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Research on the Construction of Modern Safety Governance System for University Laboratories from the Perspective of Balancing Development and Security

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Abstract: Laboratories in universities serve as core hubs for talent cultivation and scientific and technological innovation, while also functioning as key governance units with concentrated risks. Grounded in the requirement of balancing development and security, this paper centers on the modernization of university laboratory governance. It identifies prominent deficiencies in current laboratory safety administration and systematically elaborates systematic governance pathways from six dimensions: responsibility framework establishment, implementation of the dual prevention mechanism, safety education for personnel, hardware support and emergency guarantee, digital empowerment, and safety culture cultivation. The study concludes that priority should be given to source prevention, closed-loop management and proactive early warning. It is essential to clarify the authority and responsibility boundaries at all levels, consolidate risk chains through classified and graded control, and facilitate the transformation of safety management from post-incident response to pre-incident prevention via digital tools. Continuous efforts should be made to foster laboratory safety culture, preserve the vitality of research openness on the premise of maintaining a solid safety bottom line, and deliver robust safety support for high-level innovation and talent training in universities.

Keywords: University Laboratories; Safety Governance; Dual Prevention Mechanism; Digital Empowerment; Laboratory Safety Culture.

1. Introduction

University laboratories constitute the core carrier for talent development, scientific innovation and disciplinary advancement in higher education institutions. They act as innovation hubs for exploring unknown frontiers and generating original research outputs, and meanwhile stand as critical control zones with densely distributed hazard sources and intertwined risk chains [1]. Functionally, these laboratories bridge the cutting-edge of basic research and original innovation on one side, and the foundation of practical teaching and talent cultivation on the other. Their operational performance exerts a direct bearing on institutional research competitiveness and education quality. Nevertheless, such facilities accommodate a wide spectrum of hazardous agents including chemical reagents, high-pressure gas cylinders, special equipment, radiation sources and biological samples. Insufficient supervision may readily trigger safety accidents with casualties, property losses and severe social repercussions.

The expansion of higher education, rapid emergence of interdisciplinary subjects and growing sharing of research platforms in recent years have brought profound shifts to the risk landscape of university laboratories. Diversified experimental categories, increasingly complex hazard sources, highly mobile researchers and frequent cross-departmental and cross-institutional collaboration jointly amplify risk coupling and uncertainties. Meanwhile, conventional governance relying on segmented and campaign-style inspections suffers from delayed risk identification, weakened accountability transmission, severe information silos and inadequate emergency preparedness, which cannot meet the practical demands of laboratory safety governance under new circumstances[2]. Balancing open innovation and safety control within laboratories to protect the life and health of faculty and students as well as campus safety represents an inherent requirement for implementing the holistic national security concept and advancing high-quality development of higher education. It also stands as a critical challenge that university safety governance must tackle effectively [1].

Essentially, advancing the modernization of laboratory safety governance entails reconstructing the logic of safety governance from a systematic perspective. It facilitates the transformation of governance paradigms: from passive response toward proactive risk prevention, from experience-based administration toward scientific management, and from isolated efforts by a single department toward multi-stakeholder collaborative governance. This paper systematically elaborates pathways and key priorities for modernizing safety governance in university laboratories across six dimensions: accountability framework, dual prevention mechanism, personnel safety training, hardware infrastructure and emergency response, digital empowerment, and safety culture development.

2. Organization of the Text

2.1. Consolidating the Hierarchical Accountability Chain and Refining the Laboratory Safety Responsibility System

The safety accountability system serves as the fundamental pillar for laboratory governance. Ambiguous obligations and weakened accountability transmission constitute major

triggers for the recurrent occurrence of hidden hazards[3]. Laboratory safety covers multiple domains including research, teaching, asset administration, logistics and infrastructure construction, and involves diverse stakeholders ranging from university administrators and functional departments to faculties, research groups and experimental operators. Only with clear accountability boundaries and an unbroken transmission chain can all regulatory requirements be implemented down to specific posts, individuals and tasks.

At present, noticeable deficiencies remain in the accountability framework construction within several universities. Certain institutions narrowly attribute laboratory safety solely to the safety management division, resulting in low engagement from research, asset and logistics departments. Vague boundaries between power and responsibility thereby create blind spots in supervision. Some academic departments fail to fulfill primary obligations, treating safety inspections as perfunctory routines to satisfy superior requirements while prioritizing formalities over practical outcomes. A small number of supervisors and principal investigators overemphasize research outputs at the expense of safety supervision, providing insufficient safety guidance and lacking in-process oversight for students. The root cause shared by these issues lies in an imperfect accountability system and ineffective delivery of safety responsibilities.

In response to these challenges, universities shall rigorously enforce the principle of "Party and administration share identical responsibilities, each post bears corresponding obligations, joint management is pursued, and accountability is imposed for dereliction of duty". A responsibility chain featuring university-level overall coordination, primary accountability by academic schools, implementation by research teams, assignment to individual posts, and collaboration among functional departments should be established. Such a framework clarifies the authority and responsibility demarcations for departments covering research, asset management, logistics, infrastructure and safety administration, so as to eliminate supervisory blind zones[4]. Principal investigators and supervisors must bear primary safety obligations. Safety review, in-process monitoring and safety instruction for students should be integrated into supervisors' research duties, encouraging researchers to voluntarily fulfill safety obligations while pursuing academic achievements[5]. Traceable assessment and accountability mechanisms for safety performance need to be developed. Safety outcomes shall be linked to school evaluation, project approval, supervisor merit assessment and platform access qualification, shifting the management logic from passive rectification to proactive responsibility-taking[6]. Meanwhile, systems for safety commitment and tiered safety briefing should be refined to cascade responsibilities from administrative leaders to frontline operators. This arrangement ensures that every laboratory, every risk category and every operational activity is assigned a designated responsible person[7], translating the core notion that safety responsibilities carry immense weight into concrete practices.

2.2. Deepening the Dual Prevention Mechanism and Implementing Hierarchical Risk Management and Closed-Loop Governance of Hidden Hazards

The dual prevention mechanism consisting of graded risk control and hazard identification and rectification serves as the core instrument for laboratory safety governance. It also represents a pivotal institutional arrangement to shift safety management forward and realize source-based risk control[8]. This mechanism prioritizes risk containment before hazards emerge and hazard remediation prior to accidents, so as to forestall and resolve major safety risks at the source.

From the perspective of hierarchical risk control, university laboratories host a wide spectrum of hazard sources with highly variable risk attributes. Furthermore, risks within a single lab shift dynamically as experimental projects get updated, making uniform one-size-fits-all control measures inapplicable to such complex scenarios. Universities shall conduct systematic hazard identification and assessment covering chemical, biological, radiation, special equipment and other hazards, based on risk probability, damage severity and control difficulty. They should build up a dynamic risk inventory and adopt differentiated management according to risk tiers and categories[9]. Red and orange high-risk sites deserve intensive oversight, equipped with independent monitoring alarms, real-time video surveillance and physical isolation barriers. For ordinary risk locations, control resources shall be allocated moderately so that excessive restrictions will not stifle regular research activities. Special risk reviews are mandatory for high-risk trials, exploratory reactions and scale-up experiments. Limits on experimental scale, protective conditions and on-site supervision must be set to curb the risks of operational runaway at the source[10].

For hazard identification and rectification, universities shall optimize the closed-loop workflow of hazard management. Four inspection modes should be distinguished: routine self-inspection by staff, school-level patrols, university-wide random checks, and ad-hoc special supervision. A standardized six-step procedure should be formulated: identification, registration, root cause analysis, rectification, re-inspection and case closure[11]. It is critical to abandon the superficial campaign-style inspections and checklist-only rectification. For recurring common hazards, managers must dig deep into root causes rooted in administration, facility conditions and personnel competence. Simple remedial actions should not replace systematic governance, shifting hazard control from isolated case handling to holistic risk mitigation[12]. Inspection frequency, protective resources and supervision intensity should be allocated differentially according to graded risk results to achieve targeted control. This arrangement prevents misallocated regulatory resources and avoids excessive restrictions that stifle research innovation[13]. By tightly linking graded risk control with hazard rectification, universities can form a full closed loop covering risk identification, evaluation, control, screening, remediation and feedback, keeping all safety risks consistently under effective control.

2.3. Building a Hierarchical and Categorized Training System to Consolidate the Foundation of Personnel Safety Competence

Personnel safety education and competency development lay the foundational groundwork for preventing unsafe human acts[14]. All rules, technical schemes and protective facilities for laboratory safety management rely ultimately on human implementation and operation. The safety literacy of practitioners directly shapes the overall performance of risk control. Statistical analysis of accident records reveals that unsafe behaviors of individuals frequently serve as the primary trigger for safety incidents. Therefore, enhancing personnel safety competency carries fundamental significance for accident prevention.

Several universities still have conspicuous defects in safety education implementation. Some training programs adopt identical materials for all participants regardless of their backgrounds and proficiency levels, reusing the same teaching slides throughout. Other assessments turn into perfunctory formalities, prioritizing credit hours over practical learning outcomes. In certain cases, training is treated merely as a one-time entry requirement without continuous learning activities aligned with experimental cycles. Given the distinct demands of diverse groups including new students, newly recruited researchers, laboratory technicians, supervisors and safety administrators, simplistic and uniform training schemes fail to effectively improve practical safety capabilities.

To address these drawbacks, universities should abandon the conventional model where a single training session grants permanent qualification and establish a tiered, categorized and phased safety education framework with customized content for different groups[15]. For junior students and new entrants, training focuses on basic hazard recognition, standardized operation protocols and fundamental emergency response skills. For supervisors and principal investigators, the curriculum emphasizes risk demonstration and safety accountability within research teams. Safety administrators receive specialized training covering risk evaluation, regulatory standards and root-cause tracing of hidden hazards[16]. Scenario-based instruction, hands-on drills and case reviews of past accidents are recommended to translate abstract safety theories into actionable response capacities. Such approaches improve training effectiveness and reduce over-reliance on written-only assessments[17].

For access administration, universities must enforce strict authorization systems based on qualification evaluation. Personnel are prohibited from conducting independent experimental operations unless they pass relevant training assessments. Researchers moving across platforms and departments need to complete secondary access verification and supplementary platform-specific safety training[18]. Additionally, postgraduate students and postdoctoral researchers can be recruited as frontline safety correspondents. This practice streamlines channels for hazard reporting and introduces a tolerance-and-incentive mechanism to ease reporters' concerns[19]. Frontline staff thereby act not only as safety implementers, but also as risk identifiers and reporters, fostering a participatory safety governance pattern involving all members.

2.4. Improving Hardware Support and Emergency Systems to Build a Physical Barrier for Risk Mitigation

Hardware support and emergency response systems constitute physical barriers for risk mitigation and accident loss control[20]. Laboratory infrastructure, protective equipment and waste disposal capacity jointly determine the tolerance and mitigation potential against hazards, which exert direct impacts on accident likelihood and severity of consequences.

In terms of hardware infrastructure, the "three-simultaneity" principle for safety facilities should be implemented throughout new construction, expansion and renovation of laboratories. Ventilation, explosion-proof, anti-seepage and isolation installations, gas detectors, emergency showers and eye wash stations shall be designed, constructed and commissioned simultaneously to avoid inherent hardware defects at the source[21]. For existing laboratories, sufficient personal protective equipment should be deployed in accordance with risk grades. Special equipment and monitoring alarms require regular calibration to prevent operations under faulty conditions. For hazardous chemical management, full-lifecycle circulation procedures must be standardized, covering acceptance upon procurement, limited-volume requisition, locked cabinet storage and traceable record-keeping. Precursor chemicals for drugs and explosives should be rigorously supervised to prevent loss and uncontrolled diffusion[22]. Regarding waste handling, hazardous waste shall be collected by category, marked with standardized labels, stored separately in designated zones and transferred periodically to licensed disposal contractors. Mixed storage and unauthorized dumping are strictly forbidden[23]. Gas cylinders, pressure vessels and high-pressure installations demand routine inspection and maintenance, together with complete lifecycle files. Outdated or malfunctioning devices should be suspended for timely assessment[24], so as to constrain the formation and escalation of risks from the hardware perspective.

For emergency response, emergency plans should be tailored to specific risk scenarios instead of adopting generic templates. Response protocols are formulated for distinct hazards such as chemical spills, fires, poisoning and deflagration, with clarified evacuation routes, communication channels and division of rescue responsibilities. Unscripted field drills should be organized regularly to strengthen core capabilities including on-site isolation, power cutoff, protection deployment and evacuation. This approach addresses the common weakness that personnel can understand written plans yet panic amid real emergencies[25]. Meanwhile, university-local government coordination mechanisms need to be refined. Linkages with fire services, disease control agencies and environmental authorities should be established to enable information sharing and joint response, improving the capacity to tackle severe incidents. Such arrangements guarantee rapid reaction and effective loss containment once risks run out of control, thereby maximizing the protection of faculty and students.

2.5. Promoting the Digital Transformation of Smart Supervision to Improve the Efficiency of Targeted Risk Governance

Digital intelligent supervision serves as a critical enabler for transforming governance modes[26]. Conventional

manual inspections and paper-based record-keeping suffer from delayed information updates, uncovered monitoring spots and difficult traceability. Such approaches cannot adapt to large-scale, highly mobile and cross-platform research activities, nor satisfy practical demands for real-time risk perception and targeted control.

Building an integrated laboratory safety supervision platform supported by the Internet of Things, sensor monitoring, intelligent video recognition and big data analytics represents an effective solution to the bottlenecks of conventional management[27]. This platform connects monitoring terminals for gas concentration, temperature and humidity, pressure and smoke detection, with tiered alarm thresholds configured to realize real-time risk perception and automatic notification of anomalies. By interconnecting data streams covering reagent procurement, collection and return, waste handover, equipment maintenance, training assessment and hazard submission, information silos can be eliminated to achieve full-factor traceability. In this way, risk status can be perceived, experimental procedures tracked, and abnormal signals alerted in a timely manner[28]. Risk profiling based on historical alarm logs, hazard records and training datasets helps identify high-incidence risk zones and frequent non-compliant operations. It supports targeted allocation of management resources and shifts the safety management paradigm from staff searching for hazards to hazard alerts guiding staff[29].

It should be emphasized that digital construction is not merely a digital migration of offline workflows, but focuses on reshaping the underlying management logic. Meanwhile, it is essential to strike a balance among safety supervision, research confidentiality and experimental privacy protection. Data access permissions shall be rationally configured to maintain controllability without rigid restrictions, avoiding excessive technical constraints that hinder regular scientific exploration[30]. In-depth deployment of intelligent supervision enables digital tools to function as a multiplier for improving laboratory safety governance efficiency, rather than an extra procedural burden placed on researchers.

2.6. Cultivating a Regular Safety Culture to Shape an Endogenous and Self-regulated Safety Ecosystem

Cultivating long-term safety culture constitutes the intrinsic foundation for sustainable safety governance[31]. Regulations, technical means and facilities act as rigid constraints, yet safety culture determines whether such constraints can be effectively implemented and voluntarily followed by researchers. Sustained improvement in safety governance performance relies on immersive and regular cultural cultivation.

At present, safety culture development in some universities remains confined to display posters and centralized lectures, marked by conspicuous formalism and superficiality, which hardly fosters self-conscious safety behaviors among faculty and students. Therefore, relevant initiatives should go beyond superficial publicity and be integrated into routine communication scenarios such as research group meetings, pre-experiment briefings and safety salons. These efforts help shape a research norm: complete risk assessment before experiments and halt operations immediately once abnormalities emerge[32]. Regular accident warning education should be carried out, where faculty and students review typical laboratory incidents to identify triggering factors and cascading evolution paths. Such activities help eliminate the psychology of luck and keep safety awareness alive throughout daily research work[33]. Research teams are encouraged to formulate operational protocols and risk reminder cards independently, embedding safety requirements into specific operational details. This practice helps internalize safety rules into researchers' voluntary conduct and builds a safety cultural ecosystem where everyone assumes and fulfills corresponding responsibilities[34].

3. Summary

Advancing the modernization of university laboratory governance essentially means reconstructing the logic of safety governance with systematic thinking. It balances innovation-driven development and safety boundaries and embeds risk prevention and control into the whole lifecycle of scientific research. This initiative represents a long-term systematic project requiring persistent efforts as well as fundamental work that demands meticulous implementation. Universities should continuously promote coordinated progress among accountability frameworks, dual prevention mechanisms, intelligent supervision, emergency support and cultural development. They need to remedy governance deficiencies and mitigate compound and dynamic risks. While firmly safeguarding the safety baseline, universities can preserve the vitality of open research, establish a solid safety foundation for breakthroughs in basic research and the cultivation of top-notch innovative talents, and offer robust support for high-level self-reliance and strength in science and technology.

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References

[1] Publicity Department of the Communist Party of China Central Committee, & Office of the Central National Security Commission. (2022). Outline for studying the overall national security outlook. Xuexi Press, People's Publishing House.

[2] Wu, G., & Li, E. J. (2024). Reflections on the modernization of university laboratory governance under the background of balancing development and security. Experimental Technology and Management, 41(2), 1–5.

[3] Wang, S., & Chen, J. (2022). Construction of safety responsibility assessment and traceability accountability system for university laboratories. Laboratory Science, 25(2), 214–217.

[4] Liu, H., & Yang, L. (2022). Research on the collaborative safety management mechanism of laboratories in interdisciplinary research platforms. Experimental Technology and Management, 39(5), 274–277.

[5] Xu, J., Jia, S., Li, Y. N., et al. (2024). Exploration of open management mode for biochemical teaching laboratories in universities. Research and Exploration in Laboratory, 43(9), 229–232.

[6] Shao, S., & Wang, L. (2023). Construction of safety performance evaluation index system for university laboratories. Laboratory Science, 26(4), 228–231.

[7] Cui, Y., & Wu, J. (2024). Research on laboratory safety supervision of off-campus cooperative research projects in

universities. Research and Exploration in Laboratory, 43(3), 292–295.

[8] Huang, D. J. (2017). Discussion on the construction of dual prevention mechanism for hierarchical safety risk control and hidden hazard investigation and governance. China Work Safety, 12(7), 36–38.

[9] Wang, H. Y., & Li, J. (2023). Research on hazard identification and risk grading methods for university chemical laboratories. Research and Exploration in Laboratory, 42(1), 294–298.

[10] Chen, R., & Liu, Y. J. (2024). Research on safety review mechanism for exploratory research experiments. Laboratory Science, 27(2), 218–221.

[11] Liu, X. L., Li, E. J., & Zhang, Z. Q. (2021). Construction of closed-loop management mode for hidden hazards in university laboratories. Research and Exploration in Laboratory, 40(8), 290–293.

[12] Li, X., Huang, K., & Zhou, Y. (2023). Research on traceability and governance path of recurring hidden hazards in university laboratories. Experimental Technology and Management, 40(4), 261–264.

[13] Fang, J., & Lu, Z. (2022). Construction of dynamic hierarchical risk control model for university laboratories. Experimental Technology and Management, 39(7), 268–272.

[14] Song, Y., & Gao, D. F. (2020). Practice of improving safety management system and management capacity of teaching laboratories in universities in the new era. Experimental Technology and Management, 37(1), 1–4.

[15] Zhu, X. M., & He, S. P. (2023). Construction of hierarchical and categorized safety training system for university laboratories. Research and Exploration in Laboratory, 42(8), 288–291.

[16] Wu, Y., & Ma, W. T. (2023). Research on the application of scenario-based safety education in university laboratories. Laboratory Science, 26(3), 235–238.

[17] Li, Y., & Xu, X. F. (2023). Construction of safety case warning education system for university laboratories. Laboratory Science, 26(1), 231–234.

[18] Zhang, L., & Sun, L. (2022). Implementation dilemmas and optimization strategies of university laboratory access system. Laboratory Science, 25(4), 227–230.

[19] Zhao, P. F., & Li, F. S. (2022). Construction and practice of safety informant system in university laboratories. Laboratory Science, 25(6), 230–233.

[20] Jiang, Z. S., Ding, G. Q., & Wang, J. Y. (2021). Exploration on the construction of emergency system and practical drills for university laboratories. Experimental Technology and Management, 38(9), 265–268.

[21] Zhang, Z. Q., & Li, N. (2021). Research on the construction of pre-review mechanism for university laboratory safety. Experimental Technology and Management, 38(6), 256–259.

[22] Huang, Y., & Lu, J. X. (2021). Practice of full-process supervision of precursor and explosive-precursor chemicals in university laboratories. Research and Exploration in Laboratory, 40(3), 285–288.

[23] Zhou, J., & Zhu, Y. H. (2020). Research on full-chain control of hazardous waste in university laboratories. Research and Exploration in Laboratory, 39(11), 291–294.

[24] Fang, J., & Lu, Z. (2023). Practice of full-lifecycle safety management of gas cylinders in university laboratories. Laboratory Science, 26(5), 224–227.

[25] Chen, L., & Wang, J. (2022). Safety risk characteristics and control countermeasures of university biological laboratories. Research and Exploration in Laboratory, 41(9), 292–295.

[26] Pei, J., Feng, L. Z., Li, H. J., et al. (2024). Practice of university laboratory safety management under the dual prevention mechanism. Research and Exploration in Laboratory, 43(5), 287–291.

[27] Yu, X. P., & Liao, Q. (2022). Research on IoT-driven active safety early warning system for university laboratories. Research and Exploration in Laboratory, 41(7), 282–286.

[28] Ma, T., & Liu, Y. (2023). Risk profiling and targeted prevention and control of university laboratories based on big data. Experimental Technology and Management, 40(8), 257–261.

[29] Tang, W., & Zhang, L. (2023). Research on laboratory risk feature analysis based on data mining. Research and Exploration in Laboratory, 42(6), 296–300.

[30] Lin, X., & Zhou, T. (2024). Research on the balance between safety and scientific research confidentiality in smart laboratory construction. Laboratory Science, 27(1), 224–227.

[31] Guo, S., & Li, G. (2022). Research on safety culture evaluation system for university laboratories. Experimental Technology and Management, 39(11), 278–282.

[32] Zhao, P. F., & Li, F. S. (2021). Cultivation path and practice of safety culture in university laboratories. Laboratory Science, 24(5), 226–229.

[33] Peng, H., & Xu, J. (2023). Research on the construction of safety fault-tolerant mechanism for university laboratories. Experimental Technology and Management, 40(6), 264–267.

[34] Chen, X., & Zhao, Y. X. (2022). Construction path of safety management capacity for university experimental technical teams. Experimental Technology and Management, 39(9), 272–275.

[35] Wang, Z. H., & Dong, F. Q. (2024). Research on the modernization of laboratory safety governance system and governance capacity in universities in the new era. Experimental Technology and Management, 41(5), 281–285.