Mature Model of Safety Hierarchy Management Capabilities in the College Chemistry Laboratory

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Abstract. In the background of the new era, college chemistry laboratory (CCL) have been developed rapidly. The safety of CCL is related to the safety of the staff and facilities of CCL. The current laboratory safety management model has the single management dimension, and the management system is not complete, which limits its application in practical management. Based on the theory of capability maturity model for software (CMM), this paper proposes a set of process models for the safety management capability of CCL. The model is constructed from three aspects of laboratory regulation, management, and prevention, which meets the requirements of the chemical environments and achieves the continuous improvement of safety management capability in CCL.

Keywords: college chemistry laboratory (CCL); capability maturity model (CMM); safety hierarchy management; continuous improvement

1 Introduction

At present, the safety management of college chemistry laboratory (CCL) is no longer a simple training in operational skills and safety awareness but serves the whole process of safety quality education [1]. In recent years, with the number of universities' laboratories increased, safety incidents of college laboratories occur from time to time, which makes the management of CCL face serious challenges. According to relevant researches [2-3], safety issues of CCL are the most prominent in various laboratories. In terms of laboratory safety standards, international standards for hierarchy management have been developed for biological laboratories [4]. However, the hierarchy management standards for chemical laboratories still face the situation of non-uniformity and imperfection. How to effectively prevent the safety of CCL has become the key to manage CCL. Academic circles have launched many discussions on the safety management of CCL [5-7]. Besides, there is a lack of research on how to establish a scientific safety hierarchy management system to continuously improve the safety management level of CCL.

In recent years, the hierarchy management of CCL has received sufficient attention in colleges and universities but still reveals many problems, such as: imperfect safety

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management system, inadequate safety management, lack of safety protection, etc. With the comprehensive analysis of these problems, it is easy to find that there is a disconnect between the three aspects of CCL: regulation, management and prevention. How to promote the deep integration of safety regulation, safety management and hazard prevention in CCL has become the primary goal of safety hierarchy management in university chemical laboratories. The aim of this paper is to build a safety hierarchy management system based on safety regulation, safety management, and hazard prevention in CCL, which can continuously improve the safety management ability of CCL and guarantee the safety of persons and facilities.

2 Laboratory safety hierarchy management system

The improvement of safety hierarchy management in CCL is a layered, gradual process of improvement and enhancement. We can compare this process to the process of software development [8-9] and learn from capability maturity model for software (CMM) [10] with five levels and three-level indicators to propose a set of safety management models as a framework for the safety hierarchy management model of CC.

3 Safety hierarchy management maturity model

The risk level of CCL is assessed based on four elements: personnel, instruments, materials, and projects, and CCL can be divided into four levels, which correspond to the four levels of CMM. Besides, requirements are set in CCL management system according to the characteristics of each level [11]. By combining the hazard level of CCL with the levels of CMM, corresponding management standards are set for each level of laboratories, which provides guidelines for the continuous improvement of laboratories under each level.

3.1 Initial

At the initial level, the safety hierarchy management of CCL because of the incomplete safety management system, inadequate safety management, and backward safety prevention facilities, laboratory operations are disorderly. The safety hierarchy management at the initial level is unpredictable [12]. The safety work of all laboratories depends on the experience and abilities of the staff, and it changes with the knowledge and skills of staff at different stages [13]. Therefore, the safety hierarchy management capacity of the laboratory at this level is the lowest. In addition, the safety hierarchy management is in chaos and unpredictable state, which makes the security of laboratories cannot be ensured.

3.2 Repeatable

At this level, as shown in Table 1, the hierarchy management of CCL already has basic safety management regulations, with initial institutionalized management standards for laboratory personnel, activities, instruments, and consumables. By analyzing the factors affecting the safety of CCL, the key process area (KPA), public characteristic (PC) and key practice (KP) of CMM are designed. In terms of safety operations, standard operating regulations for laboratory personnel activities have been established. In terms of safety facilities, basic fire-fighting facilities and escape routes are equipped. Laboratory instrument rentals, consumable use, and personnel activities are recorded through files. The goal of the repeatable level is to standardize and institutionalize the process of laboratory safety hierarchy and management. At the repeatable level, CCL has met the requirements of low-risk type laboratory hierarchy management, the laboratories are equipped with more basic materials and equipment, and the laboratories are engaged in projects with the low-risk index.

Table 1. Repeatable indicator system

Level	KPA	PC	KP
Repeatable	Basic Management Regulations	Operating regulations	With the use of protective equipment, work area control procedures, safety training procedures, waste processing procedures, emergency plan procedures, etc.
		Facility standard	Facilities application standards, facility use standards, facility maintenance standards, facilities scrap standards
		File record	Instrument rent also records, consumables use records, personnel entry, and exit records, etc.

3.3 Defined

The hierarchy management capability of CCL at the defined level has been further refined in terms of safety regulations. As shown in Table 2, from the four aspects of personnel management, project management, material management, and instrument management, formulate a regulation that meets the management characteristics of CCL's standard. In terms of safety management, CCL improves the safety management regulation [14]. From the actual situation of laboratory safety, a safety management regulation headed by the person in charge of the laboratory and supplemented by the laboratory safety staff is established to form a safety responsibility regulation which is from the horizontal to the edge and from the vertical to the bottom. Secondly, a laboratory safety manager is set up to check and supervise the daily management of laboratory safety, forming a safety management model with both management and supervision.

Table 2. Defined indicator system

Level	KPA	PC	KP
Defined	Personnel management	Personnel category	With relevant personnel division standards, the laboratory personnel divide them into various functions
		Personnel qualification	Laboratory practitioners can have specific positions and obtain relevant qualifications
		Personnel assessment	Regular post assessment of various types of persons and adjust personnel positions for the assessment results
		Safety Training	Laboratory personnel conduct safety training and assessment and enter the laboratory after passing the assessment
	Material management	Material classification	List of material classification standards and material classification
		Material logo	The material logo contains the name of the material, the type, and the relevant profile information
		Access and transportation	There are reliable measures and management procedures to ensure the secure access and transportation of materials
		Detection and scrap	Perform regular standard inspections of materials and scrapped unqualified materials
	Instrument management	Instrument operation manual	Operation standard manual with various types of instruments
		Instrument classification	Reasonable classification of all instruments by relevant criteria
		Instrument rental and return	The instrument is leased according to the project needs [15], and it is returned according to regulations
		Instrument maintenance and scrap	Perform regular testing of the instrument, and it is maintained and scrapped by professionals
	Project management	Item category	The project is classified according to the difficulty and danger of renting instruments and the requirements [16] for the use of materials.
		Personnel structure	Experimental projects have specific project personnel structures, including applicants, experiments, security officers, etc.
		Project instrument and material	Reasonable concession and distribution of the instruments and materials required by the project

3.4 Managed

At this level, as shown in Table 3, the hierarchy management of CCL has been fully implemented in terms of hazard prevention based on the defined level. Environmental monitoring equipment that can screen for hazardous sources in chemical laboratories is installed around various hazard source facilities. When abnormalities near the hazard sources, the alarm facilities prompt the laboratory to handle the timely processing and safety evacuation. In terms of personal protection, the laboratory is equipped with complete protective facilities. Laboratory personnel need wear relevant protective equipment before and during the experiments according to the regulations of the experimental projects. After the experiment, the laboratory safety officers must handle waste according to the standard of CCL. The chemical laboratories in colleges and universities at the managed level have achieved effective prevention of predictable dangerous sources.

Table 3. Managed indicator system

Level	KPA	PC	KP
Managed	Environmental management	Environmental monitoring	Real-time monitoring of various dangerous sources of laboratory
		Real-time alarm	Establish a safety threshold, and perform real-time alarms based on real -time monitoring data
		Waste management	Perform the laboratory waste for harmless treatment
	Security	Protection standard	All kinds of experiments formulate protection standards
		Protective facilities	The laboratory is equipped with complete protection facilities according to the requirements of the experiment

3.5 Optimizing

Because the high-risk laboratory is mainly used for research experiments, the experimental process and results are unpredictable [17]. Therefore, as is shown in Table 4, risk assessment is required before conducting various experiments, and corresponding prevention measures are formulated for various types of hazardous sources. In the process of optimizing laboratory safety hierarchy management capabilities, laboratory safety management has been continuously improved during the continuous introduction of new technologies.

Table 4. Optimizing indicator system

Level	KPA	PC	KP
Optimizing	New technology	New technology assessment	Evaluate the advantages and disadvantages brought by the introduction of new technologies

		New technology introduce	Introduce emerging technologies into laboratory safety management
		Defect prevention	In the introduction of emerging technology, prevent the system, management and technical defects that may be ensured
	Dangerous source evaluation	Dangerous source detection	Regularly investigate the danger of laboratory
		Risk assessment	Make risk assessment of the hazard sources and formulate related prevention measures

Through the maturity model of the safety hierarchy management of CCL, it can not only evaluate the current safety hierarchy management capabilities of CCL, but also use the evaluation results to analyze the safety defects in the current laboratory and propose corresponding rectification measures according to the safety defects [18]. The continuous improvement of the safety hierarchy management capabilities of the chemistry laboratory provides guidelines.

4 Conclusions

According to the development model of the safety hierarchy management of CCL, this paper selects CMM of the process of focusing on the process as a model to evaluate the management capabilities of CCL. By analyzing the factors affecting the safety of university chemical laboratories, the key process domains, public features and key practices of CMM are designed from the three points of safety regulation, safety management and safety prevention, and finally clear and operable assessment criteria are formed.

The development of the safety and hierarchy management capabilities of the chemical laboratory of colleges and universities will be a long-term process that needs to go through long-term practical accumulation and exploration. Based on the management model and laboratory status of this article, finding out the weaknesses of laboratory safety hierarchy management, analyzing and formulating improvement suggestions, and promoting the continuous improvement of the safety hierarchy management of CCL will be an effective method and measure.

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