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Risk Management Analysis of Educational Laboratory at XYZ State University

Analisis Manajemen Risiko Laboratorium Pendidikan di Perguruan Negeri Tinggi XYZ

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ABSTRACT

Educational laboratories play a strategic role as executors of practical and research activities by students, lecturers, technicians, and laboratory assistants. Chemical laboratories use chemicals intensively when conducting research and practical work. This study aimed to analyze the risk categories, risk assessments, and mitigation strategies of educational laboratories at XYZ State University. The data collection methods used in this study were questionnaires and direct interviews. The method for determining the respondent sample used purposive sampling, by determining the criteria for respondents who were directly involved in laboratory activities, consisting of laboratory officials and laboratory technicians. This study applied an in-depth study approach to 17 laboratories with characteristics of laboratory category, laboratory type, chemical use, and laboratory certification status. The data analysis method used in this study was qualitative descriptive analysis, risk assessment using the Failure Mode and Effects Analysis (FMEA) method, and risk mitigation using the Hierarchy of Controls approach based on ISO 45001:2018. The results showed that laboratory risk assessments were divided into four risk categories: nine potential risks that affect humans, the environment, and laboratory equipment; seven risks are related to the use of chemicals; four risks are related to the use of laboratory equipment; and nine risks are related to security and safety procedures. Risk mitigation was carried out for risks with the highest Risk Priority Number (RPN), namely the risk of being exposed to cracked or broken glassware, the risk of the laboratory not providing emergency eyewash facilities or safety showers, the risk of damaged equipment not being promptly replaced, and the risk of an unavailable evacuation route.

Keywords: FMEA, laboratories, PTN BH, *risk.*

ABSTRAK

Laboratorium pendidikan memiliki peran strategis sebagai pelaksana kegiatan praktikum dan penelitian oleh mahasiswa, dosen, teknisi, dan laboran. Laboratorium kimia merupakan laboratorium yang menggunakan bahan kimia secara intensif saat melakukan penelitian dan praktikum. Tujuan penelitian ini adalah menganalisis kategori risiko, menganalisis penilaian risiko, dan menganalisis strategi mitigasi laboratorium pendidikan di Perguruan Tinggi Negeri XYZ. Metode pengumpulan data penelitian ini menggunakan kuesioner dan wawancara langsung. Metode penentuan sampel responden menggunakan purposive sampling dengan menentukan kriteria responden yang terlibat langsung dalam aktivitas di laboratorium. Penelitian ini menerapkan pendekatan studi mendalam pada 17 laboratorium dengan karakteristik kategori laboratorium, tipe laboratorium, penggunaan bahan kimia, dan status sertifikasi laboratorium. Metode analisis data yang digunakan dalam penelitian ini adalah analisis deskriptif kualitatif, penilaian risiko dengan menggunakan metode *Failure Mode and Effects Analysis* (FMEA), dan mitigasi risiko dengan menggunakan pendekatan hierarki pengendalian (*Hierarchy of Controls*) dengan

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berlandaskan ISO 45001: 2018. Hasil penelitian menunjukkan bahwa penilaian risiko laboratorium dibagi ke dalam empat kategori risiko: sembilan potensi risiko yang memengaruhi manusia, lingkungan, dan alat-alat laboratorium; tujuh risiko terkait penggunaan bahan kimia; empat risiko terkait dengan penggunaan peralatan laboratorium; dan sembilan risiko terkait prosedur keamanan dan keselamatan. Mitigasi risiko dilakukan untuk risiko dengan *Risk Priority Number* (RPN) tertinggi, yaitu risiko terkena retakan atau pecahan alat kaca, risiko laboratorium tidak menyediakan fasilitas darurat pencuci mata atau *shower* keselamatan, risiko peralatan rusak tidak segera diganti, dan risiko jalur evakuasi tidak tersedia.

Keywords: FMEA, laboratorium, PTN BH, risiko.

INTRODUCTION

Higher education governance is based on the concept of good university governance (GUG). This concept refers to a structured governance system within a university environment for setting goals, carrying out operations, and managing educational institutions, including physical, financial, human resources, academic, and student skills development aspects (Suryani, 2015). Risk management is one of the main pillars of GUG and functions as an early warning system tool in organizational activities. The implementation of governance in State Universities with Legal Entities (PTN-BH) not only influences the general managerial aspects of the university but also impacts the management of educational facilities, including educational laboratories.

Educational laboratories play a strategic role as venues for practical and research activities by students, lecturers, technicians, and laboratory assistants. Research activities in laboratories generally involve various chemicals, equipment, and supporting facilities such as electricity, gas, water, and fume hoods. These conditions pose a potential risk of workplace accidents if not managed properly (Syakbania & Wahyuningsih, 2017). As an institution that implements autonomous management, PTN BH is required to implement effective and integrated laboratory governance and risk management to ensure the safety of the entire academic community (Supriyadi & Mukhlis, 2018). Systematic risk management implemented in PTN BH educational laboratories can protect students, lecturers, and laboratory assistants from potential hazards or accidents (Daryono, 2025). A chemistry laboratory is a laboratory that uses chemicals intensively in practical classes. These hazardous materials include corrosive, explosive, easily oxidized, flammable, and irritating materials, as well as radioactive and toxic materials that also cause environmental pollution (Adane & Abeje, 2012). Potential hazards in chemistry laboratories can result in work accidents and reduce a person's quality of life (Walters *et al*., 2017). A survey on school laboratory safety indicated that chemistry laboratories have the second-highest number of cases, followed by biology and physics laboratories in the following order. The percentage of cases in chemistry laboratories were scratch incidents (39.1 percent), minor injuries (37.6 percent), eye irritation (8 percent), and exposure to chemical spills (7.2 percent) (Bureau, 2013). One important element to be applied to all types of work is occupational safety and health (K3) (Redjeki, 2016).

Eyire *et al*., (2013) reported that in the eight departments studied between 2008 and 2012, chemistry laboratories recorded the highest number of accidents, with an average of 180 cases per year. The U.S. Chemical Safety (CSB, 2018) also recorded 261 laboratory incidents between 2001 and 2018, with 130 incidents occurring in educational settings, resulting in 185 injuries and five deaths. In Indonesia, Putra (2018) identified eight potential risks at the Faculty of Pharmacy, Airlangga University, one of Indonesia's state universities, including three high-risk hazards: HCl, nitric acid, and sulfuric acid spills, which are corrosive and can potentially cause burns and poisoning in laboratory users. In line with this research, research conducted by Ridasta (2020) at the Chemistry Laboratory of Semarang State University, which conducted an initial assessment of the chemistry laboratory where accidents had occurred, such as scratches from laboratory equipment that had broken or peeled off, chemical spills that resulted in burning laboratory coats, eye irritation when taking reagents in the fume cupboard.

The number of new students at PTN XYZ in the 2025 academic year is projected to increase by 9 percent compared to the previous year, with a total enrollment of 8,573 new undergraduate and diploma students, up from 7,859 in 2024. This indicates an increased demand for educational services and laboratory facilities in the region. Increasing laboratory activity has the potential to increase operational risks, such as non-compliance with work safety procedures, exposure to hazardous materials, and damage to laboratory equipment. Research related to risk management within the Legal Entity State University (PTN BH) environment still shows limitations, especially in terms of implementing a risk management system that is integrated with institutional governance. Research conducted by Putra (2018) and Ridasta (2020) only highlights the aspect of hazard identification or risk types in chemical laboratories, but has not examined in depth how the process of categorization, assessment, and risk mitigation strategies are carried out systematically according to applicable risk management standards such as ISO 31000:2018. Although many studies have been conducted in Indonesia and abroad, no study has integrated FMEA with the Hierarchy of Control in the context of PTN BH in Indonesia involving more than one laboratory in a university. This study focuses on risk management, including activities carried out in laboratories that use chemicals. This study aimed to categorize risks, conduct risk assessments, and develop risk strategies for educational laboratories at PTN XYZ. This study is expected to provide strategies that can be used to mitigate risks in educational laboratories at PTN XYZ.

LITERATURE REVIEW

Risk Management

According to ISO 31000 (2018), risk management is defined as the coordinated activities to direct and control an organization's response to risk. This international standard emphasizes that risk management is not merely a reactive activity but must be proactively integrated into all organizational processes. Vaughan & Vaughan (2008) state that effective risk management must include five main stages: risk identification, risk measurement, selection of risk management techniques, implementation of the selected techniques, and monitoring and control. According to Hubbard (2009), risk management is the identification, assessment, and prioritization of risks, followed by the coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of undesirable events.

Educational Laboratory

According to Regulation of the Minister of State for Empowerment of State Apparatus and Bureaucratic Reform Number 3 of 2010, a laboratory is an academic support unit in an educational institution, in the form of a closed or open room, permanent or mobile, managed systematically for testing, calibration, and/or production activities on a limited scale, using equipment and materials based on certain scientific methods, in the context of implementing education, research, and community service.

Educational laboratories are divided into four types, namely:

a. Type I Laboratory is a basic science laboratory found in schools. secondary education level, or technical implementation units that organize education and/or training with supporting facilities for category I and II equipment, and materials. The materials managed are general category materials to serve students' educational activities.
b. Type II Laboratory is a basic science laboratory located in higher education institutions at the preparatory level (semesters I and II) or technical implementation units that organize education and/or training with supporting facilities for category I and II equipment, and the materials managed are general category materials to support student educational activities.
c. Type III Laboratory is a scientific laboratory located in a department or study program or technical implementation unit that organizes education and/or training with supporting facilities for equipment in categories I, II, and III, and the materials managed are general and special category materials to serve educational activities and student and lecturer research.
d. Type IV Laboratory is an integrated laboratory located in a faculty or university study center or a technical implementation unit that organizes education and/or training with supporting facilities for category I, II, and III equipment; the materials managed are general and special category materials to serve research and community service activities, students, and lecturers.

Occupational Safety and Health (K3)

Occupational safety and health (K3) (Ramli, 2010) refers to the activities undertaken to guarantee and protect the safety and health of workers by preventing workplace accidents and occupational diseases. Occupational safety and health is an unavoidable obligation for companies, educational institutions, and other organizations, aimed at preventing workplace accidents that can result in casualties and loss of property (Kementerian Ketenagakerjaan, 2022).

ISO 31000:2018

ISO 31000:2018 is an international standard published by the International Organization for Standardization (ISO) as a general guideline for implementing risk management. This standard is an update of the previous version (ISO 31000:2009) and has been adopted by the National Standardization Agency (BSN) as ISO 31000:2018, which serves as a reference for implementing risk management for various types of organizations. ISO 31000 helps organizations develop risk management strategies to effectively identify and mitigate risks, identify positive opportunities, and mitigate negative consequences related to risks. The implementation of ISO 31000:2018 is designed to improve governance, performance, achievement of objectives, and protection of organizational assets, which is based on three main elements: principles, frameworks, and processes (Figure 1).

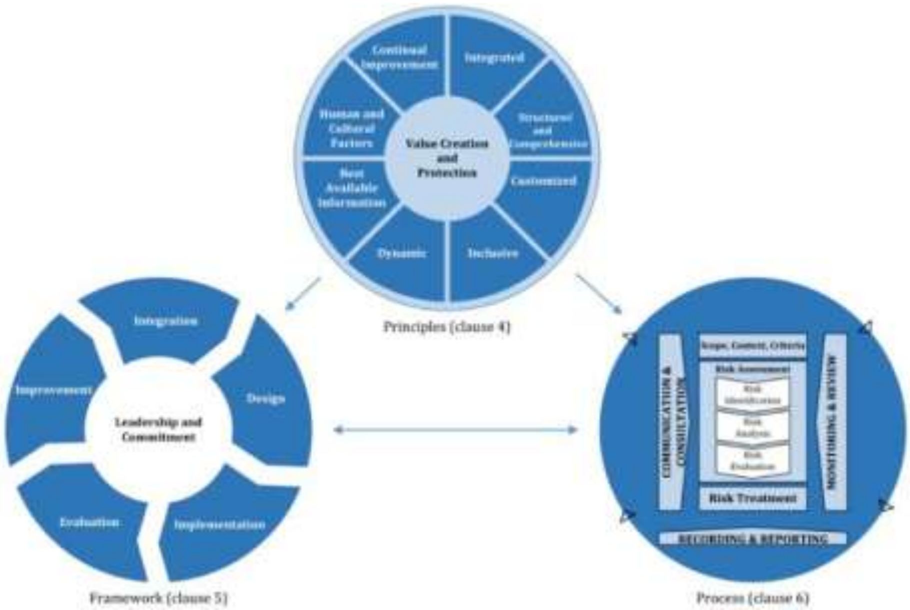

Figure 1. Principles, Framework, and Processes

RESEARCH METHODS

Data Types and Sources

The data used in this study comprised primary and secondary data. Primary data were obtained directly through field surveys and observations in uncertified chemistry laboratories and other certifications at XYZ University. Secondary data were obtained from educational laboratories at XYZ State University, the Risk Management Office, and from literature reviews, including journals, websites, and previous research.

Sampling Determination Method

This research applied an in-depth case study approach (qualitative case study) to explore the dangers of all PTN XYZ laboratory activities. The population of this research object was 385 educational laboratories. Seventeen sample laboratories were selected using a purposive sampling technique based on laboratory category, laboratory type, use of chemicals, laboratories that did not yet have certification, and other competency certificates. The primary data collection method used questionnaires and direct interviews and involved 23 respondents representing 17 selected sample laboratories. The technique for determining the respondent sample used purposive sampling. Purposive sampling is a type of sampling technique that determines certain criteria and considers several positions and employees who have extensive knowledge related to what will be studied (Sugiyono, 2013). The criteria for respondents selected were laboratory technicians, laboratory management lecturers, and Education Laboratory Staff at PTN XYZ. The selection of these three professions is the main actor in charge of managing, supervising, and operating all operational activities in the laboratory. Thus, respondents are considered to have comprehensive capabilities, experience, and knowledge regarding potential chemical hazards and risks in the laboratory.

Data Processing and Analysis Techniques

The data processing and analysis methods in this study used qualitative descriptive analysis and the Failure Mode and Effects Analysis (FMEA) method using Microsoft Excel. According to Sugiyono (2013), descriptive analysis is a statistical analysis tool that functions to describe or provide an overview of the object being studied through sample or population data to draw generally applicable conclusions. Descriptive analysis was used to explain the characteristics of the respondents and the characteristics of the educational laboratories at PTN XYZ. According to Priambodo *et al.* (2021), Failure Mode and Effects Analysis (FMEA) is a method of risk analysis and generally aims to determine priorities and risks and recommended actions. The assessment of the parameters of severity (Severity), occurrence level (Occurrence), and level (Detection) in the FMEA table is calculated based on the accumulation of respondents' assessments. The score for each parameter was obtained by using the average value (mean) from all respondents in each sample laboratory to ensure an objective assessment representation. The priority and level of operational risk were determined based on the Risk Priority Number (RPN) value, which is the result of multiplying the average scores of the three parameters. Based on the sequence of RPN values for each potential risk, the next step was to determine the critical RPN value to indicate which risks are above the critical value and therefore need to be evaluated for improvement (Fithri *et al.*, 2021).

RPN = S x O x D.. (1)

Critical Value = $\frac{Total\ RPN}{Amount\ Risk}$ .... (2)

Parameter measurements were modified from Sellappan & Palanikumar (2013) study at the time of occurrence. An assessment scale of 1 to 5 was used to describe the potential risk with assessment criteria for each dimension, in accordance with the assessment scale in Table 1.

Table 1. Risk Assessment Scale

Scale	*Occurrence (O)*	*Severity (S)*	*Detection (D)*
1	Almost never, very rarely happens	No injuries, minimal financial loss	Very easy to detect
2	Seldom	Minor injuries, moderate financial loss	Easy to detect
3	It can happen once in a while	Moderate injury, requiring medical attention, major financial loss	Just detected
4	Often	Serious injury >1 person, major loss, production disruption	Hard to detect
5	Can happen at any Time	Fatal > 1 person, very large losses and very wide impact, stopping all activities	Very difficult to detect

The results of the risk assessment are used to determine risk priorities, and risk levels are mapped using a risk matrix. The risk matrix provides a comprehensive overview of risk levels based on the severity and frequency of occurrence. The matrix criteria ara Figure 2:

Occurance \ Severity	1	2	3	4	5
5	T	T	E	E	E
4	S	T	T	E	E
3	R	S	T	E	E
2	R	R	S	T	E
1	R	R	S	T	T

Figure 2. Risk Matrix

Information:
1. Green (low) means the risk is at a low level and can be addressed with routine procedures.
2. Yellow (medium) indicates that the risk is at a moderate level, and action is required.
3. Orange (high) indicates that the risk is at a serious level and requires action and attention from management.
4. Red (extreme) indicates the most severe level of risk, meaning immediate action must be taken because it is an emergency situation and activities must be temporarily stopped until the risk is resolved.

The risk priority number (RPN) values on the worksheet use approach *hierarchy of controls* based (Figure 3) on ISO 45001:2018 to determine the priority of values that must be addressed first. The risk control hierarchy consists of five control hierarchies, including: elimination, substitution, design, administration, and personal protective equipment (PPE).

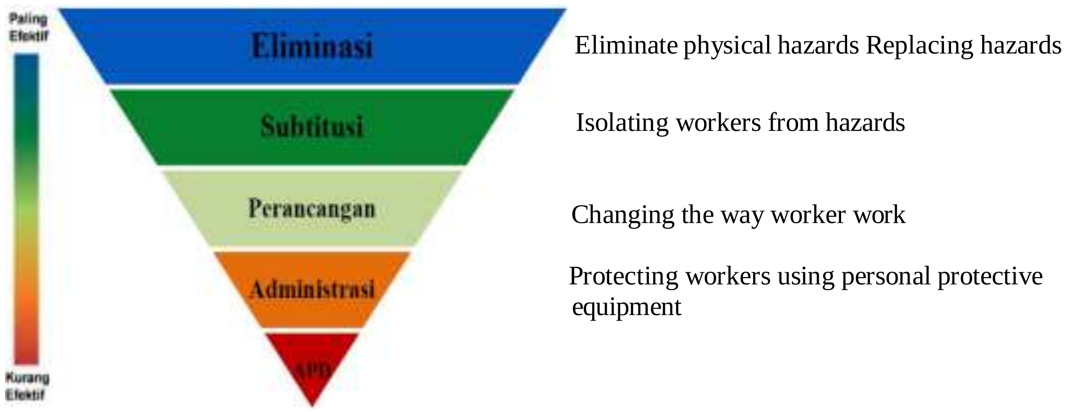

Figure 3. Control Hierarchy Diagram

RESULTS AND DISCUSSION

Descriptive Analysis

Descriptive analysis was conducted to obtain a clearer and more detailed picture of the characteristics of laboratory respondents at PTN XYZ. The characteristics of respondents in educational laboratories and the distribution of laboratories using chemicals at PTN XYZ can be seen in Tables 2 and 3.

Table 2. Characteristics of Educational Laboratory Respondents at XYZ College

Characteristics	Results	Total (N=23)	Percentage (%)
Gender	Man	12	52.17
Age	31-40	8	34.78
Last education	D4/S1	9	39.13
Employment Status	civil servant	11	47.83
Position	Laboratory Technician	12	52.17
Length of Service	1-10 years	13	56.52

Based on Table 2, the characteristics of respondents in educational laboratories at XYZ College show that of the 23 respondents, the majority were male (52.17 percent), respondents were aged 31–40 years (34.78 percent), respondents' last education was D4/S1 (39.13 percent), respondents' employment status was civil servant (47.83 percent), respondents' positions were laboratory technicians (52.17 percent), and respondents' length of service was 1–10 years (56.52 percent). The distribution of educational laboratories that use chemicals and do not have certification and other certificates at XYZ College is presented in Table 3.

Tabel 3. Distribution of Educational Laboratories Using Chemicals at XYZ College

Faculty	Number of Laboratories	Percentage %
Faculty A	5	29.4
Faculty B	8	47.1
Faculty C	1	5.9
Faculty D	3	17.6

Table 3 shows the distribution of educational laboratories by category, including those that use chemicals, do not have certification or other certificates, and are Type 3 laboratories. The distribution of educational laboratories at PTN XYZ shows the largest concentration in Faculty B (47.1 percent). This indicates that many laboratories at Faculty B still require attention in terms of risk management. Furthermore, Faculty A (29.4 percent), Faculty D (17.6 percent), and Faculty C (5.9 percent). Thus, the uneven distribution of laboratories between faculties can be the basis for prioritizing risk management.

FMEA Analysis

The FMEA analysis began with the identification of potential laboratory risks at XYZ University, which comprised 17 laboratories. Based on the identification of potential risks through field observations, these potentials were classified into the following categories: 1) risks based on potential hazards that affect personnel/humans, the environment, and laboratory equipment; 2) risks based on the use of chemicals; 3) risks based on the use of laboratory equipment; 4) risks based on security and safety procedures.

Risk assessment based on potential hazards affecting personnel/humans, the environment, and laboratory equipment

The risk assessment of educational laboratories at PTN XYZ aimed to determine the level of risk, enabling the planning of prevention and mitigation measures to be implemented. The results of risk identification in 17 educational laboratories at XYZ University indicate that there are 21 (twenty-one) risk indicators that affect the safety of personnel/humans, the environment, and laboratory equipment. These risk indicators are assessed using the *Failure Mode and Effects Analysis* (FMEA) method and using *critical values*. The results of the assessment indicate 9 potential risks that need to be mitigated.

Table 4. Results of Risk Assessment Affecting Human Safety, the Environment, and Laboratory Equipment

Code	Risk Indicators	O	S	D	RPN	Rank
PKM4	Affected by cracks or broken glass tools	1.94	2.00	1.65	6.39	1
PKM5	Not wearing PPE	1.94	1.88	1.53	5.59	2
PL3	Dumping chemical liquid waste into drains	1.65	1.71	1.76	4.96	3
PKM3	Electrocuted while unplugging electronic cables	1.41	1.82	1.88	4.85	4
PKM7	There is dust in the laboratory that causes nasal irritation.	1.71	1.76	1.47	4.43	5
PA2	Laboratory equipment is affected by corrosion so much that it can no longer be used	1.76	1.71	1.24	3.72	6
PKM6	There is dust in the laboratory that causes eye irritation.	1.59	1.65	1.41	3.69	7
PKM1	Having an incident (slipping/being hit by a falling object/being trapped by an object)	1.41	1.65	1.59	3.69	8
PA3	Exposed and rusty metal tools	1.82	1.47	1.29	3.47	9

Based on the calculation of the Risk Priority Number (RPN) value—the product of severity, occurrence, and detection in Table 4, of the 21 indicators identified, nine potential major risks were identified, dominated by the human safety category (six risks), confirming that the consequences for human safety are considered far more critical than damage to equipment or the environment. The highest risks are the potential for being hit by broken glass equipment (PKM4) and non-compliance with the use of complete PPE (PKM5) due to the high frequency of occurrences, which reflects weak supervision and enforcement of standard procedures in the XYZ State University laboratory, in line with the findings of Fatemi *et al*. (2022) regarding the tendency to ignore safe practices and the use of PPE in university laboratories. Overall, the five highest RPN risks represent two fundamental weaknesses in laboratory management: user behavior/compliance with basic safety procedures and infrastructure/governance (such as chemical waste systems and preventive equipment maintenance). Therefore, future interventions should strengthen the safety culture and supervision simultaneously.

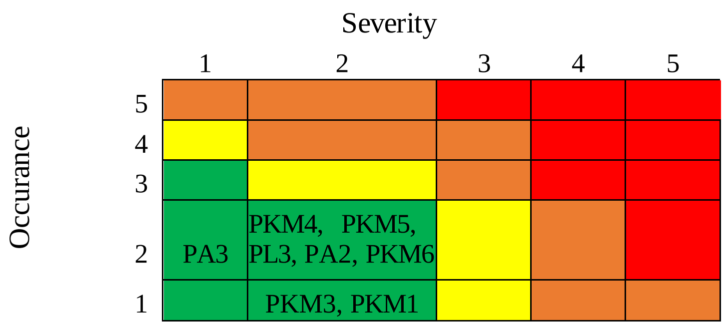

Figure 4. Risk Matrix Affecting Human Safety, the Environment, and Laboratory Equipment

The difference in results between Risk Priority Number (RPN)-based prioritization and a risk matrix stems from their evaluation parameters: a risk matrix only maps the combination of severity and occurrence, while an RPN also considers the detection rate, which measures the reliability of the existing control system. Consequently, risks categorized as low in the matrix can be prioritized in an RPN analysis if the detection and

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monitoring capacity are still weak, confirming that the RPN analysis provides a more comprehensive picture of the effectiveness of actual mitigation in the laboratory. Although the majority of potential risks are classified as low (acceptable risks) and have been proven to be effectively suppressed through the implementation of standardized SOPs and PPE, these risks are still included in the risk register for regular monitoring to anticipate operational dynamics, in line with the principles of sustainable risk management in ISO 31000:2018 and ISO 45001:2018.

Risk Assessment Based on the Use of Chemicals

Risk identification based on chemical use was obtained from respondent observations and a review of several previous studies. Within this potential risk, there are 15 risk indicators that will be assessed in the 17 laboratories subject to the study. The results of the risk assessment are presented in Table 5.

Table 5. Risk Assessment of Chemical Use

Code	Risk Indicators	O	S	D	RPN	Rank
RBK10	The laboratory does not have emergency facilities such as *eyewash* and *safety shower*.	2.59	2.24	1.53	8.85	1
RBK5	Handling of chemical spills does not meet standards	2.29	2.24	1.65	8.45	2
RBK12	The risk of spillage increases due to improper storage.	2.06	1.82	1.71	6.40	3
RBK13	Hazardous chemicals are not managed by safe dilution and transfer procedures.	1.76	1.88	1.76	5.86	4
RBK11	Chemicals were not stored according to proper procedures, including segregation.	1.88	1.88	1.59	5.63	5
RBK15	Chemical waste is not managed according to regulations	1.65	1.88	1.76	5.47	6
RBK9	Safety instructions for the use of chemicals were not followed.	1.76	2.12	1.29	4.84	7

The Risk Priority Number (RPN) assessment results for the chemical use category (15 indicators) identified seven major potential risks, with the highest RPN value being the absence of emergency facilities such as eyewashes or safety showers (RBK10), driven by a high occurrence rate due to limited safety budget allocations, where observations showed that 15 out of 17 laboratories did not have them. This finding aligns with Daryono (2025), who noted that 44 percent of laboratories lack emergency showers, and is supported by Nasrallah *et al.*, (2023), who demonstrated that the absence of emergency facilities is strongly correlated with a high rate of laboratory accidents. Furthermore, the high RPN for the risk of substandard chemical spill handling (RBK5) in second place confirms that chemical safety vulnerabilities at the study site are multilayered, encompassing both physical infrastructure deficits and weaknesses in procedural compliance.

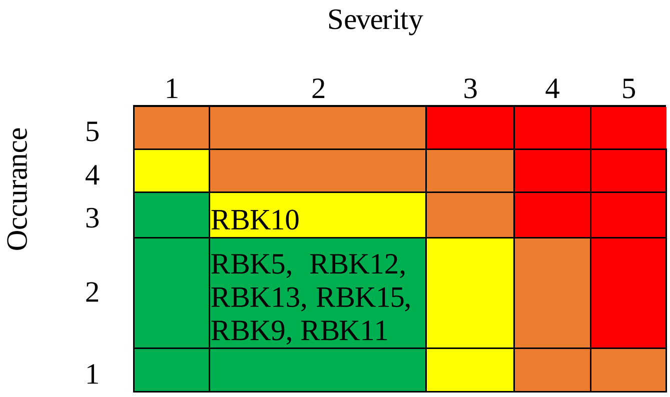

Figure 5. Risk Matrix Based on Chemical Use

Based on the risk matrix mapping from Figure 5, the absence of emergency facilities such as eyewash or safety showers (RBK10) is classified as a medium risk with an incident frequency of "may occur occasionally" and a low severity level, thus requiring special attention in the handling priority scale. Meanwhile, six other potential chemical risks (RBK5, RBK12, RBK13, RBK15, RBK9, and RBK11) are in the low-risk category (acceptable risk) because the frequency of occurrence is relatively rare. Although classified as acceptable and not requiring immediate massive corrective action, these six risks still require regular monitoring to prevent an increase in the level of danger owing to changes in operational conditions. Therefore, the recommended control strategy focuses on strengthening the detection system and preventive measures, such as conducting routine compliance audits for chemical storage and handling procedures.

Risk Assessment Based on the Use of Laboratory Equipment

A risk assessment based on the use of laboratory equipment was conducted to identify potential hazards arising from the operation of equipment during practical and research activities at universities. The use of equipment in laboratories carries different potential risks depending on the type of laboratory, the type of equipment, the operating method, and the level of user interaction with the equipment. Based on the results obtained, four risk priorities were identified. The risk assessment based on the use of laboratory equipment is presented in Table 6.

Table 6. Risk Assessment of Laboratory Equipment Use

Code	Risk Indicators	O	S	D	RPN	Rank
RPL8	The equipment is not promptly repaired or replaced	2.41	2.24	1.82	9.83	1
RPL9	Equipment suitability is not checked before use	1.94	2.12	1.82	7.50	2
RPL5	Damaged laboratory equipment continues to be used	1.71	2.12	1.53	5.52	3
RPL2	Do not turn off machines/equipment that are not in use	1.53	2.18	1.65	5.48	4

Table 6 presents the risk assessment of laboratory equipment use using the FMEA method. Based on these results, four risk priorities were obtained and ranked from highest to lowest. These risks include equipment that is damaged and not immediately repaired or replaced (RRPL8), equipment often not being checked for functional suitability before use (RPL9), the risk of using damaged laboratory equipment (RPL5), and machines or equipment that are no longer in use. The results of this risk assessment indicate that equipment asset management in the laboratory studied is still reactive, meaning that repairs are only taken after damage occurs, rather than being prevented through periodic inspections before equipment is used. The matrix analysis is shown in Figure 6.

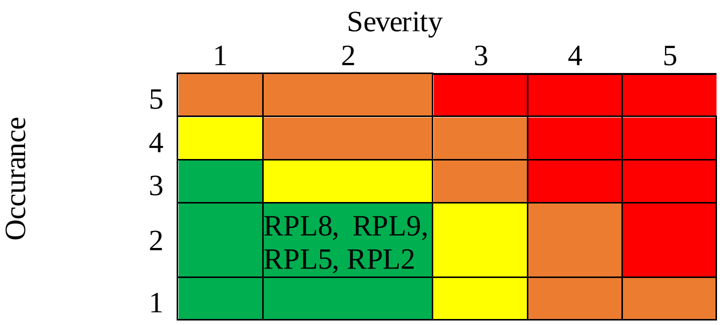

Figure 6. Risk Matrix Based on Laboratory Equipment Use

Figure 6 presents the risk assessment of laboratory equipment use using the FMEA method. Based on these results, four risk priorities were obtained and ranked from highest to lowest. These risks include equipment that is damaged and not immediately repaired or replaced (RRPL8), equipment often not being checked for functional suitability before use (RPL9), the risk of using damaged laboratory equipment (RPL5), and machines or equipment that are no longer in use. The results of this risk assessment indicate that equipment asset management in the laboratory studied is still reactive, meaning that repairs are only taken after damage occurs, rather than being prevented through periodic inspections before equipment is used. The matrix analysis is shown in Figure 6.

Risk Assessment Based on Security and Safety Procedures

Laboratory safety and security procedures aim to control potential hazards that could impact laboratory activities. Risk identification based on safety and security procedures was obtained through questionnaires and a review of several previous studies. The results of the risk assessment based on safety and security procedures are as follows.

Table 7. Risk assessment results based on security and safety procedures

Code	Risk indicators	O	S	D	RPN	Rank
RKK12	Evacuation routes are not available in case of an emergency	2.35	2.47	1.53	8.89	1
RKK14	Not following SOP when handling chemicals	1.88	2.18	1.53	6.27	2
RKK10	Ventilation and air circulation in the laboratory are not good	1.94	1.94	1.47	5.54	3
RKK8	Lack of first aid facilities (P3K)	1.88	1.88	1.41	5.00	4
RKK9	The lighting in the laboratory is not good	2.06	1.65	1.41	4.79	5
RKK5	Not understanding the emergency procedures to follow in the event of an accident involving chemicals	1.65	2.12	1.35	4.72	6
RKK1	Safety and security procedures for working with chemicals were not explained prior to the start of the experiment.	1.53	2.00	1.53	4.68	7
RKK2	Training related to handling chemicals in the laboratories is not routinely.	1.71	1.76	1.35	4.07	8
RKK3	Training on emergency procedures in the laboratory is not conducted routinely.	1.88	1.76	1.18	3.91	9

The risk assessment results for the security and safety procedures category (15 indicators) identified nine main risk priorities, with the highest RPN value being the lack of an evacuation route during an emergency (RKK12), which recorded the highest severity and occurrence scores in Table 7. The absence of this specific evacuation route, where observations show that some laboratories have only one door for entry and exit, indicates a fundamental gap in emergency response planning, a crucial element of the Laboratory OHS Management System. The second highest ranking was non-compliance with SOPs when handling chemicals (RKK14), which showed a similar pattern to the risk of handling chemical spills (RBK5) in the previous category. The consistency of these findings confirms that non-compliance with SOPs is a recurring systemic weakness across various laboratory activities, thus requiring urgent intervention in the form of improved socialization and comprehensive enforcement of SOPs.

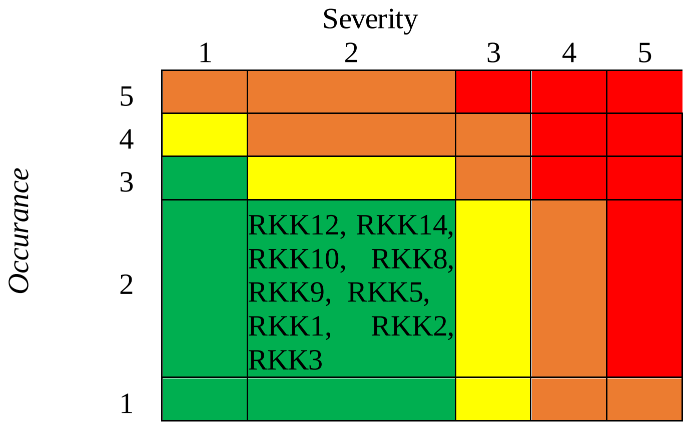

Figure 7. Risk Matrix Based on Security and Safety Procedures

The mapping results in the risk matrix in Figure 7 show that all 9 risk indicators are in the low risk category (frequency "rare" and severity "low"), underscoring the limited resolution of the two-dimensional matrix in distinguishing the level of urgency of treatment. The Risk Priority Number (RPN) analysis successfully provides a more precise sharpening of priorities by including the detection dimension, as seen in the risk of the absence of evacuation routes (RKK12, RPN 8.89), which is much more urgent than the lack of routine emergency training (RKK2, RPN 3.91). Within the Organizational Accident framework (Reason, 2016), RKK12 acts as a latent condition due to the loss of a fundamental defense layer (defense-in-depth), while non-compliance with SOPs (RKK14) represents an active failure that reflects a systemic weakness in safety culture. Therefore, an objective comparison with certified laboratories, as shown in Table 7, is crucial for identifying risk governance gaps and developing targeted improvement recommendations for non-certified laboratories.

Risk Mitigation

Risk control is applied to all hazards identified during the hazard identification process, considering risk rankings to determine priorities and control methods (Ramadhan, 2017). Hazard sources with high RPNs need to be prioritized by providing control actions or proposals (Pratama & Basuki, 2022). The results of hazard identification and risk assessments indicate that several potential hazards in the laboratory are at low to moderate levels. Therefore, structured risk-mitigation efforts are needed to reduce these risks. The Hierarchy of Control approach emphasizes that the most effective controls, from most to least effective, are elimination, substitution, engineering controls, administrative controls, and the use of personal protective equipment (PPE). Recommendations for risk mitigation that must be implemented for risks with the highest RPN in each risk aspect are listed in Table 8.

Table 8. *Hierarchy of control* risk mitigation

Potential Risks	Elimination	Substitution	Technical Control	Administrative Control	PPE
Affected by cracks/broken glass tools	Eliminates unnecessary use of glass tools	Replacing glass tools with polycarbonate plastic or impact materials	Providing containers for broken glass waste	SOP for handling the disposal of broken glass	Safety goggles, gloves, lab coat
The laboratory does not provide emergency facilities such as an eye wash/safety shower.	Eliminate the use of highly hazardous chemicals if they are not essential	Replacing corrosive chemicals with those with a lower hazard level	Installation of eyewash and safety shower according to standards	SOP for chemical spill emergency response, emergency simulation	Face shield, goggles, chemical -resistant apron
Equipment that is damaged is not immediately repaired or replaced	Stop using the damaged tool	Replacing old equipment with new equipment that meets safety standards	*Lock out/tag out* (LOTO) system, preventive maintenance schedule Checklist-based damage reporting system	SOP for equipment maintenance	PPE according to the type of equipment (e.g., gloves, goggles)
Evacuation routes are not available in case of an emergency		Change the layout of the room/laboratory to provide direct exit access to the assembly point.	Design and build evacuation routes according to building safety standards	SOP evacuation procedures Evacuation route map in the room	Emergency masks, safety shoes

CONCLUSION

Based on the results of hazard identification, risk assessment, and risk mitigation that were carried out in 17 laboratories at XYZ University, several conclusions were obtained, including the following: Identification of laboratory hazard risks is grouped into four potential hazards, namely; a) risks based on potential hazards affecting personnel/humans, the environment, and laboratory equipment, totaling 21 potential hazards; b) risks based on the use of chemicals, totaling 15 potential hazards; c) risks based on the use of laboratory equipment, totaling 11 potential hazards; d) risks based on security and safety procedures, totaling 15 potential hazards.

Risk assessment analysis using the FMEA approach yielded the highest RPN for the hazard source categories; a) Risk of being exposed to cracked or broken glassware. b)

Risk of the laboratory not providing emergency facilities such as eyewash or safety showers. c) Risk of damaged equipment not being promptly replaced. d) Evacuation routes not being available in the event of an emergency. Risk mitigation in educational laboratories at PTN XYZ is carried out on risks with the highest RPN, namely, eliminating the use of unnecessary glassware, eliminating the use of highly hazardous chemicals, discontinuing the use of damaged equipment, and changing the laboratory layout to provide direct exit access to the assembly pointy.

The managerial implications of this study emphasize the shift in the role of laboratory managers from merely facilitating academic activities to active risk governance agents based on the COSO Enterprise Risk Management (ERM) framework (Moeller, 2011). In the Governance and Culture dimension, PTN XYZ is responsible for upholding an OHS culture through mandatory user competency certification before permitting laboratory activities, as well as advocating for a dedicated budg*et al*location for safety facility maintenance. In the Strategy and Objective-Setting aspect, PTN XYZ sets a zero-accident target by standardizing the local emergency response infrastructure and leading regular evacuation drills/drills. In terms of Performance, PTN XYZ holds direct operational control through digitizing glassware inventory, organizing chemical storage based on Material Safety Data Sheets (MSDS), and strictly monitoring post-activity equipment shutdown protocols. Finally, in the Review and Revision dimension, PTN XYZ acts as the executor of routine internal audits and the manager of a centralized waste disposal system to independently ensure compliance with procedures and the sustainability of laboratory operational safety.

REFERENCES

Adane, L., & Abeje, A. (2012). Assessment of Familiarity and Understanding of Chemical Hazard Warning Signs among University Students Majoring Chemistry and Biology: A Case Study at Jimma University, Southwestern Ethiopia. *World Applied Sciences Journal*, *16*(2), 290–299.

Bureau, E. (2013). *Report of the Survey on Laboratory Accidents in Secondary Schools for the*. http://resources.edb.gov.hk/~ses.

Daryono, R. (2025). Asesmen Tingkat Potensi Bahaya dan Fasilitas Keselamatan Kerja di Laboratorium Pendidikan. *Journal of Community Development and Disaster Management*, *7*(1), 197–207. https://doi.org/10.37680/jcd.v7i1.6669.

Eyire, J., Emmanuel, O., & Igwe, O. (2013). Evaluations of the Effect of Workshop / Laboratory Accidents and Precautionary Steps towards Safety Practice. *Journal of Electronics and Communication Engineering (IOSR-JECE)*, *6*(3), 16–22.

Fatemi, F., Dehdashti, A., & Jannati, M. (2022). Implementation of Chemical Health, Safety, and Environmental Risk Assessment in Laboratories: A Case-Series Study. *Frontiers in Public Health*, *10*(June), 1–9. https://doi.org/10.3389/fpubh.2022.898826.

Fithri, P., Rafi, M., Pawenary, & Prabuwono, A. S. (2021). Risk analysis of production process for food SMEs using FMEA method: a case study. *E3S Web of Conferences*, *331*. https://doi.org/10.1051/e3sconf/202133102010.

Hubbard, D. (2009). *The Failure of Risk Management*. John Wiley & Sons, Inc.

International Organization for Standardization. (2018). *ISO 45001:2018. Occupational health and safety management systems — Requirements with guidance for use*. International Organization for Standardization.

ISO. (2018). International Standard Risk Management- Guidelines. *ISO 31000: 2018 Risk*

Management - Guidelines, 1–24.
Kementerian Ketenagakerjaan. (2022). Profil Keselamatan dan Kesehatan Kerja Nasional Indonesia Tahun 2022. In *Profil K3 Nasional Tahun 2022 Kementerian Ketenagakerjaan RI*. Kementerian Ketenagakerjaan. https://satudata.kemnaker.go.id/satudata-public/2022/10/files/publikasi/1675652225177_Profil%2520K3%2520Nasional%25202022.pdf
Moeller, R. R. (2011). *COSO Enterprose Risk Management* (Second). Wiley Online Books.
Nasrallah, I., Sabbah, I., Haddad, C., Ismaiil, L., Kotaich, J., Salameh, P., Kak, A. EL, Nasr, R., & Bawab, W. (2023). Evaluating the academic scientific laboratories' safety by applying failure mode and effect analysis (FMEA) at the public university in Lebanon. *Heliyon*, *9*(12), e21145. https://doi.org/10.1016/j.heliyon.2023.e21145.
Pratama, R., & Basuki, M. (2022). Mitigasi Risiko K3 Pada Pekerjaan Pemeliharaan dan Perbaikan di Area Kamar Mesin Kapal General Cargo Menggunakan Metode Mode and Effect Analysis. *Sumberdaya Bumi Berkelanjutan (SEMITAN)*, *1*(1), 100–110.
Priambodo, B., Nursanti, E., & Laksmana, I. (2021). Analisa Risiko Lift (Elevator) dengan Metode FMEA. *Tekonologi Dan Manajemen Industri*, *7*(2), 7–12.
Putra, I. O. (2018). Manajemen Risiko Pada Laboratorium Biofarmasetika dan Analisis Farmasi Fakultas Farmasi Universitas Airlangga. *The Indonesian Journal of Occupational Safety and Health*, *7*(1), 81–90.
Ramadhan, F. (2017). Analisis Kesehatan dan Keselamatan Kerja (K3) Menggunakan Metode Hazard Identification Risk Assessment and Risk Control (HIRARC). *Seminar Nasional Riset Terapan*, *November*.
Ramli, S. (2010). *Sistem Manajemen Keselamatan dan Kesehatan Kerja OHSAS 18001* (ed. 1). Dian Rakyat.
Reason, J. (2016). *Managing The Risks of Organizational Accidents*. Taylor & Francis.
Redjeki, S. (2016). *Kesehatan dan Keselamatan Kerja*. Pusdik SDM Kesehatan – Badan PPSDM Kesehatan Instansi: Kementerian Kesehatan Republik Indonesia.
Ridasta, B. A. (2020). Penilaian Sistem Manajemen Keselamatan dan Kesehatan Kerja di Laboratorium Kimia. *HIGEIA Journal of Public Health Research and Development*, *4*(1), 64–75.
Sellappan, N., & Palanikumar, K. (2013). Modified Prioritization Methodology for Risk Priority Number in Failure Mode and Effects Analysis. *International Journal of Applied Science and Technology*, *03*(04), 27–36.
Sugiyono. (2013). *Metode Penelitian Kuantitatif Kualitatif dan R&D*. ALFABETA.
Supriyadi & Mukhlis. (2018). Desain Sistem Manajemen Risiko pada Perguruan Tinggi Negeri Badan Hukum (PTN BH) Studi Kasus pada Universitas Gadjah Mada. *Journal of Applied Accounting and Taxation*, *3*(2), 158–167.
Suryani. (2015). Good University Governance. *Jurnal Riset Akuntansi*, *7*(2), 51–67.
Syakbania, D.N & Wahyuningsih, A. (2017). Program Keselamatan dan Kesehatan. Kerja di Laboratorium. *HIGEIA Journal of Public Health Research and Development*, *1*(2), 49–57.
Vaughan, E.J & Vaughan, T. (2008). *Fundamentals of Risk and Insurance* (10th ed.). John Wiley & Sons.
Walters, A. U. C., Lawrence, W., & Jalsa, N. K. (2017). Chemical laboratory safety awareness, attitudes and practices of tertiary students. *Safety Science*, *96*, 161–171.