and systems.

Furthermore, the university has instituted a Health and Safety Committee, comprised of representatives from the entire university staff. This committee is responsible for discussing and summarizing safety incidents, assisting WHSU in enhancing existing policies, regulations, and systems, and providing consultation on health and safety for teachers and students [5].

For individuals entering the laboratory, whether they are teachers, students, or researchers, mandatory laboratory induction training is required. This training consists of two components: self-study of laboratory safety training materials and on-site training conducted by laboratory managers. During a scheduled appointment, the laboratory manager guides applicants through a comprehensive laboratory tour, explaining relevant safety knowledge. This includes basic laboratory rules and regulations, the location and use of emergency facilities, experimental safety protection facilities, precautions for using various instruments and equipment, chemical storage standards, waste disposal procedures, and precautions for entering the laboratory outside of regular working hours.

Following the training, the applicant acknowledges their commitment to safety by signing a safety agreement. Subsequently, the laboratory manager grants access permissions to the corresponding rooms. For large and complex equipment, specialized experimental technicians provide operational training, and usage is permitted only after the successful completion of this training. Before commencing experiments, a laboratory risk assessment form must be submitted. This form details the experimental plan, required equipment and consumables, potential risks involved, specific incidents that might occur for each type of risk, and prevention and control methods. For experiments involving hazardous chemicals, the laboratory risk assessment form should specify the chemical names (e.g., alcohol) and their characteristics (flammable), storage and usage precautions, potential dangers, and response measures [6].

3.2. Strengthen the management of chemical reagents and replace dangerous reagents where possible

At the conclusion of each semester, the quantity of reagents, such as hydrochloric acid and chloroform, needed for the next semester is determined based on the inventory of hazardous chemicals and the number of scheduled experimental courses and classes. A written application is then submitted to the university's Laboratory and Asset Management Department and registered with the city's public security bureau. Following approval by university and college leaders, these reagents are purchased through the Laboratory and Asset Management Department and received and registered by two individuals.

To ensure the correct and safe storage of hazardous chemicals, the college invites professional organizations to conduct training on the storage of hazardous chemicals. Additionally, assessments for laboratory management personnel on the knowledge of the use and storage of hazardous chemicals are organized. Laboratories store hazardous chemicals separately from regular reagents, with solid and liquid hazardous chemicals, flammable, explosive, and volatile reagents stored individually. Regular ventilation of hazardous chemical cabinets is necessary to prevent dangerous concentrations of reagents.

When using hazardous chemicals, double registration is required, noting the usage time, quantity, and inventory to facilitate tracking of reagent usage. To actively promote reform in experimental teaching, experiments that involve significant risk and use a large number of hazardous chemicals are modified to find substitutes. This helps in reducing the risk to students. For example, nucleic acid extraction experiments now utilize reagent kits, leading to a significant reduction in the use of hazardous chemicals. Borate buffer solution replaces the anesthetic barbiturates in acetate cellulose membrane electrophoresis of serum proteins, and non-toxic or low-toxic nucleic acid dyes replace the carcinogenic ethidium bromide in agarose gel electrophoresis for DNA identification.

3.3. Standardization in the use of experimental instruments

Prior to the commencement of laboratory classes, technical staff should diligently inspect and adjust equipment such as centrifuges, electrophoresis apparatus, constant temperature water baths, and electrophoresis tanks. If any issues are identified, they should be promptly rectified by replacing faulty instruments, and ensuring that students do not utilize malfunctioning equipment.

It is essential to standardize student experimental procedures, which includes practices such as refraining from storing flammable and volatile reagents in refrigerators and ovens, ensuring proper sample balancing in centrifuges, and monitoring water levels in constant temperature water baths, and disconnecting power before removing gels from electrophoresis tanks. Additionally, installing cameras at the front and back of teaching laboratories can aid in promptly identifying and correcting improper instrument usage, thereby ensuring the safe operation of equipment.

For more complex instruments, it is advisable to create pre-recorded standard operating procedure videos in advance. These videos can cover a range of equipment, such as low-speed and high-speed centrifuges, adjustable micropipettes, UV spectrophotometers, PCR machines, nucleic acid and protein detectors, gel imaging systems, and others. Students can access these instructional videos online before class, facilitating standardized equipment usage and effectively reducing the likelihood of equipment damage and accidents.

3.4. Rational division of laboratory areas and standardization of experimental procedures

Animal laboratories, utilized for scientific research involving experimental animals, differ from general laboratories. Standardized animal laboratory structures must adhere to the regulations of various departments and meet the functional requirements of animal experiments. The basic structure of an animal laboratory should include a changing room, air shower room, clean corridor, preparation room, operation room, dirty corridor, and washing and disinfection room. This setup aims to prevent potential hazards within the laboratory area from causing harm to personnel and effectively reduce pollution risks to the surrounding environment [7].

For example, in an animal laboratory, research personnel enter the facility by swiping their card at the entrance. They proceed to the first changing room to hang their coats in a designated area and disinfect their hands with alcohol. Then, they move to the second changing room to don isolation suits, masks, goggles, and gloves before passing through the air shower in the air shower room. Upon entering the animal room, they change into slippers at a designated spot, retrieve necessary items and disinfectant in the inner preparation room, and conduct experiments in the animal operation room.

After completing the experiment, personnel must wipe down the experimental operation table, sweep the floor, mop, and spray disinfectant before leaving the operation room. They exit the barrier facility through the contaminated buffer zone, removing and placing isolation suits, goggles, gloves, masks, and hair caps in designated spots. Finally, they return to the signature room to retrieve personal items and record their activities, placing slippers in a designated area.

4. Conclusion

The study conclusively highlights the critical need for enhanced safety management in Chinese university biochemical laboratories. It identifies key challenges such as the lack of safety awareness among researchers, the inherent risks of chemical reagents, and the potential hazards posed by laboratory equipment. By examining successful international models, notably from Australian universities, this research offers a pathway toward implementing more effective safety protocols in Chinese institutions.

The proposed solutions, including the establishment of a laboratory admission system, rigorous management of chemical reagents, and standardization of experimental equipment usage, are not only practical but also pivotal in mitigating risks. These strategies aim to cultivate a culture of safety, ensuring that both students and faculty are well-versed in the best practices of laboratory safety.

This research underscores the importance of an ongoing commitment to safety, suggesting that continuous evaluation and adaptation of safety measures are essential in the ever-evolving landscape of scientific research. The study's insights and recommendations serve as a valuable guide for universities seeking to bolster their laboratory safety protocols, ultimately contributing to a safer, more productive academic research environment.

Disclosure statement

The author declares no conflict of interest.

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