

# Challenges and Remedial Measures in the Management of Hazardous Chemicals at Undergraduate Institutions



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**Abstract:** Laboratory safety management is essential for teaching, research, and experimentation in higher education institutions. As local undergraduate colleges intensify practical teaching efforts, the frequency of laboratory use increases, highlighting the growing challenge of managing hazardous chemicals. This paper analyzes the issues in hazardous chemical management at local undergraduate institutions based on actual conditions and experiences, and proposes strategies and recommendations to improve such management.

**Keywords:** Undergraduate institutions; Laboratories; Hazardous chemicals; Safety management

## 1. Introduction

In recent years, accidents in university laboratories due to issues like hazardous chemicals have drawn significant attention from all sectors of society. Most severe incidents stem from improper management, non-standard storage, incomplete procedures for requisition, and inadequate usage controls of hazardous chemicals (Yang et al., 2022). Research laboratories in undergraduate institutions play a crucial role in cultivating students' practical skills, innovation capabilities, scientific literacy, and social service awareness. With increasing emphasis on university research, experimental projects are continuously innovating and expanding, leading to a broader range of hazardous chemicals being used in larger quantities (Qi et al., 2022). Insufficient emphasis on safety education before laboratory entry for both faculty and students, along with inadequate and incomplete management systems for hazardous materials and security lapses, pose hidden dangers to laboratory safety. Laboratory safety is a critical guarantee for university research, and the management of hazardous chemicals is a key component (FRF et al., 2024). Given that hazardous chemicals are flammable, explosive, and toxic, proper management is fundamental to ensuring the property safety of universities, the lives of teachers and students, and campus security. It is also of great significance for the advancement and development of

university research. Laboratories, while being the cradle of science, are also places fraught with various safety hazards. A minor oversight can easily lead to explosions, fires, and other accidents, causing severe loss of life and property. Here are some example about safety status of laboratories:

Firstly: On April 20, 2022, an explosion occurred in a laboratory at Central South University in Hunan Province during an experiment involving hazardous chemicals. One doctoral student from the School of Materials Science and Engineering was injured, suffering extensive burns after inhaling a large amount of hot aluminum powder (Wang et al., 2024).

Secondly: On October 24, 2021, an explosion and fire broke out in a laboratory at the College of Materials Science and Technology, Nanjing University of Aeronautics and Astronautics, due to improper experimental procedures. Eleven people were injured and taken to the hospital, two of whom later died despite medical efforts (Su et al., 2023).

Thirdly: On July 24, 2021, an explosion occurred in a chemical laboratory at a glass factory in Jishui County, Ji'an City, Jiangxi Province. The explosion, caused by improper operation by a lab technician, resulted in a gas flow impact and a localized blast. The incident led to one death and one minor injury (Li et al., 2021).

In recent years, laboratory accidents in Chinese

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universities have been frequent. According to incomplete statistics, from 2001 to 2021, there were 126 laboratory accidents across major institutions in China, resulting in 127 deaths, with over 80% caused by explosions due to chemical hazards. Chemical laboratories have the highest accident rates and the most casualties (L et al., 2019). To better address safety issues in laboratories, this paper discusses some of the challenges faced in the management of hazardous chemicals at higher education institutions in China and explores ways to improve these practices.

## 2 Issues in the Management of Hazardous Chemicals at Undergraduate Institutions

### 2.1 The relevant legal system is not perfect, and the enforcement force is insufficient

The Regulations on the Safety Management of Hazardous Chemicals provide detailed provisions for the production, procurement, transportation, operation, storage, use, and recycling of hazardous chemicals. However, these regulations are not sufficiently tailored to the specific circumstances of hazardous chemicals in university laboratories, and the penalties for violations are inadequate. There is a lack of detailed rules and emergency response plans. Additionally, with the increasing number of students, many universities fail to fully comply with these regulations, leading to potential safety hazards (MS & N, 2020). The management systems lack detailed and standardized requirements.

### 2.2 Teachers and students have weak awareness of the safety of hazardous chemicals

Most undergraduate universities face challenges in managing hazardous chemicals due to large laboratory spaces, a wide range of experiments, and high student turnover, including annual graduations and new student intakes. Compounding these issues, there are often insufficient dedicated laboratory management staff, with many hazardous chemical administrators working part-time and lacking specialized safety expertise. This leads to uneven distribution of management time, creating loopholes and safety risks (Peng et al., 2018).

Safety education and training for laboratory hazardous chemicals often remain superficial and are not integrated into the regular experimental curriculum. For instance, some faculty and students combine hazardous and non-hazardous chemicals in purchase requests for convenience; others buy excessive amounts of hazardous chemicals due to poor estimation, leading to waste and environmental pollution; and some dispose of toxic and harmful

waste liquids directly into sewers for ease. These common practices in undergraduate laboratories highlight a weak safety awareness among faculty and students, further increasing the risk of laboratory accidents.

### 2.3 The special funds are insufficient and the supporting facilities are not complete

Most undergraduate universities did not adequately consider the varying risks and hazards associated with different disciplines when initially planning and constructing laboratories. As a result, many laboratories and teaching buildings are located in the same building or on the same floor, especially those involving the daily use and storage of specialized hazardous chemicals, which significantly increases management difficulties and hidden risks (H et al., 2022).

Additionally, many undergraduate institutions lack appropriate storage and handling facilities for hazardous chemicals due to limited funding or space resources. The expansion of research activities has further strained existing storage capacities, with many storage areas and equipment failing to meet national standards for hazardous chemical warehouses. Poor environmental cleanliness and hygiene management further exacerbate the risk of accidents.

### 2.4 The emergency plan is inadequate

Undergraduate institutions have yet to establish comprehensive emergency response plans for hazardous chemical accidents. For example, many do not fully understand how to use emergency equipment such as smoke detectors, emergency eyewash stations, fire sand boxes, fire blankets, and fire extinguishers. There is also a lack of thorough investigation into the purpose, process, and operating conditions of experiments, and actual drills are rarely conducted. As a result, many faculty and students, who may only observe others using the equipment, are unfamiliar with or unable to operate it themselves when needed. This lack of familiarity can lead to improper use and missed optimal rescue times during emergencies (Nasrallah et al., 2022).

Furthermore, many faculty and students are not well-informed about escape routes, which can prevent them from evacuating quickly and effectively in the event of an accident.

## 3 Strengthen Laboratory Hazardous Chemicals Safety Management Countermeasures

### 3.1 Enhance the awareness of hazardous chemical safety management

Hazardous chemical safety management is

essential for university research and a prerequisite for laboratory safety. Regular safety training should be provided to all faculty, staff, and students entering the laboratory, covering correct operating procedures, first aid knowledge, and emergency evacuation, to enhance their safety awareness.

Moreover, the management level, responsibility, and execution capability of hazardous chemical administrators directly impact the overall safety management. Strengthening the awareness, execution, and service orientation of safety administrators is crucial to reducing safety issues at their source, elevating the management of hazardous chemicals to a new level, and providing better support for university research.

### 3.2 Strengthen the construction of hazardous chemicals management team

Increase the number of full-time hazardous chemical safety managers and strengthen the management team. Recruit professionals with strong ethics, responsibility, execution capabilities, and rich experience to focus on hazardous chemical safety management. Conduct regular safety education and training to enhance the professional skills of hazardous chemical managers through systematic and specialized training. Organize periodic exchanges and training sessions at provincial or national university experimental teaching centers for managers from secondary colleges and the university level to improve their expertise.

Appropriately increase the benefits of hazardous chemical managers, and implement effective evaluation mechanisms to enhance their business capabilities and experience. This will boost their work enthusiasm and help build a highly skilled, responsible, and well-structured team for hazardous chemical management.

### 3.3 Establish a safety target management responsibility system for hazardous chemicals

Establishing a dedicated team for hazardous chemical safety management and clarifying the laboratory management structure and responsibility system is essential for ensuring the safe and stable operation of laboratories. Clearly define the responsibilities of each school department and units using hazardous chemicals within the safety management system. Follow the principle of safety first, prevention-oriented, and comprehensive governance, and strictly adhere to the requirements of dual responsibilities for each post, joint management, and accountability for dereliction of duty. Implement a three-level safety management system involving secondary colleges, experimental

centers, and individual laboratory personnel, with signed safety responsibility agreements at each level to ensure personal accountability.

Maintain records of all hazards in the laboratory, including precursors for controlled substances, flammable and explosive materials, waste liquids, gas cylinders, and steel bottles. Ensure that records match the physical inventory. Enhance awareness of hazardous chemical procurement, purchasing only the required amounts to minimize storage and waste, and control the procurement application process effectively (Figure 1).

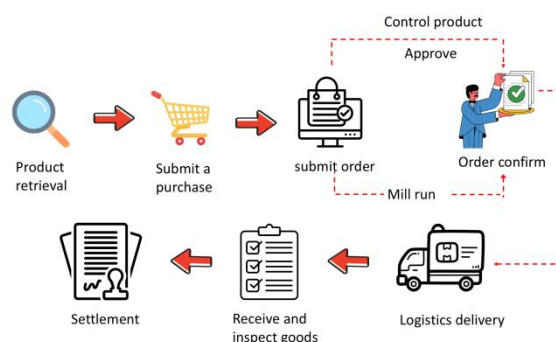


Figure 1 Application process of hazardous chemicals procurement

### 3.4 Establish strict storage requirements for hazardous chemicals

Strictly adhere to hazardous chemical storage standards by establishing proper storage areas for dangerous goods, ensuring chemicals are correctly labeled and classified (Table 1) to prevent the risk of reactions between different substances. Regularly inspect and deploy monitoring equipment to detect leaks and hazards in real time, minimizing potential harm and taking timely and effective measures.

Category	Variety	Amount
Common hazardous chemicals	1074	8465
Explosive chemicals	54	930
Precursor chemicals	28	1137
Highly toxic chemicals	9	65

Table 1 Statistical table of classification of hazardous chemicals in universities

### 3.5 Improve the management system for

## **hazardous chemicals**

Improve the management system and work norms for hazardous chemicals. Follow legal and regulatory safety management requirements and standards, and develop relevant systems based on the actual conditions of each institution. Strengthen closed-loop management and strictly control every step, including procurement, storage, issuance, and disposal.

**Procurement:** Only purchase from vendors with national qualifications. Submit procurement requests through the secondary college, obtain approval from the designated school leadership, file with the police department, and supervise unloading and warehousing on-site. Verify quantities to ensure accuracy and check for damage.

**Storage:** Store chemicals according to their properties, with clear and accurate inventory records. Classify and store them properly.

**Issuance:** Use a "system application, one-for-one return" model. Implement the "five doubles management system": dual control, dual receipt, dual issuance, dual records, and dual locks.

**Disposal:** Collect and classify toxic and hazardous waste liquids generated during experiments, clearly marking the main components, reaction processes, and quantities. Dispose of them according to relevant requirements.

### **3.5.1 Strictly control the sources of danger**

Include laboratory safety rules and regulations in foundational courses, requiring students to learn about the proper use of hazardous chemicals before entering the laboratory. Conduct safety risk assessments for all experimental projects to identify potential hazards and preventive measures. All faculty and students must complete training and pass an examination on the safe use of hazardous chemicals before they are allowed to enter the laboratory for experimental activities.

### **3.5.2 Full process coverage management**

Under the regulations for laboratory hazardous chemicals, implement full lifecycle supervision and control, covering every step from application and procurement, inventory verification, departmental review and approval, procurement, inventory check, proper use, to waste management. Ensure that all operations at each stage comply with regulations, maintaining quality and quantity standards and avoiding any unauthorized deviations. The safety responsible of the experimental training center should clearly define safety management elements at all levels of the university. University Level: Establish comprehensive evaluation metrics tailored

to each college based on their specific disciplines. Experimental Training Center: Strictly enforce the management system for hazardous chemicals, focusing on key challenges and specialties of the discipline, and proactively develop corresponding emergency response plans. Secondary College Laboratories: Implement daily access control, maintain records for goods entry and exit, and conduct regular safety self-inspections.

### **3.5.3 Check and rectify, closed-loop management**

Each secondary college laboratory should conduct daily safety checks after work and perform regular self-inspections, including targeted inspections for specific projects. The experimental training center should establish inspection teams to conduct random checks and patrols, ensuring comprehensive coverage and identifying potential issues early for timely resolution. Enhance the awareness and attitude towards rectification, implement corrective actions, and eliminate potential hazards. Ensure the reporting, registration, rectification, and acceptance of hazardous chemical safety issues. Implement a closed-loop management system of "self-inspection, notification, inspection, rectification, feedback, and acceptance" to systematically address and eliminate safety hazards, and establish a robust feedback and handling mechanism.

### **3.5.4 Carry out special safety education and training**

Establish a dedicated safety management department with specialized safety personnel. New students must complete a laboratory safety education exam before entering the laboratory. Specialized safety managers, such as those for precursor chemicals, fire safety, special equipment, and waste gas/liquid management, should hold the appropriate certifications. Ensure comprehensive education and training for all faculty and students who handle hazardous chemicals, covering basic safety knowledge, specialized safety knowledge, and emergency drills. This ensures that everyone has a solid foundation in safety basics, can proficiently use specialized rescue knowledge, and can promptly avoid potential hazards.

### **3.5.5 Modern information management**

Establish a disciplinary hazardous chemical management system through an online platform. This platform will handle all aspects of hazardous chemical usage, including application for procurement, approval, inventory management, application for use, return of leftovers, and disposal of empty containers. The management process

involves approval by supervisors and laboratory directors. The platform also facilitates sharing of hazardous chemicals. Teachers can share excess chemicals they are not currently using with others who need them, ensuring minimal inventory and reducing risks. This system ensures that chemicals are replenished as needed, maintaining low stock levels and minimizing danger. Additionally, establish a comprehensive laboratory safety patrol system. Install cameras in each laboratory, and have student assistants review the day's hazardous chemical usage and handle waste residues and liquids before leaving. In case of emergencies, notify the involved parties and supervisors immediately for on-site resolution. Document any safety issues found on the laboratory safety patrol form, report them through the proper channels, and designate supervisors as the primary safety responsible for their respective laboratories.

#### 4. Conclusion

Laboratories are crucial for experimental teaching and research in higher education institutions. Hazardous chemicals are essential for these activities, and strengthening their safety management is fundamental to ensuring laboratory safety. Safety issues related to hazardous chemicals cannot be overlooked. It is essential to strictly control the incremental risks of hazardous chemicals, raise the safety admittance threshold for university laboratories, enforce rigorous safety reviews and administrative permits, and continuously improve the safety levels of research projects and the skills of personnel.

Implement precise law enforcement, prioritize safety, and adopt modern risk monitoring and early warning systems. Establish robust safety management systems and supervision mechanisms for hazardous chemicals, enhance safety awareness among faculty and students, and strengthen the safety management workforce for hazardous chemicals. These measures ensure the safe and orderly operation of undergraduate laboratory facilities, providing a solid foundation for research and experimentation.

#### Conflict of Interest

The author declares that she has no conflicts of interest to this work.

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**How to Cite:** Yang, Y. (2024). Challenges and Remedial Measures in the Management of Hazardous Chemicals at Undergraduate Institutions. *Contemporary Education and Teaching Research*, 05(11), 389–393.  
<https://doi.org/10.61360/BoniCETR242017261102>