Journal of Electronic Research and Application, 2024, Volume 8, Issue 1
http://ojs.bbwpublisher.com/index.php/JERA
ISSN Online: 2208-3510
ISSN Print: 2208-3502

Enhancing Hazardous Chemical Management in Chinese University Laboratories: Strategies for Safety and Efficiency

Yizhe Li*

Northwest Normal University, Lanzhou 730070, Gansu Province, China

***Corresponding author:** Yizhe Li, 202131805514@nwnu.edu.cn

Abstract: This paper examines the management of hazardous chemicals in Chinese university laboratories, identifying key challenges and proposing improvements. It reviews current practices and safety measures, highlighting deficiencies such as inadequate safety systems and insufficient awareness among personnel. The study emphasizes the necessity of tailored safety management systems, the integration of digital tracking technologies like Radio Frequency Identification, and enhanced safety training for staff. The proposed recommendations aim to mitigate risks and enhance laboratory safety and efficiency. In conclusion, the paper asserts that a comprehensive approach, encompassing improved management systems, technological advancements, and educational initiatives, is essential for safer chemical handling in academic research environments

Keywords: Hazardous chemicals; Laboratory safety; RFID technology; Safety management; Chinese universities

Online publication: January 18, 2024

1. Introduction

University laboratories serve as primary vessels for conducting teaching and research activities, playing a crucial role in nurturing students' innovative and practical skills. They are pivotal in the construction of "Double First-Class" universities. Laboratories in experimental disciplines often require various reagents and chemicals, including regulated chemicals. Regulated chemicals refer to those substances that, under legal and regulatory provisions, are subject to special control measures by the state to prevent their misuse in illegal activities. This category includes highly toxic substances, precursors for drug and explosive production, civilian explosives, psychotropic drugs, and anesthetics. Improper use or management of these regulated chemicals can potentially lead to significant safety incidents, adversely impacting social stability [1].

According to relevant statistics, between 2016 and 2020, China witnessed 929 chemical and hazardous chemical accidents, resulting in 1,176 fatalities. These series of safety incidents have sounded another alarm for laboratory safety management and have drawn close attention from all sectors of society to the safe

management of hazardous chemicals. It is evident from these events that accidents caused by hazardous chemicals are characterized by their unpredictability and immeasurable consequences. Laboratory accidents inevitably lead to severe repercussions, including loss of property in scientific institutions, hindrance in research progress and project timelines, and even threats to the safety of scientific personnel. Considering the diversity of laboratories, the complexity and fluidity of personnel levels, and the characteristics of hazardous chemicals, research institutions must control the process risk factors of hazardous chemical safety management before, during, and after usage. By perfecting related laboratory safety management systems, fulfilling the responsibilities of various functional departments, and enhancing the safety awareness of scientific personnel, it is possible to prevent laboratory accidents and ensure the smooth progression of research projects, thereby providing a safe research environment for scientists [2].

2. Issues in chemical management in China

2.1. Inadequate safety management systems

In recent years, to enhance laboratory safety management, the Chinese government has introduced a series of laws, regulations, and standards regarding the procurement, storage, dispensing, and supervision of hazardous chemicals. These measures have fortified the foundation of laboratory safety management. However, in practice, some research institutes simply replicate upper-level management systems without tailoring them to their specific circumstances, leading to inappropriate safety management methods for hazardous chemicals. In some cases, the established laboratory hazardous chemical safety management methods are merely to comply with various safety "supervision inspections," and the absence of dedicated management personnel leads to loopholes in the safety management of hazardous chemicals, diminishing their practical effectiveness in safety supervision.

Although university asset management and laboratory safety management departments conduct periodic inspections of the inventory and placement of regulated chemicals, difficulties in data acquisition and timeliness result in only obtaining "static" data at the time of inspection. This limits the capability for real-time monitoring of regulated chemical usage, making it challenging to rapidly trace chemical use. Consequently, issues such as idle chemicals and expired reagents not being safely disposed of promptly, difficulty in obtaining real-time ledgers, and discrepancies between records and actual inventory are common. These issues create safety hazards in every aspect of regulated chemicals' journey into the laboratory, significantly increasing laboratory risk factors.

2.2. Non-standardized storage and access

Universities involve a wide range of disciplines using regulated chemicals, covering hundreds of laboratories with highly dispersed storage, many of which involve regulated chemicals. The diverse types and characteristics of these chemicals significantly complicate the management of regulated chemicals, making uniform, standardized, and precise management challenging to achieve. Additionally, since the management of regulated chemicals involves multiple campus authorities and secondary units, the existing uni-directional vertical management model struggles to ensure timely and effective management processes and impedes data sharing among various management and user departments. This necessitates the adoption of target-oriented informational tools to assist in enhancing management efficiency and meeting the current research needs of universities.

University laboratories are characterized by a diversity of specialties, broad research directions, and rapidly updating research content. Consequently, the use of regulated chemicals also presents traits such as variety,

quantity, widespread distribution, and frequent procurement. Many universities still have considerable room for improvement in their management approaches to regulated chemicals. For instance, although a registration system is in place for the issuance and use of regulated chemicals, the variety and high frequency of use lead to frequent inventory movements, making registration work cumbersome. Coupled with the relatively small total volume used, the importance of these processes is often overlooked by users, leading to oversights. Manual registration methods not only consume significant manpower and resources and are inefficient, but they also fail to provide real-time insight into the procurement, storage, usage, and disposal of regulated chemicals. This can lead to inventory backlog, spoilage of chemicals, and untimely disposal of waste, increasing the safety management risks of regulated chemicals.

2.3. Weak awareness of hazardous chemical safety among scientific personnel

There is a cognitive blind spot among staff regarding the hazards and adverse effects of hazardous chemicals due to insufficient awareness. Some managerial department leaders are lax in their approach, leading to a diluted sense of safety management among staff members. A portion of the personnel also lack proper professional ethics, believing that they are not responsible for any safety incidents, thus neglecting management duties. Some staff members lack higher-level consciousness, do not proactively learn new laws, regulations, and management models, and have limited knowledge of hazardous chemicals, failing to manage them scientifically in categorized and batched manners. Moreover, they show indifference towards the transportation and usage status of hazardous chemicals. The absence of an assessment mechanism related to hazardous chemicals leads to a lack of focus in staff work. Some personnel perceive overly stringent management practices as impediments to the normal use of chemicals, thus harboring resistance to enhancing management levels.

2.4. Lack of health protection awareness among employees

In dealing with hazardous chemicals, staff members fail to comply with safety regulations by not wearing protective face shields, safety goggles, protective gloves, masks, and other safety equipment. Some leaders neglect the health issues of their staff, not conducting regular physical examinations. Additionally, the volatile nature of certain hazardous chemicals is overlooked, allowing their spread throughout corridors and laboratories, and even through air circulation systems into office areas, thereby affecting the health of the staff. When transporting hazardous gas cylinders, there is a lack of adherence to strict transportation standards, including the absence of shock-proof measures and uninstalled control valves. Moreover, there is a practice of touching communal items with gloves and protective clothing contaminated with hazardous chemicals [3].

3. Several recommendations for chemical management in China

3.1. Improving hazardous chemical safety management systems

The management of hazardous chemicals should implement the principle of 'people-oriented, safety first, prevention-focused, and comprehensive management,' aiming to create a safe, efficient, orderly, and clean laboratory working environment. Research institutions should earnestly implement national laws and regulations and establish a set of hazardous chemical safety management systems that align with their specific circumstances. These systems could include procurement, storage, dispensation, waste liquid collection, and responsibilities of hazardous chemical management personnel, to better ensure laboratory safety and efficient operation. In the implementation process, consideration could be given to establishing a laboratory management leadership team, led by the institute director, who would be fully responsible for the leadership and decision-making in hazardous chemical safety management. The deputy director in charge of safety production could

serve as the deputy team leader, responsible for the development and revision of laboratory regulations, supervision of hazardous chemical use safety, hidden danger investigation and supervision, and the disposal of laboratory waste and toxic substances. The team members would include laboratory management personnel, hazardous chemical management personnel, and personnel directly using hazardous chemicals, responsible for the daily storage, use, and custody of hazardous chemicals, as well as the collection and disposal of waste. After determining the responsible persons at all levels, a safety responsibility agreement should be signed to clarify their responsibilities, linking laboratory safety management issues with the performance of related personnel, and fundamentally addressing the issue of laboratory safety responsibility.

3.2. Digital recording of chemical use and storage

Radio Frequency Identification (RFID) technology, commonly abbreviated as RFID, is a method for using radio frequency communication to automatically identify and exchange information about non-contact moving or movable objects. Owing to its advantages such as its non-contact nature, large data capacity, high information processing speed, long recognition distance, and low cost, it is widely applied in fields like logistics, retail, manufacturing, apparel, and healthcare. For instance, RFID tags are used to collect data throughout the entire process from raw material procurement, production, and processing to warehouse distribution and final sales, enabling real-time monitoring and tracking of pharmaceuticals. International logistics giants like UPS, DHL, and FedEx are actively experimenting with RFID technology for widespread use in automatic information collection, cargo tracking, and warehouse management processes.

As a novel technology in hazardous chemical management, RFID is still in its infancy and faces many challenges during its development. However, the growth of technology is a process of twists and turns. The application of RFID in the production, storage, and transport management of hazardous chemicals can address issues of low production efficiency encountered in production. At the same time, it enhances supply chain management, improving its scientific nature. Furthermore, it can fill the gaps in the logistics management of hazardous chemicals, ensuring their safety and quality to the greatest extent. With the development of RFID technology, a revolution in the field of hazardous chemical logistics management is emerging, which will become a growth point in the future economy, creating significant value [4].

Traditional laboratory hazardous chemical labels are prone to falling off and slow to update information. The use of RFID electronic tags brings significant innovation to traditional hazardous chemical storage methods. Consisting of a coil, control circuit, and storage device, RFID electronic tags store identifiable data about objects, such as numbers, names, purchase times, usage records, and responsible persons, and can be integrated with intelligent control cabinets for real-time data updates and maintenance. As the unique identification mark of each inventory hazardous chemical, RFID tags are fundamental to the entire inventory management of hazardous chemicals. Scanning RFID tags with an RFID handheld terminal forms a dynamic electronic ledger from stock entry to waste bottle disposal, which is key to establishing a sound, scientific, efficient, and standardized hazardous chemical safety management system [5].

Leveraging information technology to establish a ‘one-code-per-bottle’ system for controlled chemicals is crucial. Each bottle of reagent is assigned a unique code (compatible with RFID technology and QR code scanning) before storage, utilizing RFID technology for inventory management, accurately recording electronic information of chemicals, and ensuring real-time, dynamic management of controlled chemicals. Through various modules such as laboratory management (safety education exams, electronic usage ledgers), procurement management (unified management, standardized procurement processes), storage management (stock shortage alerts, scan-to-stock, environmental monitoring), and inspection management (user information

authorization verification, reagent usage records, safety status, reagent inventory), controlled chemicals can be monitored informatively at each stage, realizing real-time supervision of the entire lifecycle from the application, approval, storage, placement, inquiry, dispensation, recycling, to disposal, ensuring online data, network collaboration, traceability, and encrypted data storage, achieving integrated management of 'people, machine, materials, and environment.'

3.3. Strengthening safety training for laboratory personnel

Inviting professionals to conduct lectures or promotional activities in laboratories, or using brochures or videos to strengthen staff awareness of relevant laws, regulations, and laboratory systems, and to enhance their safety consciousness. Training on responsibility awareness should also be strengthened, promoting staff awareness of responsibility, so that they act conscientiously and responsibly during work, avoiding oversights in the management of hazardous chemicals due to human factors.

Periodic training using hazardous chemical safety accident case studies as warnings should be conducted. Various forms of warning education, such as accident videos, promotional boards, and firsthand accounts from victims, can be used to enhance staff safety awareness and serve as a deterrent.

Regular and appropriate emergency drills for hazardous chemical accidents should be conducted, such as how to respond to inhalation of hazardous chemical gases, emergency treatment after contact with hazardous chemical reagents, and how to respond to laboratory fires or explosions. Emergency drills can improve staff response speed in emergencies and enhance the emergency handling capabilities of all members [3].

4. Conclusion

In conclusion, the effective management of hazardous chemicals in Chinese research institutions is a multifaceted challenge that demands comprehensive and meticulous approaches. The current scenario, characterized by gaps in safety management systems, insufficient awareness among scientific personnel, and outdated storage and tracking methods, underscores the need for systemic reform and innovation.

To address these challenges, it is imperative to refine and implement safety management systems that are tailored to the specific needs of each institution, grounded in the principles of prioritizing human safety and employing a prevention-focused strategy. The integration of digital technologies, such as RFID tagging, plays a pivotal role in transforming the management of hazardous chemicals from a traditional, static approach to a dynamic, real-time, and efficient system. This technological shift not only enhances the accuracy of chemical tracking but also ensures compliance with safety regulations and facilitates a responsive management process. Furthermore, the reinforcement of safety consciousness among laboratory personnel is crucial. Through regular training, emergency drills, and the dissemination of information on hazardous chemical management and health protection, a culture of safety and responsibility can be cultivated among staff and management alike. Such an approach not only mitigates the risk of accidents but also promotes a proactive stance towards safety and health concerns.

In light of these recommendations, it is clear that addressing the current deficiencies in hazardous chemical management requires a holistic approach. This involves not only upgrading management systems and adopting new technologies but also fostering a culture of safety and responsibility at all levels of the institution. By doing so, research institutions in China can create a safer, more efficient, and more conducive environment for scientific advancement, ultimately contributing to the broader goal of societal progress and stability.

Disclosure statement

The author declares no conflict of interest.

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