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Analysis of Potential Risk Hazard with The HIRA and HAZOP Approach (Case Study: Laboratory of Engineering Faculty, Universitas Sultan Ageng Tirtayasa)

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Abstract:- The laboratory is a place to simulate actual conditions equipped with equipment. All equipment has potential hazards: mechanical, electrical, chemical, physical, biological and ergonomic. This study aims to determine the potential risks, assess the risks' level, and then provide solutions for each hazard found. The method used in this research is HIRA and HAZOP. The results obtained in this study are that three laboratories have several extreme risk values, five laboratories have a high-risk value. Then five laboratories with medium category and eight laboratories with low class.

Keywords:- *Laboratory; Risk; Hazard; HIRA; HAZOP.*

I. INTRODUCTION

Potential hazards in a work environment can trigger work accidents. Potential risks can be caused by many factors, including unsafe working conditions and unsafe activities. In process risk assessment and management, hazard identification is the first and notable step [1][2]. And potential hazards need to be controlled and prevented not to cause losses, accidents or damage to equipment in the work environment.

The definition of the work environment, in general, is the physical, social, and psychological life in one place. It affects employee performance and productivity. In the work environment, everyone does their job and fulfils their duties. The work environment is not limited to the place where a person works but also includes the physical and non-physical environment, work methods and even work arrangements both individually and in groups.

One of the working environments at Sultan Ageng Tirtayasa University is the Engineering Faculty. The Engineering Faculty, Universitas Sultan Ageng Tirtayasa, has six departments and several laboratories. The laboratories are in the Department of Electrical Engineering has five laboratories with twelve practices; Mechanical Engineering with three laboratories, and three externships; Industrial Engineering with four laboratories and fourteen practices. Meanwhile, Metallurgical Engineering has two laboratories with five apprenticeships; Civil Engineering has one laboratory with three practices. And then Chemical Engineering with three laboratories, and six internships. The laboratory is equipped with equipment and chemicals.

The laboratory is a small workplace which use to simulate the actual work. Laboratories may contain mechanical hazards, electrical hazards, chemical hazards, physical hazards, biological hazards, and ergonomic hazards. Table 1 shows the types and forms of hazards. Work safety in the laboratory is one of the programs to protect students when carrying out practical lectures or while at work from the risk of work accidents and damage to machines or work tools. Therefore, the execution of Occupational Health and Safety is critical to be applied in various types of work to reduce or even eliminate the potential risk of danger that results in accidents. And so does the laboratory.

Table 1. Types and forms of hazards

Type Hazard	Forms of hazards
Mechanical hazards	Clamp point, pulley or roller rotation
Electrical hazards	Electric shock, or sparks
Chemical hazards	Gases, Smoke, Steam, Chemicals
Physical hazards	Lighting, Vibration, Noise
Biological hazards	Micro Biology (Virus, bacteria, fungi, etc.); Macro Biology (Animals, insects, plants)
Ergonomic hazards	Physical stress (repetitive movement, tight space, forcing energy); Mental Stress (tired/bored, overloaded)

Identification of the hazards, sources, and the effort to ensure the risk level of each hazard is the step of risk assessment in the workplace [3]. A simple definition of hazard is anything that can cause an accident. However, OHSAS 18001: 2007 stated that hazards are all sources, situations or activities that can result in work accidents (injury) and work-related diseases. There are many methods for conducting a risk assessment in the workplace. This study carried out a risk assessment using the Hazard Identification and Risk approach

Assessment (HIRA) and Hazard and Operability Study (HAZOP). HIRA is an approach to identify hazards and evaluate risks in an activity [4]. The HIRA approach ensures that it can control existing risks within the tolerance limits of an organization[5]. Research on HIRA, among others, was carried out by [5]–[11]. While HAZOP is an impersonal technique for hazard identification and risk ranking in hazardous facilities[12]. Meanwhile [8], [13]–[20] solving risk and hazard research problems with HAZOP.

This study aims to identify and classify laboratories based on the types of risks and hazards. Meanwhile, the urgency of this research is that it is necessary to identify potential hazard risks in laboratories in the Engineering Faculty, Universitas Sultan Ageng Tirtayasa. The research results are recommendations for improvement and solutions to overcome potential hazards and risks in the laboratory to avoid work accidents, from near misses to fatal ones.

The rest of the work is organized as follows: a brief explanation about HIRA and HAZOP in section 2. The methodology in section 3. Result and discussion describe in section 4. And the last is the conclusion present in section 5.

II. HIRA AND HAZOP

A. Hazard and Risk

Hazard and risk are different things. The following illustration explains the two terms. (1) The live power cable is open (without wrapping) located behind your house; this condition is a hazard. However, if family members play or are in the vicinity of the exposed power lines, it will be called risk. (2) Rocks hanging on the cliff road, the condition is a hazard. It will be a risk if there are road users who pass through the area. (3) The condition of a rotating machine that is not protected is a hazard. If mechanical workers are repairing the unit or close to the area, it will turn into a risk. So the risk is something we live with as individuals daily. People are constantly making decisions based on risk. Simple choices in everyday life such as driving, crossing the street, and investing money imply acceptance risk. Risk is the combination of the likelihood and severity of a particular hazardous event occurring. Mathematically, the risk is calculated by the equation[21]:

$$\text{Risk} = \text{Likelihood } (L) \times \text{Severity } (S) \quad (1)$$

The likelihood is an event that is likely to occur within a certain period or under certain circumstances. Severity is the result of an event such as the severity of an injury or person's health, property damage, an insult to the environment, or any combination caused by the event. Table 2 indicates the likelihood value, and Table 3 represent severity. While Table 4 states the risk value. The risk assessment reveals priority actions to manage the hazard effectively.

Table 2. The likelihood values

Likelihood (*L*)	**Example**	**Rating**
Most likely	The most likely result of the hazard/event being realized	5
Possible	Has a good chance of occurring and is not unusual	4
Conceivable	Might be occur at sometime in future	3
Remote	Has not been known to occur after many years	2
Inconceivable	Is practically impossible and has never occurred	1

(Source: DOSH 2008)

Table 3. The severity values

Severity (*S*)	Example	Rating
Catastrophic	Numerous fatalities, irrecoverable property damage and productivity	5
Fatal	Approximately one single fatality major property damage if hazard is realized	4
Serious	Non-fatal injury, permanent disability	3
Minor	Disabling but not permanent injury	2
Negligible	Minor abrasions, bruises, cuts, first aid type injury	1

(Source: DOSH 2008)

Table 4. The risk values

Risk	Description	Action
15 - 25	High	A HIGH risk requires immediate action to control the hazard as detailed in the hierarchy of control. Actions taken must be documented on the rish assessment from including date dor completion.
5 – 12	Medium	A MEDIUM risk requires a planned approach to controlling the hazard and applies temporary measure if required. Actions taken must be documented on the risk assessment from including date for completion
1 – 4	Low	A risk identified as LOW may be considered as acceptable and futher reduction may not be necessary. However, if the risk can be resolved quickly and efficientty, control measures should be implemented and recorded.

(Source: DOSH 2008)

B. Hazard Identification and Risk approach Assessment (HIRA)

HIRA is a process to find out the existence of a hazard, then calculate the magnitude of risk and determine whether the risk is acceptable or not. HIRA is a technique used to recognize potential hazards of workplace accidents[8]. It's systematic, comprehensive and convenient to perform algorithms. Based on [5][10][22], the HIRA process consists of four processes, i.e. 1) Hazard identification, 2) risk assessment, 3) risk analysis, 4) monitor and review.

The objectives of HIRA are as follows:

1) To identify all factors that can cause harm to employees and others (hazard);
2) To consider the high probability of harm that afflicts anyone in the circumstances of a particular case and the severity that may arise from it (risk);
3) To enable employers to plan, introduce and monitor preventive measures to ensure that risks care is adequately controlled at all times.

C. Hazard and Operability Study (HAZOP)

Hazard and Operability Analysis (HAZOP) is an approach to identify potential hazards and operational problems in a sequential manner[23]. The whole system is assessed by asking how a part has deviation. Then decide whether the deviation will pose a danger [24]. Figure 1 is an example of a HAZOP template. states HAZOP belongs to the qualitative risk analysis group. The risk index of the hazard is determine by multiplying the frequency (*F*) and the severity (*S*) of the effect of each hazard [12]. This step did after the identification of the hazard.

No.	Guide Word	Element	Deviation	Possible Causes	Consequences	Safeguards	Comments	Actions Required	Actions Assigned to
Assign each entry a unique tracking number	Insert deviation guide word used	Describe what the guide word pertains to (material, process step, etc.)	Describe the deviation	Describe how the deviation may occur	Describe what may happen if the deviation occurs	List controls (preventive or reactive) that reduce deviation likelihood or severity	Capture key relevant rationale, assumptions, data, etc.	Identify any hazard mitigation or control actions required	Record who is responsible for actions
Examples from Cleaning Agent Deviations that were used to explain HAZOP Guide Words									
1	No	Cleaning Agent	No detergent added during cleaning cycle	Detergent supply reservoir empty	Residues not effectively removed, leaving system in an unclean state	Technicians check detergent reservoir before every cycle	Assumes technicians can reliably estimate volume visually	Consider alarm for low detergent reservoir level	Engineer
2	Other than	Cleaning Agent	Wrong detergent used	Technician retrieves wrong detergent from warehouse	Incorrect detergent may be ineffective at removing residues, leaving system in an unclean state	Cleaning log requires verification of proper detergent use. Detergent is labeled.	Many different detergent containers look alike	Ensure technician training addresses detergent selection	Trainer

Fig 1. A HAZOP template [24]

HAZOP steps are as follows[25]:

1) Each HAZOP should be led by an experienced HAZOP facilitator.
2) An essential issue for HAZOP is the definition of nodes and their designation on piping and instrumentation (P&ID) diagrams.
3) "Distortion" can be caused by various reasons, for example, human error, equipment failure, process failure.
4) Causes are established at the site's perimeter, but consequences can occur during the process.
5) Consequences can be sorted by severity using Risk Matrix Analysis.
6) All protective measures identified under HAZOP must be documented and implemented.

III. METHODOLOGY

HIRA and HAZOP are applied to analyze the potential hazard in the laboratory Engineering Faculty. Execution of collection data did in three ways: 1) observation, 2) interviews, and 3) measurement. We made direct observations to determine the activities in each laboratory. At the observation stage, will carry out identification of potential hazards in the laboratory environment, activities in the laboratory, equipment and materials used. During the observation process, documentation is also carried out to support the findings of potential hazards.

Then undertook the interview to know a risk assessment. While conducting a discussion on each head of the laboratory and practicum assistant. The results obtained from the risk assessment become a reference in risk control efforts.

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Measurements made to determine the condition of the physical environment (temperature, humidity, and wind speed) and work posture.

There are three stages to apply the HIRA and the HAZOP methods in this research. The first stage is the implementation of HIRA. Then the execution of HAZOP did in stage two. And the last is giving alternative solutions to reduce a hazard. A concise explanation for each stage is as follows.

- First stage: the implementation of HIRA.
  1) Conduct visits in each laboratory. Observation aims to observe the conditions of the laboratory environment, equipment, materials, and practicum conditions. Then conduct interviews with laboratory assistants or laboratory assistants regarding the activities carried out in the laboratory. Then analyze activities that have the potential to have a hazard risk. Observe and document field conditions that can have a hazard risk and an accident.
  2) Analyzing in more detail potential hazards and risks from observations.
  3) After analyzing the potential hazards and risks that occur, it is then assigning a value (1-5) related to the severity experienced from the potential risks and hazards. Assessment can be seen from the seriousness of the injury or loss that occurred. Or it can also be assessed from the number of lost working days.
  4) Conjunction with the severity, frequency assessment (1-5) did. The evaluation took based on how often the incident occurs or the possibility that the potential hazard can occur.
  5) The risk value is obtained by multiplying the severity value with the frequency of occurrence. This value mapping is related to the risk mapping level, which is low, medium, high, extreme risk.
  6) After getting the risk level, the next step is to determine the recommended solution for each laboratory.

- Second stage: the execution of HAZOP
  Processing using HAZOP carried out several identification processes:
  1) Determine the source of the hazard from the finding data (hazard sources such as electricity, machinery, chemicals, biology, physics, etc.).
  2) After identification based on the source of the hazard, it is necessary to find out what deviations or activities can be dangerous and cause accidents.
  3) Look for the cause the deviation can occur.
  4) Identify what harmful consequences will occur.
  5) Determining corrective action here contains general solutions to existing hazard sources.
- Third stage: based on HIRA and HAZOP proposed alternative solutions that can apply to reduce or even eliminate the potential hazards.

IV. RESULT AND DISCUSSION

The laboratories observed in this study were 18 laboratories from 6 departments. The first is a laboratory in the industrial engineering department with four laboratories, i.e the production systems laboratory. The electrical engineering department has five laboratories: electricity. While the chemical engineering department with three laboratories. The metallurgical engineering department consists of two laboratories, one in the civil engineering department. And finally, three laboratories in the mechanical engineering department. The laboratories in each department are as follows:

1) Industrial engineering department: production system laboratory, work system engineering and ergonomics laboratory, industrial & quality system optimization laboratory, and industrial management studio.
2) Electrical engineering department: computer laboratory, energy laboratory, control laboratory, basic electrical laboratory, telecommunications laboratory.
3) Chemical engineering department: basic chemistry laboratory, chemical engineering operation laboratory, integrated computer laboratory.
4) Metallurgical engineering department: metallurgy 1 and 2 laboratory, engineering drawing and simulation laboratory.
5) Civil engineering department: civil engineering laboratory.
6) Mechanical engineering department: manufacturing engineering laboratory, engineering measurement laboratory, drawing-design and simulation laboratory.

Each laboratory has its practicum. The total number of internships that have been recorded is 45 practicums. Each apprenticeship has its equipment, which is adjusted to the objectives to be achieved by the training. Each practicum observes to carry out the potential hazards. From this manner, find out the risk value for each training. In this way, suggestions for improvement will be more appropriate.

Implementation HIRA proposed risk identification and hazard assessment. HIRA implementation offers risk identification and hazard assessment. In contrast, HAZOP is more detailed to know the deviation which may occur in the workspace. Based on the steps in the HIRA, most of the practicum activities from laboratories in the engineering faculty are in the low-risk category. Other activities are split into medium, high and extreme categories. Figure 2 shows the proportions for each group. While Table 5 is a more detailed description of each exercise in the laboratory.

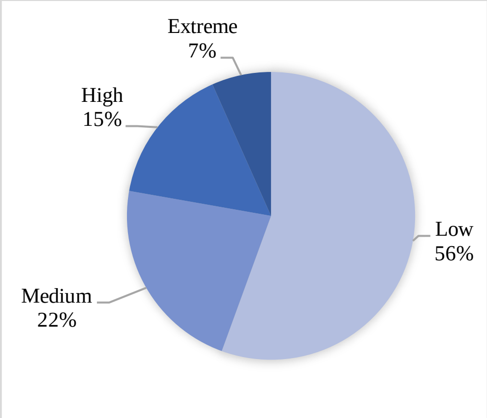

Fig 2. Level of practicum risk in the laboratory, Engineering Faculty

According to Figure 2, the risk scores for the 45 practicums spread across all levels. A total of 56% or equivalent to 25 practicums belonging to the low-risk category. Ten practices or 22% medium risk category. High risk as much as 7% or seven practices. And finally, a high-risk level of 3% occurred in three internships. Practicum with extreme risk belongs to Metallurgical Engineering in Metallurgy 1 and 2 laboratories. Risk in extreme category should be given priority to improvement. Improvement should give priority to risk in the extreme category.

Tabel 5. Risk value category for each laboratory and practices

Dept	Laboratory	Practice	Risk catagory			
			L	M	H	E
Industrial Engineering	Production System	Engineering drawing		v		
		Industrial Eng Design 1		v		
		Industrial Eng Design 2		v		
	Work System Engineering and Ergonomic	Industrial Eng Design 1		v		
		Product Design and Development		v		
	Industrial & Quality System Optimization	Industry Statistics 1	v			
		Operational Research 1	v			
		Industry Statistics 2	v			
		Operational Research 2	v			
		Industrial Eng Design 1	v			
		Industrial Eng Design 2	v			
		Quality Control and Assurance	v			
		Computer Simulation	v			
	Industrial Management Studio	Basic Computer Programming	v			
		Industrial Eng Design 3	v			
Electrical Engineering	Computer	-	v			
	Energy	Electrical Circuits			v	
		Electric Machine			v	
	Control	Basic Control System	v			
		Control Instrumentation	v			
		Digital Control System	v			
	Basic Electrical Laboratory	Digital Engineering	v			
		Electrical Measurement			v	
		Microprocessor Basics	v			
		Basic Electronics	v			
Chemical Engineering	Basic Chemical	Basic chemistry		v		
		Analytical and Physical Chemistry			v	
	Chemical Engineering Operation	Chemical Engineering Operation 1			v	
		Chemical Engineering Operation 2			v	
	Integrated Computer	Engineering Drawing	v			
		Numerical Method	v			
		Process Simulation	v			
Metallurgical Engineering	Metallurgy 1 and 2	Material Engineering				v
		Destructive Testing				v
		Metallurgical Lab 1			v	

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		Metallurgical Lab 2				V
	Engineering Drawing and Simulation	-	v			
Civil Engineering	Civil Engineering	Hydraulics Practicum		v		
		Soil Surveying Prac		v		
Mechanical Engineering	Manufacturing Engineering	Manufacturing Eng 1		v		
		Manufacturing Eng 2		v		
	Engineering Measurement	Metrologya and Measurement Techniques	v			
	Drawing Design and Simulation	-	v			

According to [21], hazards consist of biological hazards, chemical and dust hazards, ergonomic hazards, work organization hazards, physical hazards, and safety hazards. Biological hazards are usually connecting with activity with animals, people, or contagious plant materials. Whereas chemical and dust hazards are types of occupational hazards caused by exposure to chemicals in the workplace. Ergonomic hazard happens when work, body position, and way of working conditions burden your body. Work organization hazards take place when a hazard or some emphasize that cause stress and pressure. Environmental or occupational hazards include physical hazards. Safety hazards are potential hazards that pose a direct risk to safety/may cause natural accidents and injuries.

Finally in accordance with HIRA and HAZOP, the following potential hazard for each department are as follows:

- Industrial Engineering Department

1) Production System Laboratory.

In technical drawing practicum activities, industrial engineering design 1, and industrial engineering design 2, there are potential hazards as follows

- Safety hazards

a. Transverse cable: When connecting the charger cable, the practitioner trips over the transverse line and can cause it to fall.
Control:
The cable is attached to the side of the room using cable clamps.
b. Disconnected socket: When the practitioner wants to connect the treadmill cable to the socket, electricity exposed the practitioner's current due to the dire state of the socket.
Control:
Fix the socket**.**
c. Sawtooth: Practice not being careful when using the cutting machine so that the hand hits the sawtooth and causes injury
Control:
Make a detailed Standard Operation Procedure practicum and attach signs for Occupational Safety and Health using Personal Protective Equipment.

- Ergonomic hazards

a. Inadequate chair size: The chair used has a small diameter of the seat, and the length of the legs of the chair is high, causing the practitioner to feel uncomfortable, and if not careful, he will fall from the chair.
Control:
Replacement of the chair to an ergonomic chair.
b. Position of the practitioner when taking measurements: When measuring the physical environment, the practitioner must measure five times in a standing position at each station. And the tool position is higher for a long and repeated periodically. It can cause the practitioner to experience soreness in the hands.
Control:
Make Standard Operational Procedures practicum in detail and practitioners who measure alternately with each other.

2) Work System Engineering and Ergonomics Laboratory
In the industrial engineering design practicum 1, the hazards that occur are safety hazards and ergonomic hazards. This danger is the same as in the laboratory of production systems. It's happening because the practicum involves two laboratories.
3) Industrial & Quality System optimization Laboratory, all potential hazards are low risk.
4) Industrial Management Studio. All potential hazards are low risk.

- Mechanical Engineering Department

1) Manufacturing Engineering Laboratory
In manufacturing engineering practicum 1, the potential hazards that occur are:

- Safety hazards

a. Scrap: During the turning process, scrap from the test object can hit the practitioner's eye.
Control:
Make detailed Standard Operating Procedures and supervision by assistants during practicum.
b. Rotating chisel: During the process of scraping the test object, the practitioner is not careful, and his hands are hit by the operating chisel.
Control:
Make detailed Standard Operating Procedures and supervision by assistants during practicum.

- Physical hazards

a. Sparks: During the welding process, some sparks can injure the practitioner.
Control:
Make detailed Standard Operating Procedures and supervision by assistants during practicum.
b. Welding process fumes: During the welding process, there is smoke that can be inhaled by the practitioner.
Control:

Make detailed Standard Operating Procedures and supervision by assistants during practicum.

2) Engineering Measurement Laboratory. All potential hazards are low risk.

- Chemical Engineering Department

1) Basic Chemistry Laboratory
In basic chemistry practicum activity, there are:

- Safety hazards

a. Furnace: When hands and other body parts hit the furnace.
Control:
Ensure that the surrounding environment is free of flammable materials.

2) Chemical Engineering Operation Laboratory

In analytical and physical chemistry, chemical engineering operation 1, and chemical engineering operation 2 practicum activities, there are potential hazards as follows.

- Chemical hazards

a. Mercury: Mercury can come out if the compressor power is too high and hits the practitioner.
Control:
Using Personal Safety Equipment (gloves, safety shoes, goggles, etc.)

- Ergonomic hazards

a. **Poor posture:** If the button rotates more than it should.
Control:
Create detailed Standard Operating Procedures and improve material layout for simulation practicum.

3) Integrated Computer Laboratory. All potential hazards are low risk for all practicum.

- Metallurgical Engineering Department

1) Metallurgy 1 and 2 Laboratory
Potential hazards in material engineering practicum, destructive testing practicum, and metallurgy 1 practicum are:

- Safety hazards

a. The pendulum fell: The pendulum lost control.
Control:
Standard Operating Procedures for checking tools before use.

- Ergonomic hazards

a. Pinched hands: During the separation process, hands or clothing can be carried by the conveyor and caught.
Control:
Availability of work display.

- Physical hazards

a. Exposed to the heat of the sample container: The hot container or sample is dropped and hits a member of the body.
Control:
Addition of Personal Protective Equipment for heat/fire resistant suits

b. Welding beam radiation: glasses are not standard compliant to protect eyes.
Control:
Wearing the Personal Protective Equipment.

2) Engineering Drawing and Simulation Laboratory. All practicum has potential hazards in low risk.

- Civil Engineering Department

1) Civil Engneering Laboratory

The following is an exposure to potential hazards in the hydraulics practicum and soil surveying practicum.

- Physical hazards

a. Calibration machine cable: Stumbled on the machine cable while calibrating the tool.

Control:
The cable is attached to the side of the room using cable clamps.

b. Stone/hammer: When setting a stake, the stone or hammer used hits the limb.

Control:
Wearing the Personal Protective Equipment, and create Standard Operating Procedures for tools before use.

- Electrical Engineering Department

1) Computer Laboratory. There are no significant potential hazards in all practicum.
2) Energy Laboratory.

Potential hazards in electrical circuits practicum and electric machine practicum are as follows.

- Safety hazards

a. Shock hazard: At the time of installation of our body parts on the chipped cable, there will be a shock hazard.

Control:
Every practitioner uses safety shoes when practicum.

b. Electric shock: When the user's hand connects the plug to the source contact and touches the socket in the socket. Or there is a chipped cable resulting in electric shock

Control:
Practitioners must obey the rules during the practicum and always be guided by the Standard Operational Procedure.

3) Control Laboratory. All potential hazards in electrical circuits practicum and electric machine practicum state no significant risks.
4) Basic Electrical Laboratory.

There are no significant hazards in digital engineering practicum, microprocessor basics practicum, and basic electronics. At the same time, safety hazards are found in electrical measurement practicum.

- Safety hazards

a. Electric shock: Practice holding the iron on the multi-meter probe wires and jumper wires.

Control:
Practitioners must obey the rules during the practicum and always be guided by the Standard Operational Procedure.

5) Telecommunications Laboratory. In practicum digital signal processing practicum, telecommunications basics practicum, and signal & system practicum, no found potential hazards. All hazards are at a low risk level.

V. CONCLUSION

This research aims to identify potential hazards in laboratories in the Engineering Faculty, Universitas Sultan Ageng Tirtayasa. This study aims to determine the potential hazards in the laboratory of the Faculty of Engineering, Sultan

Ageng Tirtayasa University. The identified potential hazards are safety, ergonomic, physical, and chemical, distributed into the low, medium, high, and extreme levels. The extreme level falls under the metallurgical engineering department, in metallurgical practicum 1 and 2. Finally, the HIRA and HAZOP approach can apply to recognize the potential hazards in the laboratories Engineering Faculty. The result can be a suggestion for the management in Engineering Faculty, especially regarding the importance of occupational health and safety in a scope of work in the laboratory.

For future work, to minimize ambiguity assessment in risk factors maybe can be proposed another method and combine with the HIRA/HAZOP. The method can adopt multi decision making using a fuzzy approach.

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