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HAZARD IDENTIFICATION, RISK ASSESSMENT, AND RISK CONTROL IN UNIVERSITY CHEMICAL LABORATORY FACILITIES

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Abstract

Introduction: *University chemistry laboratories are essential facilities supporting teaching, learning, and research activities. Chemistry laboratories are also known to be highly accident-prone. Laboratory incidents occur quite frequently in educational institutions, especially universities. This research aims to conduct a comprehensive hazard identification, risk assessment and risk control of the university chemical laboratory. By systematically evaluating existing safety protocols and identifying potential areas for improvement, this study also seeks to enhance overall safety and risk management practices in the laboratory.*

Methods: *This study employs observational research, where data are analyzed descriptively to determine the risk management process for the university chemical laboratory. The HIRARC method is used in accordance with AS/NZS 4360:2004 and ISO 45001:2018.*

Results: *The risk assessment identified a total of 25 risk items across two sections, with the Laboratory Section exhibiting significantly higher danger levels than the Office. In the Office Section, the majority of risks were classified as Medium (9 items) or Low (1 item), primarily relating to ergonomics and administrative stressors. Conversely, the Laboratory Section contained 10 High-level risks and 5 Medium-level risks, driven by chemical exposure, glassware breakage, and furnace operations.*

Conclusion: *The comparison of safety management strategies between the Office and Laboratory sections highlights the need for tailored approaches to mitigate specific risks. To reduce Medium and High risks to Low, it's recommended to implement higher-level Engineering and Substitution controls, shifting focus from administrative reminders to more robust safety measures. This upgrade will enhance safety in both environments, addressing gradual injuries in offices and high-severity hazards in laboratories.*

Keywords: HIRARC, Chemical Laboratory, Incident, Likelihood, Consequence

INTRODUCTIONS

University chemistry laboratories are essential facilities supporting teaching, learning, and research activities(1). Chemistry laboratories are also known to be highly accident-

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prone(2). The frequent use of hazardous chemicals, high-pressure equipment, and other complex equipment increases the likelihood of incidents such as spills, fires, explosions, and chemical exposure(3). This condition can increase the likelihood of incidents occurring, as reflected in a number of accident cases in university chemistry laboratories(1).

Laboratory accidents that have ever happened in universities in China are mostly caused by human error and inadequate safety management systems**.** This exemplifies the need for a risk assessment and strict safety measures, especially in laboratories(2). Based on research conducted by the laboratory, incidents occur quite frequently in educational institutions, especially universities. Using comparative data on incident case reports in laboratories in the United States and Canada, there are also several cases originating from Europe, Asia, and Australia(4).

Several previous studies have investigated hazard identification, risk assessment, and safety management in chemical laboratories. A chemical health, safety, and environmental risk assessment conducted in five academic laboratories in Iran reported that 25.9% of laboratory chemicals were classified as having a high potential for occupational exposure, indicating that laboratory personnel remain at considerable risk despite existing safety measures (5). Other studies have identified improper chemical handling, inadequate gas cylinder management, insufficient implementation of engineering controls, limited safety training, and poor compliance with laboratory safety procedures as major contributors to laboratory accidents and occupational injuries (6–8). Although these studies have provided valuable insights into laboratory safety, most were conducted in a limited number of laboratories or focused on specific hazards or individual laboratory activities. Consequently, they did not comprehensively evaluate hazards, risk levels, and the effectiveness of existing control measures across all laboratory operations, limiting their applicability to large research universities with diverse laboratory environments (5,8,9).

Therefore, this research aims to conduct a comprehensive hazard identification, risk assessment, and risk control evaluation of the university chemical laboratory using a systematic HIRARC approach. By assessing hazards associated with chemical, physical, biological, ergonomic, and operational activities, as well as evaluating the adequacy of existing control measures, this study seeks to provide evidence-based recommendations for improving laboratory safety management. This university was selected because it is one of Thailand's leading research universities, with multiple campuses, more than 40 research centers, extensive

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chemical laboratory infrastructure, and strong international recognition for academic excellence and research productivity, making it an ideal setting for a comprehensive laboratory safety evaluation (10,11).

Several previous studies have examined risk analysis and safety assessment in chemical laboratories. A chemical risk assessment conducted in five academic laboratories in Iran revealed that 25.9% of laboratory chemicals were categorized as having high potential exposure(5). Improper chemical handling practices and inadequate gas cylinder management in university laboratories have been identified as significant contributors to laboratory safety risks, underscoring the importance of implementing a comprehensive hazard control system(12). These studies were conducted in limited geographic contexts and focused on either hazard identification or risk assessment separately, without integrating risk control measures. This study, addreses these gaps by conducting a comprehensive hazard identification, risk assessment, and risk control in a leading Thai research University.

This research produces several outcomes that are expected to contribute significantly to the development of more effective safety strategies. The positive benefits generated expected to provide a good contribution for other institutions in similar contexts. By addressing the identified shortcomings and implementing the recommended control measures, this research aims to create a safer laboratory environment that supports academic and research excellence.

METHODOLOGY

This study employed an observational research design with a cross-sectional approach. The study was conducted in 2025 at a university chemical laboratory in Thailand. A total of two chemical laboratories were observed. Hazard identification and data collection were performed by three trained observers through direct observation of laboratory activities, work practices, equipment, and existing safety measures. The collected data were qualitative in nature, consisting of descriptions, observed conditions, and laboratory workers' behaviors related to occupational safety and health.

The study applied the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method in accordance with AS/NZS 4360:2004 and ISO 45001:2018 to determine the laboratory risk management process. The HIRARC procedure consisted of three stages: hazard identification, risk assessment, and risk control. Hazard identification was conducted through systematic observations of routine laboratory activities. Subsequently, each identified

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hazard was assessed by assigning likelihood (L) and severity (S) scores based on the AS/NZS 4360:2004 risk assessment criteria. The observation findings and risk ratings were then verified through discussions with laboratory personnel to ensure the accuracy of the assessment. Finally, appropriate control measures were proposed to minimize or eliminate the identified occupational hazards following the hierarchy of controls.

The risk level was determined using the AS/NZS 4360:2004 risk assessment matrix, which combines the likelihood (L) and severity (S) scores to produce a risk score (L × S). Likelihood was classified into five levels ranging from Rare (1) to Almost Certain (5), while severity was categorized from Insignificant (1) to Catastrophic (5). The resulting risk scores were classified into low, medium, high, and very high risk categories, which were subsequently used to prioritize the implementation of appropriate risk control measures.

Table 1. Risk Assessment Matrix

Likelihood (L)	**Insignificant (S=1)**	**Minor (S=2)**	**Moderate (S=3)**	**Major (S=4)**	**Catastrophic (S=5)**
Almost Certain (L=5)	5	10	15	20	25
Likely (L=4)	4	8	12	16	20
Possible (L=3)	3	6	9	12	15
Unlikely (L=2)	2	4	6	8	10
Rare (L=1)	1	2	3	4	5

Table 2. Risk Profile Identification Based on Risk Registered Matrix

17 - 25 = Very High	**VH**
10 - 16 = High	**H**
5 - 9 = Medium	**M**
1 - 4 = Low	**L**

Table 3. Scale for Likelihood and Severity of Hazards

Likelihood (L)	**Severity (S)**
A = Almost Certain	1 = First aid, minor material loss
B = Likely	2 = Minor injuries, medium material loss
C = Occasional	3 = Restricted work duty injury, Significant material loss
D = Unlikely	4 = Lost time injury, Major material loss
E = Rare	5 = Fatality, very major material loss

Based on the analysis of the risk likelihood and severity (Table 1 and Table 2). The relative risk can be calculated from the likelihood (L) and Severity (S) using the following formula : Relative Risk (R) = Likelihood (L) x Severity (S)

Consequence

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The consequences are obtained from the results of Relative risks calculations, the consequences can be analyzed to what extent the impact would be if the risks occur, both in terms of worker safety, financial and operational aspects of the chemical laboratory.

Risk Control

Risk control is a step to mitigate, minimize or eliminate potential hazards based on the results of priority scales in the risk control hierarchy after the hazard identification and risk assessment being applied. The hierarchy was carried out to control risk, including elimination, substitution, engineering control, administration and personal protective equipment (PPE). Risk control is one of the most essential steps to be applied, because at this steps, must be able to select carefully the most effective type of risk control to the risk level.

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RESULT

Activities in chemical laboratory are separated by 2 different section such as office section and laboratory section. In the office area, there are so many various administrative activities that will affect either health and safety of the people there involves 3 main activities: laboratory data and document management, preparation and archiving of laboratory report, and internal coordination and communication. General process in chemical laboratory.

Table 4. Risk Assessment Office Section

No	Task	Hazard Identification	Risk	Existing Control	L	S	R	Additional Control
1	Laboratory data and Documentation Management	Prolonged PC/laptop use with poor posture	Chronic musculoskeletal disorders (e.g., carpal tunnel syndrome, lower back pain)	Provision ergonomic comfortable seat, monitor screen aligned with the eyes, applying the visual hygiene method (20-20-20 rule : every 20 minutes, look at an object 20 feet away for 20 seconds)	3	3	9 M	**Engineering Control :** - Provision of wrist support/palm rest devices to prevent excessive wrist flexion **Administrative Control :** - Provision of ergonomics education programs and proper posture training.
		Faulty PC or outlet connections	Risk of electrical fire or electrocution, Electrical shock, equipment damage	Periodic inspection of work equipment (PC, keyboard, printer), reporting procedures and replacement of damaged equipment, preventive maintenance by IT or technicians	2	4	8 M	**Engineering Control :** - Provision of a cable management system (cable protection) to prevent physical damage - Installation of an ELCB/RCD (Earth Leakage Circuit Breaker) to automatically disconnect power when electrical leakage is detected **Administrative Control :** - Provision of SOPs for the safe use of electrical equipment - Implementation of damaged cable labeling and weekly inspections of electrical installations.
		Tight deadlines or repetitive tasks	Stress, decreased concentration, Occupational stress leading to burnout and productivity loss	Short breaks periodically to reduce the muscle tension, Job rotation when possible, periodic workload evaluation, management of stress and good time also work planning	3	2	6 M	**Engineering Control :** - Implementation of a reminder system to regulate work and rest periods - Provision of a comfortable working environment with adequate lighting, proper ventilation, and controlled noise levels. **Administrative Control :** - Provision of an Employee Assistance Program (EAP). - Development of a work-life balance policy.

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								- Implementation of flexible working hours.
2	Preparation and Archiving of laboratory Reports	Lifting or moving large folder or files	Ergonomic injury (e.g., lower back strain, tendonitis) wrist injury	Sharing burden, lifting aid ex : trolley, heavy folder placed on the bottom shelf	3	3	9 M	**Engineering Control** - Use of archive boxes with handles to improve grip and minimize wrist strain. - Implementation of an ergonomic storage layout to reduce awkward postures, such as excessive bending and reaching. **Administrative Control** - Establishment of maximum permissible weight limits for manual handling activities - Provision of training on proper and safe lifting techniques.
		Paper cuts or improper storage shelves	Minor injuries, falling object	Education the ways to hold documents, provision small plaster in the work area for quick handling, labeling the maximum load of the rack/ equipped the rack with stability supports, racks arranged according to standards	2	2	4 L	**Engineering Control** - Installation of anti-tip brackets and document dividers to improve shelf stability. - Use of enclosed storage cabinets with doors to reduce the risk of falling objects and dust exposure. - Provision of sturdy shelves that meet the required load capacity. **Administrative Control** - Establishment and implementation of SOPs for safe document storage and retrieval. - Posting of clear signage indicating the maximum load capacity to prevent overloading.
		Dust accumulation in storage areas	Allergic reaction, respiratory discomfort	Routine Housekeeping schedule for the storage area, good ventilation in the archive room, use of closed boxes to reduce direct dust exposure.	3	2	6 M	**Engineering Control** - Installation of a local exhaust ventilation or air filtration system. - Use of dehumidifiers to prevent dust accumulation. **Administrative Control** - Periodic air quality monitoring. - Implementation of a scheduled deep-cleaning program. **Personal Protective Equipment (PPE)** - Disposable dust masks - Gloves to prevent skin irritation
		Pressure to complete documentation quickly	Fatigue, reduces accuracy, mental stress	Mental health support programs and work counselling, time and stress management training for workers, fair distribution of task and realistic work scheduling	3	2	6 M	**Engineering Control** - Implementation of digital documentation systems to reduce manual workload. - Use of task management software to improve workflow tracking and prioritization. **Administrative Control** - Regular workload assessments. - Job rotation to prevent prolonged mental strain.

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3	Internal Coordination and Communication	Miscommunication or interpersonal conflict	Reduced team cohesion, increased stress	Implementation of effective communication and conflict resolution, Use communication tools such as email, memos, or internal communication, recordings of meeting outcomes to avoid miscommunication.	4	2	8 M	**Administrative Control** - Establishment of clear communication and reporting lines. - Regular team briefings to ensure alignment of tasks and expectations. - Implementation of structured feedback mechanisms. - Provision of leadership training in conflict management.
		Long meeting without breaks	Physical fatigue, loss of focus impacting safety and accuracy	Provision of coffee breaks, drinking water and good room ventilation. Structured meeting agenda to ensure efficiency. Recommendation for break every 90 minutes during the meeting.	4	2	8 M	**Engineering Control** - Provision of ergonomic seating - Provision of adjustable tables and proper seating arrangements **Administrative Control** - Limitation of meeting duration - Distribution of meeting materials in advance to shorten discussion time
		Close discussing in contaminated area	Cross-contamination or exposure to lab substance	Placement of meeting rooms separate from laboratory or containment zones, establishing a safe communication/coordination zone away from areas with high potential danger, warning signs to prevent interaction in unsuitable areas. Education of safe areas for informal/formal communication.	2	3	6 M	**Engineering Control** - Installation of directional airflow systems to prevent the spread of contaminants. - Provision of digital hybrid communication systems to reduce the need for physical presence in contaminated areas - Clear demarcation lines separating clean and contaminated zones. **Personal Protective Equipment (PPE)** - Laboratory coats - Gloves and safety goggles

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Table 4. Risk Assessment Laboratory Section

No	Task	Hazard Identification	Risk	Existing Control	L	S	Initial Risk	Additional Control
1	Preparation and Setup for Laboratory Activities	Chemical exposure during the preparation (spill,splashes, fumes)	Acute chemical injuries (e.g., skin burns, eye damage, inhalation poisoning) due to contact with corrosive or reactive chemicals	Clean up any chemical spill using appropriate spill kits, following the spill response procedure. Work with volatile or hazardous substances only in a well-ventilated area or inside a fume hood to prevent inhalation of toxic fumes.	3	4	12 H	**Engineering Control** - Use fume hoods to minimize exposure to hazardous fumes and vapors. **Administrative Control** - Conduct education and training courses on chemical spill response. - Display posters for emergency situations in visible locations. - Provide and communicate clear first aid procedures for chemical exposure. - Establish evacuation procedures for spill incidents. - Restrict access to the affected area during and after the spill. - Provide spill kits containing: Absorbent materials (e.g., clay, sand, vermiculite),Booms or dikes to contain and control the spread of the spill. - Ensure proper ventilation or use fume hoods to remove remaining hazardous fumes

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	Glassware Breakage	Cuts or puncture wounds, contamination from broken sample containers	Handle glassware carefully to avoid accidents. Inspect each item for cracks or defects before use and after use.	3	3	9 M	**Engineering Control** - Use splash guards and rubber mats - Use a tray when carrying multiple glassware short distances - Use cart or tray with sides when transporting multiple glassware **Administrative Control** 1. Develop and implement SOPs for : - Broken glass disposal - Safe handling and transport of glassware 2. Educate and socialize : - safety equipment location (e.g., sinks, eyewashes station, safety showers, first aid kits, and phone. - Emergency exit and safety response procedure - Restrict unauthorized personnel from receiving or handling sensitive materials **Personal Protective Equipment (PPE)** - Wear safety glasses with side shield for transporting glassware outside the lab. - Wear a face shield and safety goggles as appropriate for the specific experiment. - Wear slip-resistant or cut-resistant gloves when handling glass to prevent cuts, abrasions, and skin puncture
	Improper use equipment	Electrical fire or serious injury due to equipment failure	Use all laboratory equipment strictly according to the manufacturer's instructions and training provided. Do not operate any equipment without proper authorization or if you are unsure of its function.	3	4	12 H	**Engeneering Control** - Installation of ELCB/RCD (Earth Leakage Circuit - Breaker) to automatically cut off power in case of electrical leakage. **Administrative Control** - Implementation of a documented equipment inspection checklist before use - Clear labeling of equipment status ("Safe to Use", "Under Maintenance", "Do Not Operate"). **Personal Protective Equipment (PPE)** - Use of electrically insulated gloves when handling electrical equipment during maintenance or troubleshooting. - se of safety shoes with non-conductive soles.

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2	Execution of Laboratory Experiments and Testing	Exothermic reaction leading to heat, pressure buildup, or explosions	Thermal burns or explosions injuries from uncontrolled reactions, property damage	All tasks involving hazardous or volatile chemicals shall be conducted inside a fume hood to ensure exposure to toxic fumes is prevented. Proper functioning of the ventilation system shall be ensured so that harmful vapors are effectively removed from the work area	3	5	15 H	**Substitution :** - Use more stable reactive chemicals or slow-release reagents in place of highly reactive or hazardous substances. **Engineering Control :** - Utilize local exhaust ventilation, such as chemical fume hoods, during operations that produce airborne chemicals or vapors. **Administrative Control :** - Plan experimental reactions carefully to anticipate potential undesired outcomes (e.g., overheating) and prepare appropriate control measures. - Check chemical compatibility, especially for solvents and aggressive solutions, before use. - Pay close attention to container size and avoid overfilling to prevent spills or over-pressurization
		Toxic fumes released during chemical reaction	Inhalation of toxic gases leading to respiratory issues	Carry out all tasks involving hazardous or volatile chemicals inside a fume hood to prevent exposure to toxic fumes. Ensure the ventilation system is functioning properly to remove harmful vapors from the work area effectively	3	4	12 H	**Engineering control :** - Use local exhaust ventilation or fume scrubber system for handling of equipment such as : Vacuum storage bulbs, Rotary evaporators, and Vacuum desiccators **Administrative Controls :** - Restrict access to areas where particularly hazardous or “high-risk” chemicals are used. - Develop and enforce Standard Operating Procedures (SOPs) for handling toxic substances. - Implement air monitoring and health surveillance programs for early detection of exposure risks**.** **Personal Protective Equipment (PPE) :** - Ensure the use of appropriate PPE (e.g., gloves, goggles, lab coats, respirators) based on the chemical hazards and nature of the task.
		Sample contamination or incorrect handling of biological/ chemical substance	Cross-contamination that may affect results or pose biohazard	Handle all samples using appropriate tools such as tongs, pipettes, or spatulas to avoid direct contact. Always place samples in properly labeled containers to ensure safe identification, prevent cross-contamination, and reduce the risk of accidental exposure.	3	3	9 M	**Engineering Controls:** - Use splash guards or automated liquid handling systems to remove the human hand from the proximity of the substance entirely. **Administrative Controls:** - Spill Response Training: Mandatory "Mock Spill" drills. It’s not enough to have a kit; staff must be able to deploy it instinctively. **Personal Protective Equipment (PPE):** - Task-Specific Gloves, Face protection
3	Post-Activity Waste Management and Housekeeping	Handling of chemical waste without	Chemical exposure, environmental contamination,	Waste shall be properly segregated into labeled containers.	3	4	12 H	**Engineering:** - Use specialized safety cans or "satellite accumulation" cabinets designed for specific waste streams **Administrative:**

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		proper segregation	legal noncompliance					- The "Two-Person Verification"
		Slips and falls due to wet or cluttered work areas	Physical injury from slipping, serious slip, trips, or falls resulting in fractures or head injury and poor housekeeping practices	Cleaned and dried the work area after the task is completed	3	3	9 M	**Engeneering Control :** - Provision of anti-slip mats or anti-slip coating in areas that are frequently wet - Improvement of floor drainage to prevent water accumulation **Administrative Control:** - Implementation of routine housekeeping inspection checklist - Installation of temporary “Wet Floot” warning signs during cleaning or when spills occur - Brief training for workers on immediate spill response andmaintaining clear walkways
4	Operation of Furnace Equipment	Touching hot surfaces	Severe burns, nerve/tissue damage, or long-term disability due to skin exposure to extreme temperatures.	Installing an insulator material shield on the furnace equipment, adding an external temperature indicator to the furnace equipment.	3	4	12 H	**Engineering Control :** - Provision of physical guards or barriers to prevent contact with high-temperature surfaces. - Installation of automatic shut off mechanisms to control overheating. - Installation of visual or audible warning systems during furnace operation. - Use of heat resistant handles and control components. - Placement of clearly visible “hot area” warning labels on equipment. - Implementation of interlock mechanisms to prevent door opening at unsafe temperatures. **Administrative Control :** - Establishment and enforcement of SOPs for safe furnace operation. - Mandatory training programs on thermal hazard awareness. - Authorization-based access control for furnace operation. - Enforcement of a mandatory cooling period prior to maintenance or cleaning activities. - Regular inspection and preventive maintenance of furnace safety systems **Personal Protective Equipment :** - Gloves - Face Shield/Heat resistant safety goggles - Laboratory Coat - Safety Shoes
		Exposure to heat	Heat stress or dehydration, loss of focus, heatstroke, and fainting, which	Limit the furnace area with safe distance, add a furnace area with the sign “hot area”.	3	3	9 M	**Engineering Control**

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		can lead to secondary accidents.					- Installation of thermal insulation around the furnace to reduce ambient heat radiation. - Installation of local exhaust ventilation or heat extraction systems. - Use of heat shields or reflective barriers to minimize radiant heat exposure. - Provision of temperature monitoring systems in the work area. - Installation of cooling fans or air-conditioning systems to maintain safe ambient temperatures. **Administrative Control** - Implementation of work–rest cycles during furnace operation. - Limitation of exposure time through task rotation. - Provision of adequate hydration facilities near the work area. - Heat stress awareness training for personnel. - Monitoring of workers for signs of heat-related illness. - Scheduling high-heat tasks during cooler periods of the day (if applicable). **Personal Protective Equipment (PPE)** - Heat resistant gloves - Flame resistant laboratory coat - Face shield - Safety shoes
	Poor ventilation	Accumulation of toxic fumes, poor air quality, risk of chronic respiratory diseases or acute breathing problems.	Adding exhaust fan and cross ventilation in the laboratory section, as well as creating an operational schedule for the furnace	3	4	12 H	**Engineering control :** - Install gas detector and add a room temperature monitor - Adding a exhaust fan and cross ventilation **Administrative Control :** - Made an operational furnace schedule at the certain times - Regular inspection at furnace equipment - Education about the signs of gas exposure and how to handle it. **Personal Protective Equipment (PPE)** - Wear respirator mask during use the furnace equipment - Wear safety goggles and safety gloves also to protect against splashes and direct contact.

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Electrical issues	Risk of electric shock, fire outbreak, equipment failure, and possible fatal injuries if contact is made with live components.	Providing sign about electrical hazard, ensuring there are no exposed wires and leaks in the electrical current by conducting regular checks	2	5	10 H	**Engineering control :** - Install ELCB (earth leakage circuit breaker) and ensure proper grounding to prevent electric shock and fire **Administrative Control :** - Limit furnace operation to trained personnel only and enforce manufacturer SOPs **Personal Protective Equipment (PPE)** - Insulated safety shoes - Safety gloves
Toxic fumes during use	Inhalation of harmful gases, exposure to heavy metals or VOCs (volatile organic compounds), leading to cancer, organ failure, or acute poisoning.	Adding a sensor gas detector in the furnace, using PPE (respiratory mask, goggles & safety gloves) during use the furnace and adding fume hood	3	4	12 H	**Administrative Control :** - Restrict access to furnace operation areas and clearly label high-risk zones. - Implement SOPs for handling materials that may release toxic fumes. **Personal Protective Equipment (PPE)** - Mask - Safety goggles - Safety gloves

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		Incorrect handling of materials	Dropped items causing foot injuries, musculoskeletal strain, or damage to expensive lab materials.	Use a furnace with automatic temperature control to avoid overheating, labelling materials with MSDS, using PPE during use of the furnace	3	3	9 M	**Engineering Control** - Provision of adjustable height workstations to minimize awkward postures - Installation of anti-slip flooring - Provision of material handling equipment (trolley) to reduce manual lifting **Administrative Control** - Development and implementation of SOPs for safe material handling and furnace operation. - Training on proper lifting techniques and the safe handling of hot or fragile materials. - Establishment of maximum permissible weight limits for manual handling. - Implementation of a buddy system when handling high-risk or heavy laboratory materials. - Routine inspection of handling equipment and storage systems. **Personal Protective Equipment (PPE)** - Safety Shoes - Heat-resistant gloves - Laboratory coat - Face shield/safety goggles
		Furnace near sink	High risk of electrocution, possibility of a short circuit due to water spillage, non-compliance with lab safety standards.	Move the furnace to a dry, well-ventilated location and revise the laboratory section.	2	5	10 H	**Engineering Control** - Use of waterproof electrical outlets and splash guards near wet areas. - Elevation of electrical equipment above floor level to prevent water contact. - Proper grounding of the furnace and all connected electrical systems. - Installation of physical separation barriers between wet and electrical zones. **Administrative Control** - Development and implementation of SOPs for electrical equipment placement and operation. - Routine inspection of electrical wiring and connections. - Establishment of a clear zoning policy separating wet areas from electrical equipment areas. **Personal Protective Equipment (PPE)** - Electrically insulated gloves - Safety shoes

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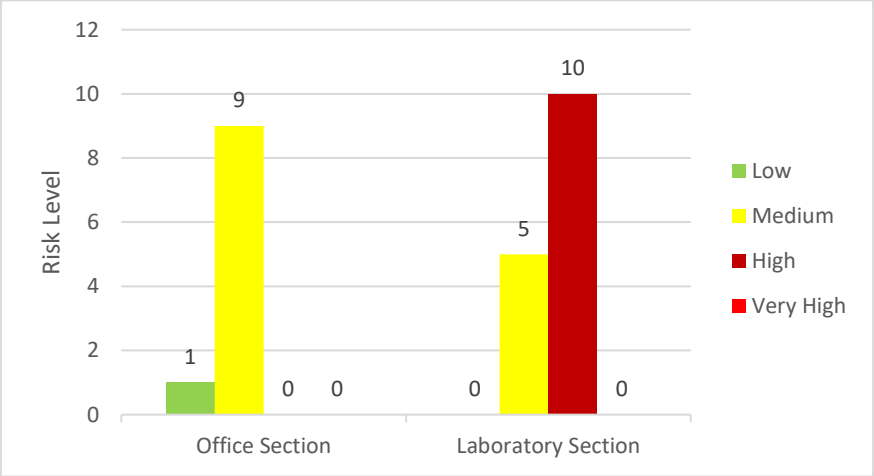
The following results show the risk levels identified in the Office Section and Laboratory Section.

Table 5. Risk Level

No	Section	Risk Level			
		Low	Medium	High	Very High
1	Office	1	9	0	0
2	Laboratory	0	5	10	0
		1	14	10	0



Picture 1. Risk Level Chart

This table was used to visualize the differences in safety management between these two environments. Here is a summary table comparing the specific control measures implemented in the Office and the Laboratory sections.

Table 6. Comparison of Control Measures

Control Category	Office Section	Laboratory Section
Engineering Controls	Ergonomic chairs, eye-level monitors, stable shelving, and natural ventilation/dust filtration.	Fume hoods, spill kits, insulation shields for furnaces, ELCB (circuit breakers), and gas sensors.
Administrative Controls	20-20-20 rule, periodic IT inspections, job rotation, and structured break agendas.	SOPs for chemical spills, mandatory safety courses, waste segregation, and restricted access to hot areas.
Workplace Organization	Use of trolleys for heavy folders, labeled shelf loads, and off-zone meeting rooms.	MSDS labeling, smoke tests for ventilation, and relocating equipment (furnaces) away from water.
Psychosocial/Mental	Counseling, workload evaluation, and effective communication tools (memos/recordings).	Focus on reaction planning and 'worst-case scenario' training to reduce operational stress.
PPE	Generally not required (focus on ergonomics).	Respirators, cut-resistant gloves, chemical-resistant goggles, and splash guards.

This table highlights the divergence in safety strategies between a standard administrative environment and a high-risk technical space. While the Office Section relies on

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comfort-based ergonomics and mental wellness to prevent gradual injuries, the Laboratory Section employs rigorous engineering and personal protective equipment to mitigate immediate, high-severity hazards such as chemical exposure and fire.

Table Summary of Targeted Risk Upgrades: These are the recommended upgrades to shift the control risk.

Table 7. Summary of Targeted Risk Upgrades

Current Risk Level	Hazard Type	Recommended Upgrade Action	Hierarchy Level
High	Chemical Fumes	Auto-sensing ventilation & scrubbing systems.	Engineering
High	Toxic Reactions	Substitution with lower-toxicity reagents.	Substitution
Medium	Heavy Lifting	Automated trolleys & digital-only records.	Elimination
Medium	Posture/Strains	Motorized height-adjustable desks.	Engineering

Based on the summary of control measures and the risk calculation, we recommend upgrading the Medium and High risks identified in the Office and Laboratory sections to Low status. The focus must shift from administrative "reminders" to higher-level Engineering and Substitution controls.

DISCUSSIONS

Office Section

For the office section, various control measures have been implemented to reduce the potential for ergonomic, electrical, and psychosocial hazards. In the case of prolonged PC use with poor posture, control has been implemented of providing comfortable ergonomic chairs, eye-level monitors, and visual hygiene methods such as the 20-20-20 rule, where every 20 minutes is followed by looking at an object 20 feet away for 20 seconds (13). Ergonomic interventions such as this significantly reduce the intensity of musculoskeletal pain (mean difference -0.28 on VAS) (14). Furthermore, to overcome the risk of faulty equipment, control has been carried out in the form of periodic inspections, damage reporting procedures, and preventive maintenance from the IT team. This is considered because OSHA recommends that laboratory equipment (such as fume hoods and electrical systems) be routinely checked and maintained (15). Furthermore, to reduce stress from repetitive tasks and tight deadlines, periodic short breaks, job rotation when possible, workload evaluation, and good work-time planning are implemented. This finding is supported by evidence demonstrating that structured

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work breaks enhance employee well-being, improve concentration, and promote recovery, particularly among knowledge workers (16).

At the Preparation and Archiving of Laboratory Reports stage, several controls have also been implemented to manage captured hazards, such as the dangers of lifting heavy folders, sharp paper edges, and unstable shelves, dusty storage areas, and work pressure. Lifting heavy folders here has been overcome by distributing the load and using aids such as trolleys, and managing the placement of heavy folders to be placed on the lower shelves. Providing mechanical aids, such as trolleys, is best practice for minimizing manual workload when lifting heavy objects. (13). In addition, ergonomic intervention studies on office and industrial workers show that training programs and mechanical support can reduce musculoskeletal symptoms by 40–50% in 6–9 months. (17), as explained by a bank staff member using the ROSA and ERI methods. Sharp paper edges and unstable shelves that cause minor injuries and threaten safety are overcome by Motamedzadeh et al., providing education on how to hold documents safely, providing small plasters, and labeling the maximum load on each shelf so that it is not overweight, and providing stable supports, which are administrative and engineering steps. In dusty storage areas, routine housekeeping, good ventilation, and the use of closed storage boxes have been carried out to minimize dust exposure (18). These measures are consistent with previous studies recommending adequate ventilation and dust control to improve indoor air quality and reduce occupational exposure to airborne contaminants (18,19). Regarding work pressure, mental health support programs and work counseling, stress management training, fair task distribution, and realistic work planning have also been carried out. (16).

Meanwhile, for internal coordination & communication, miscommunication and conflict are minimized by implementing effective communication practices and using tools such as email, memos, and meeting recordings. This strategy reduces misinformation and increases team cohesion. (20). Long meetings without breaks are managed by providing coffee breaks, drinking water, adequate ventilation, structured meeting agendas, and scheduled breaks every 90 minutes. Previous studies have shown that organized and routine work breaks improve employees' physical and psychological well-being while enhancing work performance. (16,21). Furthermore, discussions are conducted outside contaminated laboratory areas by providing designated meeting rooms, establishing safe communication zones, installing warning signs, and educating personnel about appropriate discussion areas. These measures are consistent

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with laboratory safety guidelines for minimizing cross-contamination and accidental chemical exposure (15,22).

Laboratory Section

In the laboratory section, technical and administrative controls focus on reducing chemical exposure to prevent equipment accidents and housekeeping dominance. For chemical spills and fumes, spill kits are available, and SOP spill response procedures are always used in well-ventilated areas or in fume hoods. Fume hoods themselves are routinely checked with smoke tests and face velocity of at least 70 fpm, in line with Stanford recommendations (23). Glassware is in handling glassware. Improper equipment use is addressed through training in accordance with manufacturer instructions and is operated only by trained staff.

For uncontrolled reactions and toxic fumes during experiments, all activities are carried out in fume hoods with optimal ventilation. Lab managers ensure that the sash hood is always in the 'open' status while the experiment is running, in accordance with CDC recommendations submitted by Harvard (White Paper) and CFAES, OSU. Sample handling is improved of using aids (tongs, pipettes, spatulas), clearly labeled containers, and handling protocols to prevent cross-contamination. Chemical waste is segregated into properly labeled containers according to its hazard classification to prevent occupational exposure and environmental contamination, consistent with recommended practices for laboratory waste management in educational laboratories (24). After the activity is completed, the work area is cleaned and dried to prevent slip hazards.

Another activity on the operation of furnace equipment introduces several tailored control measures. To prevent burns from hot surfaces, insulation shields are installed on the exteriors of furnaces, along with external temperature indicators that alert operators to residual heat. Exposure to heat is further mitigated by clearly marking a “Hot Area” and restricting access to trained personnel, in line with best practices in industrial furnace safety (15,25). To address poor ventilation, exhaust fans and cross-ventilation systems are installed, and furnace operation follows a defined schedule to prevent air stagnation and fume accumulation. Engineering controls of this type are strongly supported in ventilation risk reviews (19), highlighting their importance for hazard containment in lab environments. For electrical safety, the laboratory posts clear hazard warning signs and performs regular inspections to verify wiring integrity and prevent exposed conductors or current leaks. In addition, risk of toxic fume exposure is addressed by deploying gas sensors around the furnace, requiring PPE (respirators, gloves, goggles), and situating the furnace near or under a fume hood to capture emissions effectively.

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To reduce handling injuries, the furnace features automatic temperature controls to prevent overheating, and materials are labeled with their MSDS and handled only with proper PPE. Finally, to eliminate the risk of electrocution from proximity to water sources, the furnace has been relocated away from sinks to a dry, well-ventilated zone.

As a first step, the hierarchy of control systems (elimination, substitution, engineering, administrative, PPE) serves as the main framework for designing controls of the five highest hazards in the laboratory. For the first major hazard, namely chemical spills or fumes, the priority is engineering control through the use of fume hoods and local ventilation systems that meet OSHA standards to reduce direct exposure to hazards (15,22). In addition, education on chemical spill response is taught through mandatory courses and emergency response posters in the work area. This is in accordance with ACS guidelines that emphasize the importance of training before an incident occurs (22). These posters and training materials include first aid procedures and evacuation plans, which are posted in strategic areas. The provision of spill kits, complete with absorbents such as clay or vermiculite, booms, and dikes, is intended to contain and clean up spills before they spread, consistent with OSHA recommendations that spill kits must be available and ready to use. Access to the spill area is controlled, and evacuation procedures are carried out automatically, while post-cleaning using the kit is carried out until the remaining chemical vapors are completely eliminated, and this step is important to prevent re-exposure.

The hazard of ‘glassware breakage’ is handled from administrative to PPE and engineering controls. All potentially cracked glassware is automatically sorted and only used according to the SOP for the distribution of broken glass and safe disposal to sharp containers. The use of splash guards and rubber mats in the sink area is added to reduce broken glass and prevent slipping. The selection of shatterproof equipment has increased, for example, with the replacement of mercury thermometers with digital ones. When carrying multiple glasses, officers are advised to use trays or carts with closed sides and to wear eye protection to reduce the risk of direct contact. In addition, intensive education on the locations of safety showers, eyewashes, and evacuation routes is provided periodically. The use of anti-slip and cut-resistant gloves is also required when moving glass, which is in line with the University of Iowa guidelines for reducing glass injuries (26).

For the dangers of improper equipment use, especially electricity, engineering control is implemented in the form of installing ELCB (earth leakage circuit breaker) and routinely checking the quality of materials and equipment construction to maintain structural integrity.

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All equipment is used only by personnel who have received training in accordance with the manufacturer's SOP. If there is any doubt, officers are not allowed to operate the equipment. This control category reduces the possibility of electrical failure or fire.

Hazard uncontrolled reactions are addressed through engineering & administrative control. Containers and vessels are carefully selected to avoid overfilling, and chemical compatibility is verified before experimentation. Local exhaust systems, such as fume hoods, are used when reactions have the potential to produce hazardous gases. Reaction planning includes worst-case scenarios to prevent overheating or high pressures that could lead to explosions. In addition, recommendations are made to substitute more stable reactive materials or slow-release reagents to reduce reaction rates. This approach is supported by the ACS study on mitigating the hazards of exothermic reactions (27).

Finally, for toxic fumes, the use of engineering controls, such of local exhaust ventilation or a fume scrubber system with ring containment, is strongly recommended. The symbiotic use of toxic chemicals in closed systems or low-toxicity alternatives reduces the risk of exposure. Access to “High-Risk” substance use areas is appropriately restricted and clearly marked. SOPs for handling hazardous substances are developed and supplemented with air monitoring and periodic health checks for work personnel. This approach is consistent with the Chemical Hygiene Plan from NIH, which recommends that dual ventilation and environmental monitoring are required (28).

CONCLUSION AND RECOMMENDATION

Workplaces are inherently exposed to various hazards and risks, particularly in laboratories where specific work activities involve potential dangers. To effectively manage these risks, the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method is widely utilized. This systematic approach assists in identifying hazards, assessing the likelihood and severity of potential incidents, and determining the consequent level of risk.

The HIRARC assessment is a multifaceted approach that integrates the probability of occurrence with the potential impact to establish the level of consequences. This evaluation will inform the development of an action plan or control measures to reduce the identified risks to an acceptable level.

While the comprehensive implementation of all five levels of the hierarchy of controls may not always be feasible, the application of appropriate and effective control measures can result in a substantial reduction in relative risk. The implementation of adequate risk controls,

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even if only partial, has been demonstrated to contribute to the enhancement of workplace safety by minimizing exposure and potential harm.

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