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Risk-Based Safety Governance in University Research Laboratories: A Case Study of the Institute of Earth Sciences, China University of Geosciences (Beijing)

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Abstract: University research laboratories face diverse hazards and changing operational risks. Taking the Institute of Earth Sciences, China University of Geosciences (Beijing), as a case, this study examines a risk-based safety governance approach based on benchmarking and management practice. The approach links responsibility allocation, laboratory classification, project risk assessment, personnel access, hazard rectification, and emergency preparedness. These measures are applied according to differences in laboratory and project risk. The case shows that clearer responsibilities, differentiated control, practical access training, and follow-up review can strengthen the continuity of laboratory safety management. The experience may provide a practical reference for universities managing research laboratories with varied risk profiles.

Keywords: University research laboratory; Laboratory safety; Risk classification; Laboratory safety governance; Closed-loop governance

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1. Introduction

University research laboratories are important settings for scientific research and student training, but their operation often involves multiple hazards and changing experimental conditions. In China, the revised Work Safety Law emphasizes risk classification and hazard investigation [1]. The Ministry of Education has also issued requirements concerning laboratory safety responsibilities, safety education, laboratory classification, project safety review, and hazard rectification [2–3].

Previous studies have examined laboratory safety from the perspectives of responsibility systems, personnel access, risk assessment, information management, and emergency response [4–9]. International

research has also highlighted the roles of human factors, equipment, safety training, and safety climate [10–13]. In practice, however, laboratory classification, project risk assessment, personnel access, inspection, and rectification are not always well coordinated, particularly in research laboratories with varied hazards and experimental activities.

Against this background, the present study takes the Institute of Earth Sciences, China University of Geosciences (Beijing), as a case and draws on benchmarking and routine management practice. It examines how responsibility allocation, laboratory classification, project risk assessment, personnel access, inspection, and emergency preparedness can be coordinated in laboratory safety management.

2. Current safety governance and benchmarking analysis

2.1. Risk characteristics

The Institute currently manages 60 laboratories with a total area of approximately 3,600 m². These laboratories involve chemical, electrical and mechanical, radiation, and compressed-gas risks. They also contain hazardous chemicals and operate high-temperature, high-pressure, and high-power instruments and equipment.

According to hazard characteristics and overall risk levels, 3 laboratories are classified as Level I, 4 as Level II, 28 as Level III, and 25 as Level IV. Considerable differences exist among laboratories in terms of hazard type, experimental activities, personnel composition, and equipment conditions. Uniform requirements alone are therefore insufficient to address different laboratory risk scenarios, making differentiated control necessary.

2.2. Benchmarking of laboratory safety governance

Benchmarking visits and discussions were conducted with the School of Chemistry and Chemical Engineering at Nanjing University, China University of Mining and Technology, and relevant schools at China University of Geosciences (Beijing). Although these institutions face different hazards and operating conditions, the benchmarking identified several practices related to responsibility allocation, risk classification, technical support, and emergency preparedness.

Table 1. Benchmarking of laboratory safety governance practices

Institution	Observed laboratory characteristics	Main practices	Key implications
School of Chemistry and Chemical Engineering, Nanjing University	Large number of researchers, hazardous chemicals, and complex hazards	Hierarchical responsibility, grid-based management, digital inspection, intrinsic safety measures	Refine responsibility allocation and strengthen technical support
China University of Mining and Technology	High-temperature equipment, reactors, and radiation facilities	Risk assessment, laboratory classification, hazard control, and multilevel inspection	Link risk classification with hazard rectification
School of Materials Science and Engineering, China University of Geosciences (Beijing)	Gas, electrical, and mechanical risks	Gas monitoring, mobile inspection, safety-skills training	Integrate digital management with practical training
School of Water Resources and Environment, China University of Geosciences (Beijing)	Gas cylinders, hazardous chemicals, and laboratory waste	Centralized cylinder management, whole-process records, joint emergency drills	Strengthen process control and emergency coordination

Note: The table was compiled from previous benchmarking activities and internal investigation materials.

The benchmarking results suggest that laboratory safety governance is moving beyond rule-based control and routine inspection toward an integrated approach combining risk classification, responsibility allocation, process control, technical support, and capacity building. For complex research laboratories, the key issue is therefore not only whether management rules exist, but whether management measures are appropriately matched to actual risks.

2.3. Main problems

The Institute has established basic mechanisms for responsibility assignment, personnel access, risk assessment, inspection, and emergency management, but several gaps remain. Safety responsibility needs to extend more clearly to individual laboratory users; laboratory classification requires closer coordination with project risk assessment, personnel training, and inspection requirements; general safety education needs stronger alignment with specific hazards and experimental scenarios; repeated hazards require stronger review and cause analysis; and information generated through access control, risk assessment, inspection, rectification, and emergency management needs to be better connected.

3. Risk-based safety governance framework

3.1. Extending responsibility to individual laboratory users

Safety responsibilities are defined at four levels: university, institute, laboratory, and individual user. In addition to responsibility agreements between the university and the Institute and between the Institute and laboratories, each laboratory requires users to sign a safety commitment before access is granted.

Laboratory leaders are responsible for safety education, hazard communication, project risk assessment, and access management. Individual users are responsible for following operating procedures, applying protective measures, and conducting experiments in accordance with safety requirements. This arrangement makes responsibility traceable to both the laboratory and the individual user.

3.2. Laboratory classification and differentiated risk control

Laboratories are assigned to Levels I–IV based on the hazards present, equipment conditions, and the types of experiments conducted. The assigned level is then used to determine inspection frequency, training requirements, and other safety measures. Higher-risk laboratories consequently receive more frequent supervision and stricter control.

Risk assessment is also carried out for individual research projects before experimental work starts. The assessment identifies relevant hazards, such as chemicals, gas cylinders, high-temperature or high-pressure equipment, and radiation devices, and specifies the measures required for safe operation and emergency response. Laboratory classification describes the general risk conditions of a laboratory, whereas project risk assessment focuses on the particular activities to be undertaken. Using the two together allows safety requirements to reflect both laboratory conditions and experimental tasks [10].

3.3. Tiered access and competence matching

Laboratory access is managed at the university, institute, and laboratory levels. The first two levels mainly address common safety requirements. Training at the laboratory level is more closely related to the hazards, equipment, and experimental activities that users will actually encounter.

For newly enrolled students in 2025, laboratory-level access also required a Research Project Risk Assessment Form and a Laboratory Safety Access Training Record. Access approval was linked to a sequence of training, assessment, project risk assessment, practical exercise, review, and door authorization.

This procedure gives practical competence a greater role in access decisions. Students are expected not only to understand safety requirements but also to demonstrate the ability to respond to risks associated with their experimental work. Previous studies have noted differences between safety training in instructional and research laboratories [12], and have also reported an association between safety knowledge, skills, and students' safe behavior [13].

3.4. Risk-based inspection and closed-loop rectification

Inspection intensity is adjusted according to laboratory risk level, allowing greater attention to higher-risk laboratories and critical activities.

Identified hazards are assigned to responsible persons for rectification and subsequent review. For repeated problems, further analysis considers possible causes related to personnel training, facility conditions, operating procedures, and responsibility implementation. Corrective measures are then adjusted according to the review results. This prevents hazard management from ending with a single rectification record and strengthens follow-up control.

3.5. Emergency preparedness and information support

Emergency exercises are organized according to major laboratory risks. In 2025, practical training covered electric shock, burns, cuts, battery fires, nitric acid burns, and hazardous-waste leakage.

Information on personnel access, project risk assessment, night experiments, inspection, and rectification is also linked at the laboratory level. These records can be used to identify laboratories requiring additional attention and to adjust subsequent inspection or training arrangements. Previous work on university laboratory process safety has similarly emphasized the importance of emergency support and information continuity [11].

Overall, these measures connect responsibility, laboratory classification, project risk assessment, personnel access, inspection, and emergency preparedness within routine laboratory management. The common principle is to match management measures with the actual risk conditions of laboratories and experimental activities.

4. Operational Outcomes

4.1. From uniform management to differentiated control

All 60 laboratories managed by the Institute have been incorporated into the four-level classification system: 3 Level I, 4 Level II, 28 Level III, and 25 Level IV laboratories. The classification is used not only to identify risk levels but also to inform inspection frequency, training requirements, and safety conditions.

Project risk assessment coverage has reached 100% [14]. Combining laboratory classification with project-level assessment has therefore shifted safety governance from relatively uniform requirements toward differentiated control based on both laboratory-level and project-specific risks.

4.2. From knowledge-based access to competence-based access

From 2020 to 2025, the number of participants in laboratory safety access training increased from 276 to 1,093, representing an increase of 296% [14]. Along with the expansion in training coverage, access control has extended from basic safety knowledge to risk identification, standardized operation, and emergency-response skills.

In 2025, 174 newly enrolled students completed university-, institute-, and laboratory-level access assessments and obtained laboratory access qualifications. Laboratory-level access incorporated targeted training, project risk assessment, documentation review, and practical exercises. Nearly 70 new students participated in emergency exercises, and practical assessment results were linked to laboratory door authorization.

Personnel access has therefore moved beyond the model of "passing an examination before entry" toward a whole-process approach linked to experimental risk and practical competence.

4.3. From hazard rectification to closed-loop tracking

Through risk-based inspection, inspections during key periods, and routine checks, hazard identification, rectification, and review have been integrated into a continuous process. Previous operational data showed that the hazard rectification rate reached 100% [14]. Repeated problems are subject to further cause analysis and review of rectification effectiveness.

Overall, implementation of the framework has produced three observable changes: management has shifted from uniform requirements toward risk classification; the focus has moved from post-event problem identification toward proactive assessment before experiments; and hazard management has extended from one-time rectification toward follow-up review and continuous improvement.

5. Conclusion

This study examined a risk-based safety governance approach for university research laboratories by linking responsibility allocation, laboratory classification, project risk assessment, personnel access, inspection, hazard rectification, and emergency preparedness. The case shows that combining laboratory-level classification with project-level assessment can support differentiated control, while practical training and follow-up review can strengthen personnel access and hazard management. The experience is based on one university unit, and its applicability may vary across laboratory types and management conditions. Further studies may use additional quantitative indicators to evaluate its effectiveness in different laboratory settings.

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Disclosure statement

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