Research on the Evaluation System of Laboratory Safety Management

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Abstract. The prerequisite and foundation for laboratory safety management lies in establishing a scientific and effective laboratory safety management evaluation system. This paper conducts a systematic and in-depth analysis of various potential safety hazards and existing problems during the operation of current laboratories, and comprehensively identifies latent risk factors at all levels and in all fields of the laboratory. On this basis, it evaluates and sorts out these factors, constructs an analytic hierarchy process structure, and accurately determines the weight coefficients of each evaluation index. Subsequently, the fuzzy evaluation model is applied to carry out quantitative analysis and comprehensive evaluation, ultimately forming a logically complete and highly operable laboratory safety evaluation system. Meanwhile, combined with the core findings from the construction of the evaluation system, a series of practical and effective suggestions are put forward regarding the optimization of laboratory safety management processes, the implementation of management responsibilities, and risk prevention and control, providing strong support for improving the level of laboratory safety management.

Keywords: Laboratory, Safety Management, Evaluation System.

1 Introduction

The Development Plan for the Taihu Bay Science and Technology Innovation Belt in Wuxi states that by 2030, it will be built into a globally competitive science and technology innovation center. World-class industrial clusters will be fostered in fields such as integrated circuits, the Internet of Things, artificial intelligence, biomedicine, and intelligent equipment. A number of first-class scientific research institutions will be established, and a batch of original emerging industries will emerge [1]. Here are a large number of research and development laboratories. The safety and stability of a laboratory are the prerequisite and foundation for it to exert its effectiveness. However, in recent years, laboratory safety accidents have occurred frequently both domestically and internationally. Therefore, it is necessary to strengthen laboratory safety management work, especially the construction of a safety management evaluation system.

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2 Establishment of the Laboratory Safety Management Evaluation System

Laboratory safety management is an extremely sophisticated and systematic undertaking involving a wide array of elements. The authenticity and effectiveness of evaluating the level of laboratory safety management hinge on the rational and efficient design of evaluation indicators. In the process of constructing the evaluation indicator system, the following principles should be adhered to: the principles of scientificity, pertinence, comprehensiveness and operability.

First and foremost, laboratory safety management requires clarifying the risk points of the laboratory, which mainly fall into four categories: management, personnel, environment, and materials. Among these, management covers responsibility systems, management regulations, and emergency plans; personnel can be further broken down into physical, psychological, and behavioral aspects; materials involve buildings, equipment, and hazardous substances; and the environment includes harmful and toxic factors, illumination and radiation, as well as high and low temperatures.

The evaluation index system for laboratory safety management constructed in this paper is divided into three levels in total, including 7 primary indicators, 18 secondary indicators, and several tertiary indicators. Taking "materials" as an example, it is subdivided into buildings, equipment, and hazardous substances. Among these, equipment is further broken down into experimental equipment and safety equipment, etc., while safety equipment is refined into fire-fighting facilities, emergency showers and eyewash stations, ventilation devices, access control and monitoring devices, explosion-proof devices, and so on.

Chemical safety is the top priority of laboratory safety. Under the category of chemical safety, there are 4 tertiary indicators, namely the procurement of hazardous chemicals, the storage of chemicals in the laboratory, the safety of experimental operations, and the management of controlled chemicals. Among these, the procurement of hazardous chemicals can be further divided into 4 assessment indicators, including whether the procurement of hazardous chemicals meets the requirements; whether the purchasing procedures for highly toxic chemicals, precursor chemicals for drugs and explosives comply with the regulations; whether the transportation of chemicals and hazardous gases conforms to the rules; and whether controlled drugs such as narcotics have been applied for and filed with the regulatory authorities [2].

3 Determination and Analysis of Weights in the Evaluation Index System

After the establishment of the laboratory safety evaluation index system, it is necessary to analyze and compare the importance of each assessment indicator and determine the weight of each indicator. There are many calculation methods for indicator weights, and the analytic hierarchy process (AHP) is adopted herein. The basic principle of the Analytic Hierarchy Process (AHP) is to regard the complex issue of laboratory safety evaluation indicators as a large and intricate system. Then, through the analysis of each assessment indicator, the problem to be analyzed is hierarchized, thereby constructing a multi-level analytical structure model. Finally, in accordance with the characteristics and principles of this model, a pairwise comparison and analysis of the factors at each level are conducted to determine their relative importance, followed by the construction of a judgment matrix. The pairwise comparison judgments in AHP are typically completed by domain experts, and the composition of the expert panel can significantly affect weighting reliability [3]. The expertise and consistency of expert judgments directly affect the construction of the judgment matrix and the stability of the weighting results. Therefore, the selection of experts must meet the following requirements: first, they should possess a high level of professional competence and be familiar with laboratory safety management work; second, they should be capable of identifying key issues, focusing on critical details, and raising representative questions to support rigorous pairwise comparisons.

Taking the primary indicator of safety facilities as an example, the process for determining the weight coefficients of its three secondary indicators-fire-fighting facilities, emergency showers and eyewash stations, and ventilation systems-is as follows: The judgment matrix established by an expert based on the relative importance of the three indicators under safety facilities is shown in the table 1.

Table 1. Judgment matrix table

Safety Facilities	Fire-fighting Facilities	Emergency Shower and Eyewash Station	Ventilation System
Fire-fighting Facilities	1	1/3	1/3
Emergency Shower and Eyewash Station	3	1	1
Ventilation System	3	1	1

List the matrix and then perform the calculation. It should be noted that to avoid large errors, a consistency test should be conducted to ensure its consistency. Judgment matrices with inconsistency shall be adjusted until a satisfactory level of consistency is achieved. The final weights of the evaluation indicators obtained from the calculation are shown in the table 2.

Table 2. Evaluation Index Weight Table

Primary Indicator	Weight coefficient	Secondary Indicator (Take chemical safety as an example)	Weight coefficient
Rules and Regulations	0.145	Procurement of Hazardous Chemicals	0.045
Safety Inspection	0.165	Storage of Chemicals	0.265
Laboratory Premises	0.120	Safety of Experimental Operations	0.248
Safety Facilities	0.115	Management of Controlled Chemicals	0.081
Basic Safety	0.159	Management of Laboratory Gases	0.139

Chemical Safety	0.278	Chemical Waste Disposal	0.108
Electromechanical and Other Safety	0.163	Hazardous Chemical Warehouse and Waste Storage Station	0.113

The weight coefficient of each safety indicator reflects its relative importance within the hierarchy. Among all the primary indicators, chemical safety ranks the most important, which is consistent with our common understanding. The management of chemicals is the top priority of laboratory safety management. The secondary indicators for chemical management include the procurement of hazardous chemicals, chemical storage, experimental operations, the management of controlled chemicals, experimental gas management, chemical waste disposal management, as well as the management of hazardous chemical warehouses and waste storage stations. Among these, the most important indicators are chemical storage and the safety of experimental operations [4].

4 Recommendations for Improving Laboratory Safety Management

Laboratory safety management is an important guarantee for the orderly development of scientific research and teaching in universities, and a key to consolidating the campus safety defense line and preventing accidents. To address the current pain points and difficulties in management and improve the scientific and refined management level, it is necessary to thoroughly implement the spirit and deployment requirements of documents issued by higher authorities. Taking institutional construction as the foundation, responsibility implementation as the core, capacity improvement as the starting point and cultural cultivation as the support, we will promote the institutionalization, standardization and regularization of laboratory safety management and build a full-process and full-coverage safety management system. The specific measures are as follows:

4.1 Revise and Improve Rules and Regulations, and Establish and Improve a Long-Term Management Mechanism

Formulate the 《Measures for Laboratory Safety Management》, establish and improve a sound safety responsibility system, and set up a laboratory safety management responsibility system featuring special-person supervision, multi-party coordination and hierarchical accountability, so as to ensure that responsibilities are assigned to every individual. Revise safety systems and operating procedures such as the 《Regulations on Laboratory Safety Inspection》 and the 《Laboratory Safety Education Plan》. Provide clear guidelines for laboratory safety management, enhance safety awareness, and foster good safety habits.

4.2 Strengthen Laboratory Safety Education and Implement Safety Access System

Earnestly carry out laboratory safety education, organize annual safety lectures, laboratory safety-themed activities and technical training programs, and ensure that laboratory safety awareness takes root in the minds of all participants through these diverse activities. Strictly implement the safety access system, and incorporate laboratory safety education into the freshman orientation education system. Students must receive relevant safety education before using the laboratory for the first time. At the first class of each course, safety education shall be conducted again in light of the actual course conditions and the characteristics of the equipment used.

4.3 Focus on Safety Emergency Capacity Building and Promote the Regularization of Safety Inspections

Formulate the Laboratory Safety Work Plan, The plan clarifies the work arrangements for command and coordination, emergency response, accident rescue, rectification and supervision in laboratory safety management. Relevant personnel are assigned to participate in the college's fire drills and new technology training sessions to master the correct operation methods of equipment, thus nipping potential safety hazards in the bud. Special safety inspections are carried out, mainly divided into regular inspections and unscheduled inspections. Regular inspections focus on daily safety patrols, while unscheduled inspections are targeted special checks conducted in accordance with the safety work requirements of higher authorities [5].

Vigorously promote the construction of laboratory safety culture and foster a strong atmosphere for it, integrate laboratory safety culture into the campus culture, and strive to create a sound environment for laboratory safety culture. Build a new safety publicity corridor in Training Building No.2, organize a Laboratory Safety Week, and establish a platform for laboratory safety exchange. Through these activities, enhance the laboratory safety awareness of all teachers and students. Disasters stem from trivial oversights; safety originates from a strong sense of responsibility.

5 Conclusion

Based on the practical demands of laboratory safety management against the backdrop of the construction of the Taihu Bay Science and Technology Innovation Belt in Wuxi, this paper conducts a systematic study on the development of an evaluation system. It identifies four major categories of risk points in laboratories, namely management, personnel, environment and materials, and constructs a three-level evaluation index system in accordance with the principles of scientificity and pertinence, with a focus on the core status of chemical safety. The analytic hierarchy process is adopted to determine the weight of each index and complete the consistency test, clarifying the importance ranking of core indicators such as chemical storage and experimental operation safety.

Combined with the fuzzy evaluation model, the quantitative and comprehensive evaluation of laboratory safety status is realized, and a logically complete and highly operable safety evaluation system is finally formed.

Based on the core conclusions of the system construction, this paper puts forward optimization suggestions from four dimensions: institutional mechanism, safety education, emergency response capacity and safety culture, providing a practical path for the institutionalization, standardization and regularized advancement of laboratory safety management. The evaluation system constructed in this study can serve as a quantitative tool for the scientific assessment of laboratory safety, helping universities and research institutions identify potential safety hazards and consolidate management responsibilities. It bears important practical value for preventing safety accidents and ensuring the orderly development of scientific research and teaching work, and also offers a useful reference for the construction and optimization of safety management evaluation systems for similar laboratories.

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