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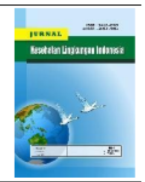

Risk Identification of Hazardous Biological and Chemical Substances in Work Safety Efforts

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ABSTRAK

Latar Belakang: Laboratorium pendidikan merupakan salah satu sistem penunjang akademik dan memiliki peran dalam meningkatkan kualitas pendidikan, khususnya di perguruan tinggi. Kegiatan di laboratorium pendidikan yang menggunakan bahan biologi dan kimia berpotensi menimbulkan infeksi dan kontaminasi terhadap pekerja laboratorium dan lingkungan sekitarnya. Oleh karena itu, penelitian ini bertujuan untuk mengidentifikasi dan menganalisis standar operasional penggunaan bahan biologi dan kimia berbahaya serta praktik keselamatan kerja di laboratorium pendidikan di Universitas Jember.

Metode: jenis penelitian ini adalah deskriptif observasional. Lokasi penelitian yang diamati adalah sembilan laboratorium pendidikan. Variabel yang diamati dalam penelitian ini adalah SOP penggunaan bahan biologi (7 komponen) dan SOP penggunaan bahan kimia berbahaya (8 komponen).

Hasil: Hasil observasi dan analisis menunjukkan bahwa laboratorium mikrobiologi, laboratorium biologi molekuler dan bioteknologi, laboratorium kedokteran molekuler, dan laboratorium biomaterial dan rekayasa bioproses memiliki standar yang baik dalam penggunaan bahan biologi (menerapkan 6 dari 7 komponen). Sementara itu, standar penggunaan bahan kimia berbahaya di laboratorium biologi molekuler dan bioteknologi dan laboratorium molekuler cukup baik (menerapkan 6 dari 8 komponen).

Simpulan: berdasarkan komponen standar laboratorium pendidikan tersebut, setidaknya ada dua standar yang sudah diterapkan, yaitu mencuci tangan menggunakan Alat Pelindung Diri (APD) saat bekerja dengan bahan berbahaya di laboratorium.

Kata Kunci: **laboratorium pendidikan, bahan berbahaya, Standar Operasional Prosedur**

ABSTRACT

Title**: **Risk Identification of Hazardous Biological and Chemical Substances in Work Safety Efforts in Educational Laboratories in Indonesia

***Background**: Educational laboratories are an academic supporting system and have a role in improving educational quality, especially in tertiary institutions. Activities in educational laboratories that use biological and chemical materials can potentially cause infection and contamination of laboratory workers and the surrounding environment. Thus, this research aims to identify and analyze operational standards for the use of hazardous biological and chemical substances and work safety practices in educational laboratories at the University of Jember.*

***Methods**: This type of research is descriptive observational. The research locations were in nine educational laboratories. The variables observed in this study were SOPs using hazardous biological materials (7 components) and SOPs using chemicals (8 components).*

***Result**: The observation and analysis results showed that the Laboratory of Microbiology, Laboratory of Molecular Biology and Biotechnology, Laboratory of Molecular Medicine, and Laboratory of Biomaterials and Bioprocess Engineering had good standards for using hazardous biological materials (applying 6 out of 7 components). Meanwhile, standards for using chemicals in the Laboratory of Molecular Biology and Biotechnology and the Laboratory of Molecular Medicine were also quite good (applying 6 out of 8 components).*

***Conclusions**: Based on these standard components in the educational laboratory, at least two standards have been implemented, such as washing hands and using Personal Protective Equipment (PPE) while working on hazardous substances in the laboratory.*

Keywords: Educational Laboratory, hazardous substances, Standard Operational Procedure

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BACKGROUND

Laboratory is a component of both social and scientific knowledge and a place for the emergence of many new branches of knowledge and technology, which also play a role in improving the learning process of students and scientists at all levels of education[1-3]. In tertiary institutions, laboratory functions as a place to carry out and support academic research and is referred to as an educational laboratory. Kertasih[4] and Kartikasari[5] state that educational laboratories support the academic system and play a role in improving the quality of education, especially in higher education. Activities in the laboratory have great potential to provide various dangerous risks to laboratory users and the surrounding environment. A study conducted by The Occupational Safety and Health Administration (OSHA) in 2013 showed that academic (educational) laboratories are 11 times more dangerous than those in the industrial sector[6]. At the same time, laboratories are also vulnerable to emergencies such as fires, chemical spills, contamination of infectious or biological agents, and poisons[7].

Higher education laboratories contain many chemical and biological substances and use various hazardous substances or equipment in experiments that can pose a risk of injury and occupational accident[8]. Educational laboratories in academic institutions generally use smaller volumes of hazardous materials than laboratories in industrial facilities, which often manipulate larger quantities of hazardous materials to develop more extensive manufacturing processes[9]. Many laboratory procedures also produce microbial residues that contaminate laboratory bench surfaces, fingers, and the body of workers or students. Once contamination has occurred, the pathogens may accidentally be carried outside the laboratory or accidentally transfer the pathogens on their hands to the e1, nose, mouth, or damaged skin tissue[10]. Laboratories that handle dangerous pathogens must be responsible for managing health and safety and even laboratory security against threats issued by these biological agents[11]. The use of hazardous biological and chemical materials in educational laboratories must comply with operational standards set by the laboratory to prevent potential infection and environmental pollution. According to Johnston et al. (10), more than 80% of laboratory-associated infections (LAI) cannot be tracked. Thus, every activity in the laboratory must comply with predetermined standards. The application of the concept of Health, Safety, and Environment (HSE) particularly aims as a mitigation measure to prevent the impact of biological and chemical materials in educational laboratories[12]. This research gap focuses on laboratories that have two dominant hazards, namely biology and chemistry in their operations and combines an descriptive-observational design and a qualitative approach (expert opinion).This study aims to identify and analyze operational standards for the use of hazardous biological and chemical substances and work safety practices in educational laboratories at the University of Jember, so that educational laboratories have adequate capabilities to carry out work safely and securely.

MATERIALS AND METHODS

This research applied descriptive-observational design and a qualitative approach. The first step of this research was observation to identify hazards, and the second step was to analyze risks using a qualitative approach using the expert opinion method. The research was conducted by direct observation without special treatment of the object. In addition, this research is cross-sectional, where researchers can find out the results of research at the same time between the variables that occur in the research object that has been measured. Structured interviews with respondents were conducted to support the observation results. The research was conducted in 9 (nine) educational laboratories at the University of Jember, which included the Biotechnology Laboratory (A), Botany Laboratory (B), Ecology Laboratory (C), Microbiology Laboratory (D), Zoology Laboratory (E), Molecular Biology and Biotechnology Laboratory (F), Molecular Medicine Laboratory (G), Nutraceutical, and Pharmaceuticals Laboratory (H), Biomaterials and Bioprocess Engineering Laboratory (I).

Informants in this research were laboratory assistants selected from the nine educational laboratories at the University of Jember based on purposive sampling. They were required to meet the following conditions: (1) being a structural or functional part of the educational laboratory at the University of Jember and (2) understanding the SOP in the educational laboratory at the University of Jember. The instrument in this study was an observation sheet consisting of two variables, namely (1) SOP using hazardous biological materials and (2) SOP using chemicals. More clearly, each variable and its constituent components can be seen in **Table 1** below.

Table 1. Variables and components in biological risk and work safety

No	Variable	Components
1	Standard Operational Procedure (SOP) for using hazardous biological materials	1. Use biological agents with the same precautions as hazardous chemicals. 2. Work very carefully with sharp objects. 3. Work carefully to reduce the aerosol formation. 4. Wash hands after contact with contaminated materials. 5. The laboratory door remains closed while the experiment is in progress. 6. Use personal protective equipment when working with hazardous biological materials. 7. Decontamination of waste before disposal to landfill.
2	Standard Operational Procedure (SOP) for using hazardous chemical materials	1. Know the nature of the handled chemical substance. 2. Use MSDS as a reference for information on physical and chemical properties. 3. Use chemicals as small as possible. 4. Store chemicals properly. 5. Provide appropriate and ready-to-use fire extinguishers. 6. Wash hands after contact with contaminated materials. 7. Use personal protective equipment when working with hazardous chemicals. 8. Decontaminate waste before disposal to landfill

Source: Research Data, 2022

Data Analysis of this research used the Miles and Huberman Model[13], which consists of data reduction, data display, and conclusion drawing. Data reduction intends to further specialize the discussion according to the desired goal. Presentation of data using narrative (descriptive). Drawing conclusions that can later be used to formulate recommendations on the problems raised by researchers. Research ethics in this study involves the procedure of requesting permission from the relevant laboratory, including the head of the laboratory and other laboratory users, so as not to interfere with ongoing laboratory activities. No ethical tests were carried out because the object of research was not humans or animals but the laboratory environment under the supervision of the supervisor and laboratory management.

RESULTS AND DISCUSSION

The results of observation and analysis of SOP variables using hazardous biological materials consisting of seven observation components in nine educational laboratories at the University of Jember can be seen in **Table 2** and **3** below.

Table 2. Result of observation and analysis based on educational laboratories

No	**Component (SOP uses hazardous biological materials)**	**Educational Laboratories A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
B1	Use biological agents with the same precautions as hazardous chemicals	1	0	0	0	0	0	0	0	0
B2	Work very carefully with sharp objects	0	0	0	0	0	0	0	0	0
B3	Work carefully to reduce the aerosol formation	0	0	0	0	0	0	0	0	0
B4	Wash hands after contact with contaminated materials	0	0	0	0	0	0	0	0	0
B5	Keep the laboratory door closed while the experiment is in progress	0	0	0	0	1	1	0	0	0
B6	Use personal protective equipment when working with hazardous biological materials	0	0	0	0	0	0	0	0	0
B7	Decontaminate waste before disposal to landfill	1	1	1	0	0	0	0	0	0
Based on Laboratory Type	**TOTAL Risky (1)**	**2**	**1**	**1**	**0**	**1**	**1**	**0**	**0**	**0**
	TOTAL Not Risky (0)	**5**	**6**	**6**	**7**	**6**	**6**	**7**	**7**	**7**

Source: Research Analysis, 2022

Based on **Table 2**, several laboratories have not implemented SOPs for using hazardous biological materials optimally. In the biotechnology laboratory, of the 7 components, 5 components have been implemented, namely components B2, B3, B4, B5, and B6. Meanwhile, in the Botanical Laboratory, 6 components have been implemented, namely components B1, B2, B3, B4, B5, and B6. In the Ecology Laboratory, there are 6 components that have been implemented, namely B1, B2, B3, B4, B5 and B6. In the Microbiology Laboratory, 7 components have been implemented, namely B1, B2, B3, B4, B5, B6, and B7. In the Zoology Laboratory, 6 components have been implemented, namely B1, B2, B3, B4, B6, and B7. In the Molecular Biology and Biotechnology Laboratory, 7 components have been implemented, namely B1, B2, B3, B4, B6, and B7. In the Molecular Medicine Laboratory, 7 components have been implemented, namely B1, B2, B3, B4, B5, B6, and B7. In the Nutraceutical and Pharmaceutical Laboratory, 7 components have been implemented, namely B1, B2, B3, B4, B5, B6, and B7. In the Biomaterials and Bioprocess Engineering Laboratory, 7 components have been implemented, namely B1, B2, B3, B4, B5, B6, and B7.

The analysis of the components observed in this study can be seen in **Table 3** below.

Table 3. Result of observation and analysis based on the type of components

No	Component (SOP uses hazardous biological materials)	Educational Laboratories									Risky (1)	Not Risky (0)
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**		
B1	Use biological agents with the same precautions as hazardous chemicals	1	0	0	0	0	0	0	0	0	**1**	**8**
B2	Work very carefully with sharp objects	0	0	0	0	0	0	0	0	0	**0**	**9**
B3	Work carefully to reduce the aerosol formation	0	0	0	0	0	0	0	0	0	**0**	**9**
B4	Wash hands after contact with contaminated materials	0	0	0	0	0	0	0	0	0	**0**	**9**
B5	Keep the laboratory door closed while the experiment is in progress	0	0	0	0	1	1	0	0	0	**2**	**7**
B6	Use personal protective equipment when working with hazardous biological materials	0	0	0	0	0	0	0	0	0	**0**	**9**
B7	Decontaminate waste before disposal to landfill	1	1	1	0	0	0	0	0	0	**3**	**7**

Source: *Research Analysis, 2022*

Based on **Table 3**, components B4 (wash hands after contact with contaminated materials) and B6 (use PPE when working with hazardous biological materials) are two components that have been implemented in 9 educational laboratories at the University of Jember. Furthermore, components B1 (use biological materials with the same precautions as hazardous chemicals) have been implemented in educational laboratories at the University of Jember, except for the Biotechnology laboratory. Component B5 (keep the laboratory door closed while the experiment is in progress) has been implemented in seven educational laboratories at the University of Jember, except for the Laboratory of Zoology, Molecular Biology and Biotechnology. Component B7 (decontaminate waste before disposal into landfills) has been implemented in six educational laboratories, except for the Laboratory of Biotechnology, Botany, and Ecology.

The results of observation and analysis of SOP variables using chemicals consisting of seven components of observation in nine educational laboratories at the University of Jember can be seen in Tables 4 and 5 below.

Table 4. Result of observation and analysis based on educational laboratories

No	Component (SOP uses hazardous chemical materials)	Educational Laboratories								
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
K1	Know the nature of the handle chemical substance	0	0	0	0	1	0	0	0	0
K2	Use MSDS as a reference for information on physical and chemical properties	0	1	0	1	1	0	0	0	0
K3	Use chemical as little as possible	1	0	1	0	0	0	0	0	0
K4	Store chemicals properly	1	1	1	1	1	0	0	1	1
K5	Provide appropriate and ready-to-use fire extinguishers	1	1	1	0	1	1	0	1	1
K6	Wash hands after contact with contaminated materials	0	0	0	0	0	0	0	0	0

No	Component (SOP uses hazardous chemical materials)	Educational Laboratories								
		A	B	C	D	E	F	G	H	I
K7	Use personal protective equipment when working with hazardous chemicals	0	0	0	0	0	0	0	0	0
K8	Decontaminate waste before disposal to landfill	1	0	1	1	1	1	1	1	1
Based on Laboratory Type	**TOTAL Risky (1)**	**4**	**3**	**4**	**3**	**5**	**2**	**1**	**3**	**3**
	TOTAL Not Risky (0)	**4**	**5**	**4**	**5**	**3**	**6**	**7**	**5**	**5**

Source: *Research Analysis, 2022*

Based on **Table 4** above, of the eight components contained in the SOP variable using chemicals, the Biotechnology laboratory has implemented 4 components which include K1, K2, K6, and K7. In the Botany laboratory, 5 components have been implemented, namely K1, K3, K6, K7, and K8. Meanwhile, the Ecology Laboratory has implemented only 4 components, namely K1, K2, K6, and K7. In the Microbiology Laboratory, 5 components have been implemented, which include K1, K3, K5, K6, and K7. The Zoology Laboratory has implemented only 3 components, namely K3, K6, and K7. The Molecular Biology and Biotechnology Laboratory has implemented 6 components which include K1, K2, K3, K4, K6, and K7. The Molecular Medicine Laboratory has implemented 7 components, namely K1, K2, K3, K4, K5, K6, and K7. The Nutraceutical and Pharmaceuticals Laboratory has implemented 5 components, namely K1, K2, K3, K6, and K7. Meanwhile, the Biomaterials and Bioprocess Engineering Laboratory has implemented 5 components, namely K1, K2, K3, K6, and K7.

Based on the observation and analysis results, no laboratory in this variable applies all the standards for the optimal use of chemicals. However, Molecular Medicine laboratories have implemented seven of the eight observed standards. Each component that has been implemented in the Jember University educational laboratory can be seen in **Table 5** below.

Table 5. Result of observation and analysis based on the type of components

No	Component (SOP uses hazardous chemical materials)	Educational Laboratories									Risky (1)	No Risky (0)
		A	B	C	D	E	F	G	H	I		
K1	Know the nature of the handle chemical substance	0	0	0	0	1	0	0	0	0	**1**	**9**
K2	Use MSDS as a reference for information on physical and chemical properties	0	1	0	1	1	0	0	0	0	**3**	**6**
K3	Use chemical as little as possible	1	0	1	0	0	0	0	0	0	**2**	**7**
K4	Store chemicals properly	1	1	1	1	1	0	0	1	1	**7**	**2**
K5	Provide appropriate and ready-to-use fire extinguishers	1	1	1	0	1	1	0	1	1	**7**	**2**
K6	Wash hands after contact with contaminated materials	0	0	0	0	0	0	0	0	0	**0**	**9**
K7	Use personal protective equipment when working with hazardous chemicals	0	0	0	0	0	0	0	0	0	**0**	**9**
K8	Decontaminate waste before disposal to landfill	1	0	1	1	1	1	1	1	1	**8**	**1**

Source: *Research Analysis, 2022*

Table 5 above shows that components K6 (wash hands after contact with contaminated materials) and K7 (use PPE when working with hazardous chemicals) have been implemented by 9 educational laboratories at the University of Jember. The K1 component (know the nature of the chemicals being handled) has been implemented by 8 educational laboratories. The K3 component (use the slightest possible chemicals) has been implemented in 7 educational laboratories at the University of Jember. The K2 component (make MSDS a reference for information on physical and chemical properties) has been implemented in 5 educational laboratories. The K5 component (provide appropriate and ready- to-use fire extinguishers) has been implemented in two educational laboratories. Components K4 (store chemicals properly) and K8 (decontaminate waste before disposal to landfill) have been applied to only one laboratory.

Table 6. Risk level based on educational laboratories

Educational Laboratories	Hazardous		Result	Risk Level
	Biological	Chemical		
A	2	2	4	Low
B	1	3	4	Low
C	1	4	5	Low
D	0	3	3	Low
E	1	5	6	Medium
F	1	2	3	Low
G	0	1	1	Low
H	0	3	3	Low
I	0	3	3	Low

Table 6 above shows that eight laboratories have a low risk level, except for the Zoology laboratory with a medium risk level.

Table 7. Risk level based on the type of components

Hazardous	No	Component	Result	Risk Level
Biological	**B1**	Use biological agents with the same precautions as hazardous chemicals	1	Low
	B2	Work very carefully with sharp objects	0	Low
	B3	Work carefully to reduce the aerosol formation	0	Low
	B4	Wash hands after contact with contaminated materials	0	Low
	B5	Keep the laboratory door closed while the experiment is in progress	2	Low
	B6	Use personal protective equipment when working with hazardous biological materials	0	Low
	B7	Decontaminate waste before disposal to landfill	3	Low
Chemical	**K1**	Know the nature of the handle chemical substance	1	Low
	K2	Use MSDS as a reference for information on physical and chemical properties	3	Low
	K3	Use chemical as little as possible	2	Low
	K4	Store chemicals properly	7	Medium
	K5	Provide appropriate and ready-to-use fire extinguishers	7	Medium
	K6	Wash hands after contact with contaminated materials	0	Low
	K7	Use personal protective equipment when working with hazardous chemicals	0	Low
	K8	Decontaminate waste before disposal to landfill	8	Medium

Table 6 above shows that twelve components have a low risk level, except for K4 (store chemical properly), K5 (provide appropriate and ready-to-use fire extinguishers), and K8 (decontaminate waster before disposal to landfill) with a medium risk level.

Standard Operational Procedure (SOP) for using hazardous biological materials

Based on the observation and analysis results, 8 educational laboratories are good at implementing SOPs for the use of hazardous biological materials, namely the Botany Laboratory, the Ecology Laboratory, the Microbiology Laboratory, the Zoology Laboratory, the Molecular Biology and Biotechnology Laboratory, the Molecular Medicine Laboratory, the Nutraceutical and Pharmaceutical Laboratory, the Biomaterials and Bioprocess Engineering Laboratory. These 4 laboratories have implemented 6 of the 7 components in the SOP variables to use hazardous biological materials, namely the Botany Laboratory, the Ecology Laboratory, the Zoology Laboratory, and the Molecular Biology and Biotechnology Laboratory. The other 4 laboratories have implemented 7 of the 7 components in the SOP variables to use hazardous biological material (**Table 2**). Laboratories must apply standard operational procedures for practicum and research activities optimally. Determining safety levels in the laboratory is especially important for personnel working in facilities potentially exposed to microbiological agents such as bacteria, viruses, fungi, related agents, and other microbiological products. Thus, applying existing standards will protect laboratory personnel and the surrounding environment from biological hazards[14]. Biological materials are widely used in these three laboratories, especially in the microbiology laboratory, which has the potential to be able to work with pathogenic bacteria that are harmful both within the laboratory and in the surrounding environment[15]. In molecular medicine laboratories, the use of biological materials that are toxic to individuals and the environment and the presence of synthetic biological processes also has the potential to be used in bioterrorism or the release of harmful organisms into the environment[16].

Meanwhile, the Biomaterials and Bioprocess Engineering Laboratory, which involves a lot of waste utilization and optimizing food, energy, and pharmaceutical activities, has the potential to trigger the growth of harmful bacteria or microbes, especially in optimizing food and pharmaceutical ingredients. As a result, it can cause problems with a bad taste in food or make drug products contain biological ingredients harmful to the body[17]. Meanwhile, the Biotechnology Laboratory still requires a lot of adjustments and preparation of SOP components because, based on observations, only 5 out of 7 components have been carried out (**Table 2**). The Biotechnology Laboratory has an enormous potential risk in its activities due to the use of biological materials to produce a new product. The lack of optimization of the implementation of standards for the use of hazardous biological materials in the Biotechnology Laboratory has the potential to pollute the environment and disrupt the balance of the surrounding ecosystem.

Component B2 (work very carefully with sharp objects), B3 (work carefully to reduce the aerosol formation), B4 (wash hands after contact with contaminated materials) and component B6 (use PPE when working with biological materials) have been implemented in all educational laboratories at the University of Jember (**Table 3**). Carefully application of the component on the use of sharp objects (B2) such as surgical instrument (including knives and tweezers) reduce risk of puncture and cut injuries. Carefully application of component work to reduce aerosol formation can reduce the risk of airborne exposure, resulting in respiratory distress for laboratory users. The potential for aerosol formation can occur with the use of disinfectants (H_2O_2) and formalin when cleaning tissue culture rooms. In addition, heavy metals used in ice rooms can also trigger aerosol formation. The use of special masks is highly recommended when using this room, but the masks used are only ordinary masks. The application of hand washing components (B4) can reduce the risk of spreading harmful biological materials such as pathogenic bacteria, viruses, GMOs, and other organisms. Fuls et al.[18] explain that hand washing is the easiest and simplest step to prevent laboratory-acquired infections. Proper hand washing can minimize infection in clinical and non-clinical settings. In line with this, Johnston et al.[10] state that using soap in hand-washing practices is recommended as a standard practice in microbiology laboratories to prevent microbial transients from laboratory workers' hands to the surrounding environment. It is implemented by requiring students to wash their hands before entering the laboratory, while working or changing work steps, and when leaving the laboratory.

Meanwhile, applying PPE components (B6) such as laboratory coats, eye protection, and gloves can provide direct protection to researchers. PPE is considered the last barrier to protect against laboratory hazards in a hazardous event. Wearing the necessary PPE can be considered a standard for how well researchers comply with safety policies within the laboratory[19].

Standard Operational Procedure (SOP) for using hazardous chemical materials

Based on the SOP variable for using chemical substances, 9 educational laboratories at the University of Jember have not optimally applied all the components in this variable. It is indicated by the number of components that have been carried out by these nine laboratories ranging from 3-6 components applied from the 8 constituent components in it (**Table 4**)—even though, based on research from Si et al.[20] and Rezaee et al.[21], working with hazardous chemicals has a high potential to cause work accidents or the spread of disease. Molecular Biology Laboratory and Molecular Medicine Laboratory have implemented 6 and 7 existing components. The K8 component (decontaminate waste before disposal to landfill) is not implemented in these two laboratories. At the same time, the K5 component (provide appropriate and ready-to-use fire extinguishers) is the specific component between these two laboratories. The Molecular Biology and Biotechnology Laboratory has not yet provided a fire extinguisher, while the Molecular Medicine Laboratory has prepared one. In the Molecular Medicine Laboratory, by law, waste disposal must be disposed of in a temporary waste container (jerry can) and neutralized with distilled water. However, many students or researchers dispose of waste carelessly through the sink or directly into the trash. Waste disposal that does not comply with this procedure can pollute the surrounding environment and be hazardous to the health of other living things. In addition, the Ecology Laboratory and the Zoology Laboratory are classified as laboratories that have not implemented optimal safety standards, where only 4 out of 8 components have been carried out (**Table 4**). Based on observations, these two laboratories have a low intensity in the use of chemicals, so some of the components in this variable are less relevant. However, the provision and implementation of standards by the provisions can minimize the risk of unexpected events that will arise in the future. This is because work accidents in the Education Laboratory are six times higher among students who have research activities in the laboratory[22]. Thus, universities and educational laboratories are expected to pay more attention to work safety, provide information regarding the materials used, continue to conduct education, and create a safe, educational laboratory environment[23].

Components K6 (wash hands after contact with contaminated materials) and K7 (use PPE when working with hazardous chemicals) have been implemented in 9 educational laboratories at the University of Jember (**Table 5**). Based on National Research Council[24] and American Chemical Society Joint Board-Council Committee on Chemical Safety[25], washing hands with soap and water is recommended after working with chemicals in the laboratory, even if in practice using latex gloves. It is intended to be able to remove skin contamination that might occur. In addition, Ruekberg[26] points out that washing hands is not a "replacement" for personal protective equipment. Indeed, it is better to use a milder antibacterial soap after coming from the research laboratory and students have to wash their hands. 9 educational laboratories at the University of Jember have implemented the practice of washing hands before, during, and after being in the laboratory. It, of course, will reduce the risk of infection and chemical contamination of the researchers' skin. The use of PPE has also been implemented in 9 educational laboratories at the University of Jember, such as footwear, laboratory coats, latex gloves, and medical masks; even for some research treatments, the use of glasses is mandatory. PPE can protect humans from chemical, radioactive, physical, electrical, mechanical, and other hazards to reduce the risk of injury and danger[27]. According to DellaValle et al.[28], PPE can include items such as gloves, safety glasses, safety shoes, earmuffs, safety helmets, respirators, vests, body clothing, and others based on the category of protection on the ears, legs, hands and arms, body, and airways. According to Chandra et al.[29], using safety glasses and a lab coat is recommended when using cannulas and needles for chemical manipulation to prevent direct contamination of the e1 and body of the researcher.

Based on observation and analysis, the level of risk in educational laboratories tends to be low. It is because 8 out of 9 laboratories have implemented risk control properly. However, the zoology laboratory is of particular concern because it has a medium risk level. It is due to several SOP components on hazardous chemicals that have not been complied with (**Table 6**). Of the 15 biological and chemical hazard SOP components, only 3 have a medium risk level, namely K4 (store chemical properly), K5 (provide appropriate and ready-to-use fire extinguishers), and K8 (decontaminate waster before disposal to landfill). Other components have a low risk level (**Tabel 7**). Compared to the SOPs for the use of hazardous biological materials, the SOP for the use of hazardous chemicals still has a medium risk level. This still allows for potential risks to user health and the environment. So, it is necessary to take crucial steps to increase the compliance of laboratory users with the existing SOPs. Efforts that need to be made to optimize SOPs for hazardous chemicals include conducting training for laboratory users on laboratory work rules and procedures to inspire enthusiasm, shape culture, and raise awareness of chemical use[30]. This assertion is in accordance with Minister of Health Regulation number 48 of 2016 regarding office safety and health standards, which mandates that the implementation of occupational health and safety must be supported by human resources who are knowledgeable in the field, facilities, and infrastructure[31]. Also, according to Health Minister Regulation number 70 of 2016, occupational health and safety is implemented in industry and must be periodically monitored[32].

CONCLUSION

Of the 9 educational laboratories observed and analyzed in this study, the Microbiology Laboratory, the Molecular Biology and Biotechnology Laboratory, the Molecular Medicine Laboratory, and the Biomaterials Engineering and Bioprocess Engineering Laboratory have good standards for the use of hazardous biological materials. Meanwhile, in terms of chemical substance usage, the Laboratory of Molecular Biology and Biotechnology and the Laboratory of Molecular Medicine are also quite good. It can be proven in the observation that the 4 laboratories have implemented at least 6 standards for the use of hazardous biological substances and chemicals. Based on the standard components for using hazardous biological materials and chemicals, components for washing hands and using PPE while working in the laboratory have been implemented in nine educational laboratories at the University of Jember.

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