Hazard Identification and Control Recommendations In The Fire Safety Engineering Laboratory

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ABSTRACT

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The Fire Safety Engineering Laboratory involves the use of chemicals, flammable gases, machinery, and work activities that may present occupational safety, health, and environmental hazards. This observational study aimed to describe existing health, safety, and environmental conditions, identify visible hazards, and formulate control recommendations. It was conducted at the Fire Safety Engineering Laboratory, Faculty of Engineering, Universitas Negeri Jakarta, using a descriptive observational design. Primary data were collected through direct observation, photographic documentation, and a checklist, while secondary data were drawn from relevant literature and regulations. Findings were classified by hazard type and mapped to the hierarchy of controls. Seven principal findings were identified: chemical storage without compatibility-based segregation; flammable gas stored near an ignition source; unsecured items on high racks; damaged roofing; floor openings or gaps; machine projections at head height; and a stooped sitting posture. Recommended measures include chemical segregation, separation of fuel and ignition sources, securing storage racks, structural repair, permanent closure of floor openings, machine repositioning or guarding, and ergonomic workstation adjustment. Engineering and administrative controls should be prioritized before reliance on personal protective equipment. Since implementation effectiveness was not assessed, follow-up inspection is required.

Key Words: hazard identification; laboratory safety; hierarchy of controls; fire safety; ergonomics

INTRODUCTION

Occupational safety, health, and environmental management (HSE) is an essential component of organizational management aimed at protecting individuals, facilities, equipment, and the environment from hazards associated with work activities. An effective occupational safety and health management system emphasizes systematic hazard identification, risk assessment, implementation of appropriate controls, monitoring, and continuous improvement [1], [2]. These principles are equally important in educational institutions because laboratories function not only as learning environments but also as workplaces where students, lecturers, technicians, and laboratory personnel interact with equipment, materials, energy sources, and potentially hazardous processes. Therefore, laboratory safety should be integrated into academic activities rather than regarded merely as an administrative requirement. International occupational safety frameworks also emphasize that proactive hazard prevention is preferable to responding to accidents after they occur [1]–[3].

Educational laboratories present distinctive safety challenges because their users may have different levels of knowledge, experience, and familiarity with laboratory procedures. Unlike professional workplaces where workers generally perform relatively standardized activities, educational laboratories involve continuously changing users, experimental procedures, equipment configurations, and learning activities. University laboratories may contain chemical, physical, mechanical, electrical, biological, fire, and ergonomic hazards, depending on their functions and equipment [4]–[6]. Previous research has demonstrated that safety awareness and safety culture among university laboratory users remain important concerns. Studies of academic laboratories indicate that safety behavior can be influenced by safety climate, knowledge, motivation, institutional policies, and users' familiarity with laboratory safety procedures [7]–[9]. Consequently, educational laboratories require systematic safety management capable of addressing both technical hazards and human factors.

Hazard identification constitutes one of the fundamental stages of occupational safety and health risk management. It involves systematically recognizing sources, situations, activities, or conditions that have the potential to cause injury, occupational illness, equipment damage, fire, environmental impact, or other adverse consequences. ISO 45001 emphasizes hazard identification and risk assessment as essential elements of an occupational health and safety management system [2]. In Indonesia, similar requirements are reflected in Regulation of the Minister of Manpower of the Republic of Indonesia No. 5 of 2018 concerning Occupational Safety and Health in the Work Environment [10]. The regulation establishes requirements related to physical, chemical, biological, ergonomic, and psychological factors in the workplace. Accordingly, hazard identification in laboratories should be based on actual conditions and activities rather than solely on the presence of safety documents, warning signs, or personal protective equipment.

Direct observation of laboratory conditions is particularly important because hazards may emerge from the interaction between users, equipment, materials, and the physical environment. Examples include inappropriate chemical storage, improperly positioned gas cylinders, damaged electrical installations, obstructed access or emergency routes, inadequate ventilation, unsafe equipment placement, poor housekeeping, inappropriate working postures, and insufficient emergency facilities. Such conditions may not be adequately represented in administrative documentation. Previous studies conducted in Indonesian university laboratories using Hazard Identification, Risk Assessment, and Determining Control (HIRADC) or related approaches have identified various hazards that require systematic evaluation and control [11], [12]. More recent investigations of academic fabrication and prototyping laboratories have similarly demonstrated that systematic hazard identification and hierarchy-based controls can support substantial reductions in occupational risk [13], [14]. These findings reinforce the importance of field-based hazard identification in educational laboratory environments.

After hazards have been identified, appropriate control measures should be selected according to the hierarchy of controls. The hierarchy prioritizes elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE), in descending order of effectiveness [15]. Elimination and substitution are generally preferred because they remove or reduce hazards at their source, while engineering controls isolate users from hazards through physical or technological interventions. Administrative controls, including standard operating procedures, training, supervision, safety signs, inspection schedules, and access restrictions, depend more strongly on consistent human behavior. PPE represents an important final layer of protection but should not be regarded as the primary solution when hazards can be eliminated or controlled through higher-level measures [15]. Therefore, laboratory safety recommendations should be developed according to the characteristics and sources of individual hazards rather than relying primarily on warning signs and PPE.

The importance of hazard identification becomes even greater in laboratories associated with fire safety engineering. Fire-related educational laboratories may involve ignition sources, electrical equipment, combustible or flammable materials, pressurized cylinders, heating equipment, mechanical devices, and experimental apparatus that can generate thermal or physical hazards. The coexistence of these elements may create interconnected hazards in which a relatively minor unsafe condition can contribute to a more serious incident. Laboratory safety guidance therefore emphasizes careful planning of experimental activities, appropriate storage and handling of hazardous substances, emergency preparedness, equipment maintenance, and systematic assessment of potential hazards before laboratory work begins [3], [16]. In addition to preventing injuries, effective hazard management contributes to protecting laboratory facilities, maintaining equipment reliability, preventing interruption of educational activities, and developing a stronger safety culture among students.

Previous studies have examined safety culture, safety awareness, and risk management in university laboratories [7]–[9], [11]–[14]. Nevertheless, laboratory safety conditions are strongly influenced by the specific characteristics of laboratory activities, equipment, spatial layout, user behavior, and existing control measures. Findings from one laboratory therefore cannot automatically represent conditions in another laboratory. Furthermore, safety evaluations that focus predominantly on documentation or general compliance may overlook observable unsafe conditions within the physical work environment. This creates a practical need for laboratory-specific field observation that systematically documents existing hazards and connects each finding with appropriate control measures. Such an approach is particularly relevant for educational laboratories because hazard identification can simultaneously support accident prevention and provide students with practical exposure to occupational safety principles.

Based on these considerations, this study focuses on hazard identification in the Fire Safety Engineering Laboratory, Faculty of Engineering, Universitas Negeri Jakarta. The laboratory is utilized for educational activities and equipment operation that may expose users to physical, chemical, mechanical, electrical, fire, and ergonomic hazards. Systematic field observation is therefore required to obtain an evidence-based description of existing HSE conditions and identify conditions that may potentially cause injury, occupational illness, property damage, fire, or disruption of laboratory activities. Accordingly, this study aims to: (1) describe the general HSE conditions of the Fire Safety Engineering Laboratory; (2) identify potential hazards observable during field observation; and (3) formulate appropriate control recommendations based on the hierarchy of controls. The findings are expected to provide practical information for improving laboratory safety management and to support the development of a proactive safety culture within educational laboratory activities.

MATERIALS AND METHODS

Observation Design, Location, and Time

A descriptive observational design was used. The observation was conducted at the Fire Safety Engineering Laboratory, Fire Safety Engineering Study Program, Faculty of Engineering, Universitas Negeri Jakarta. The assessment covered laboratory areas and facilities accessible during the activity.

Data Sources and Instruments

Primary data were obtained through direct observation of the physical condition of the laboratory, equipment layout, material storage, user activities, safety facilities, and photographic documentation. The main instrument was a checklist covering general laboratory conditions, potential hazards, and safety systems. Secondary data were drawn from HSE literature, work-environment regulations, and supporting documents cited in the observation report.

Procedures and Data Analysis

The procedure comprised a literature review, checklist preparation, field observation, documentation, hazard identification and classification, mapping of recommendations to the hierarchy of controls, and formulation of conclusions (Figure 1). Data were analyzed descriptively by linking observed conditions, potential consequences, and the most relevant controls. Because the checklist did not include likelihood and severity scales, the analysis did not produce quantitative risk scores or rankings. The study output is therefore limited to hazard identification and control recommendations.

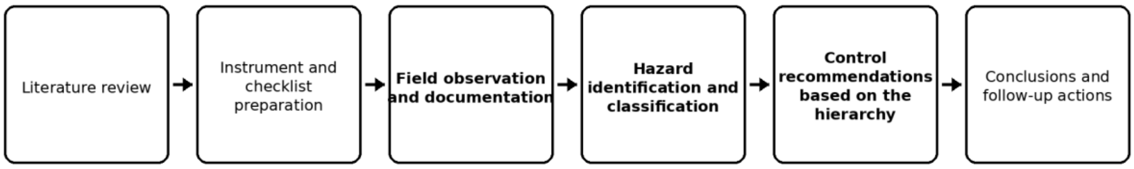

Figure 1. Observation, hazard identification, and control recommendation process.

RESULTS AND DISCUSSION

General Laboratory Conditions

The checklist indicated that the laboratory was generally clean and organized, lighting and ventilation were considered adequate, and evacuation routes were accessible. Safety facilities—including portable fire extinguishers, safety signs, standard operating procedures, a fire alarm, and personal protective equipment—were recorded as available. Nevertheless, several machines were positioned relatively close together, restricting movement. No visible electrical hazard was identified during the observation; however, this finding reflects only the conditions at the time and does not replace a technical electrical inspection.

The presence of safety facilities does not in itself eliminate hazards. This is demonstrated by the remaining deficiencies in storage arrangements, building condition, and equipment layout. HSE evaluation must therefore assess how controls function in practice rather than merely confirm that safety equipment exists.

Hazard Identification and Control Recommendations

Figure 2. Storage-related hazards: (A) chemicals stored without adequate segregation; (B) flammable gas located near an ignition source; (C) items placed on high racks without adequate restraint.

Figure 3. Physical and ergonomic hazards: (A) roof damage; (B) floor opening or gap; (C) machine projection at head height; (D) stooped sitting posture.

Table 1. Summary of hazard findings, potential impacts, and recommended controls

No.	Finding	Potential impact	Recommended controls
1	Chemicals are not segregated according to compatibility (chemical hazard).	Interaction between substances, exposure to hazardous chemicals, or container damage.	Group chemicals by compatibility; follow SDS/MSDS guidance; provide clear labels; use separate racks for reactive substances.

No.	Finding	Potential impact	Recommended controls
2	Flammable gas is stored near an ignition source (fire hazard).	Ignition of leaking gas, potentially causing a fire.	Separate gas and ignition-source storage; keep gas away from heat or flame; post prohibition signs; conduct routine leak checks.
3	Items are placed on high racks without adequate restraint (falling-object hazard).	Falling objects may strike laboratory users.	Use guarded or restrained racks; stack within rated capacity; place heavy items at lower levels; restrict access beneath racks. Helmets are supplementary only.
4	The roof is damaged or perforated (environmental/physical hazard).	Water intrusion, slippery floors, corrosion, and equipment damage.	Complete permanent repairs; use a waterproof cover as a temporary measure; ensure drainage functions; conduct periodic inspections.
5	A floor opening or gap is present (physical hazard).	Trips, slips, or falls, particularly under poor visibility.	Close the opening permanently; install temporary barriers and warning signs; maintain adequate lighting until repairs are completed.
6	A machine component projects at head height (mechanical/physical hazard).	Head impact that may cause injury.	Reposition or adjust the machine height; maintain adequate head clearance; install guards and warning signs; use helmets as an additional layer.
7	Users adopt a stooped sitting posture while working (ergonomic hazard).	Excessive load on the back, shoulders, and neck.	Adjust sitting position; use a chair with back support; match table and monitor heights; provide posture education.

Chemical and Fire Hazards

Storing chemicals close together without compatibility-based segregation increases the possibility of unintended interaction if containers leak or are damaged. The principal recommendation is not merely improved labeling, but segregation according to chemical characteristics and SDS/MSDS information. Labels and procedures constitute administrative controls, whereas separate storage racks provide an engineering control that reduces contact between incompatible substances.

The proximity of flammable gas to an ignition source creates a direct combination of fuel and ignition. Physical separation should be the first action, supported by prohibiting ignition sources, checking for leaks, and supervising storage conditions. This approach is more appropriate than relying solely on user vigilance because the hazard remains within a distance that could permit ignition.

Physical, Mechanical, and Building-Condition Hazards

Items stored on high racks, floor gaps, roof damage, and machine projections at head height show that several hazards arise from spatial arrangement and the physical condition of the laboratory. For overhead storage, helmets should not be treated as the primary control. Securing racks, relocating heavy items to lower levels, and restricting access beneath them are more consistent with source-based control. Likewise, floor openings and roof damage require permanent repair; warning signs and barriers are temporary measures only until engineering work is completed.

Machine projections extending into user movement paths create a head-strike hazard. Repositioning or adjusting the height of the machine and installing guards are engineering controls that directly reduce the likelihood of contact. “Mind your head” signs and safety helmets may still be used, but only as additional layers after layout modifications have been made.

Ergonomic Hazards

A stooped sitting posture was observed when users worked at a table or in front of equipment. This condition indicates a mismatch between body position and workstation configuration. Controls should focus on adjusting the height of the table, monitor, and back-supported chair, accompanied by education on proper sitting posture. This recommendation is appropriate because ergonomic improvement should reduce the need to maintain an awkward posture rather than simply instruct users to sit upright.

Implications and Limitations

Overall, the findings reveal a combination of hazards that require immediate action at the source and hazards that require stronger procedures. Priority should be given to chemical segregation, separation of gas from ignition sources, securing elevated storage, repairing the roof and floor, and redesigning machine placement. Routine inspection and user education are necessary to sustain the effectiveness of these engineering measures.

The observation was conducted at a single site and at one point in time. The instrument did not include a likelihood-severity matrix; consequently, the study cannot assign numerical risk levels or demonstrate the effectiveness of recommendations after implementation. In addition, the absence of an observed hazard—such as electrical, biological, or psychosocial hazards—cannot be interpreted as evidence that the risk does not exist. A follow-up audit using a formal risk-assessment instrument and post-correction verification is required to evaluate changes empirically.

CONCLUSION

This observation at the Fire Safety Engineering Laboratory identified seven principal findings encompassing chemical, fire, physical, mechanical, environmental, and ergonomic hazards. These findings comprised chemical storage without compatibility-based segregation, flammable gas located near an ignition source, unsecured items on high racks, damaged roofing, floor openings or gaps, machine projections at head height, and a stooped sitting posture. Recommended controls should prioritize segregation, separation of ignition sources, securing racks, structural repair, permanent floor closure, and engineering improvements to layout and ergonomics. Warning signs, training, inspections, and personal protective equipment are supporting controls. The effectiveness of these recommendations was not tested; a follow-up audit is therefore required to confirm implementation and determine whether risk has been reduced.

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