Assessment of Laboratory Occupational Safety and Health at Engineering Faculty of Diponegoro University

Heru Prastawa, Manik Mahachandra, Dita Rizkiana
Industrial Engineering Department, Faculty of Engineering
Diponegoro University
Semarang, Central Java 50269, Indonesia
heru.prastawa@gmail.com, manik.mahachandra@ft.undip.ac.id, drizkiana21@gmail.com

Abstract

Occupational Health and Safety (OH&S) is an inseparable part of the labor and human resource system. Not only in industry but also educational institutions, everyone needs an OH&S guarantee. One particular place that has many risks and dangers in educational institutions is the laboratory. In the Engineering Faculty of Diponegoro University, there are sixty-two laboratories spread across twelve departments. This study aimed to identify the potential hazards that occur, determine the highest risk, and then design any improvements needed. This study applied the Hazard Identification Risk Assessment and Risk Control (HIRARC) framework. From the identification results, there were nine highest risks found in the Production Systems Laboratory, Microbiology Laboratory, Thermofluidic Laboratory, Electrical Energy Conversion, Power Systems Laboratory, and one non-routine activity with a risk rating ranging from 240-300 (200-400 = high risk, >400 = very high risk). Proposals for improvements were made based on five hierarchies of control, i.e., elimination, substitution, engineering control, administrative control, and personal protective equipment. Among the proposed solutions, there were also standard operating procedures and work permit forms to ensure the safety and health of each activity in the laboratories.

Keywords
Occupational safety, Occupational health, HIRARC, laboratory, university and work permit

1. Introduction

Hazard can be defined as series of phenomenon that occur and cause losses (Pranolo, 2013). Hazard can happen anywhere and anytime, including in an educational institution such as Universitas Diponegoro (Undip). One of the concerns is the handling of Occupational Safety and Health (OSH). It does not only manage the upgrades of social security and welfare of workers, but also Occupational Safety and Health which impacted positively on productivity sustainability. OSH creates guarantees of all assets owned by related individuals. Within the scope of Undip, individuals that are referred consist of students, lecturers, and guests.

Among various existing facilities and infrastructures in an educational institution, laboratory has higher hazard probability compared to others. Faculty of Engineering is one of the places in Undip that has various laboratories. In those laboratories, there are a lot of facilities and activities that are considered not safe in terms of OSH as found in on-site visits by OSH team of Engineering Faculty, Undip. The completeness of facilities is also left unnoticed. For example, there are no key for fire extinguisher cabinets, messy wiring, as well as a lot of hazardous and toxic waste that does not have Material Safety Data Sheet (MSDS). Besides, other problems regarding OSH are also founded such as dirty laboratory, unavailability of detector and emergency contact, and expired light fire extinguisher. Even, there are some laboratories which do not have fire extinguishers and Personal Protective Equipment (PPE) at all. All these findings are examples of lack on OSH aspects.

With many shortcomings founded in OSH aspects in laboratories of Faculty of Engineering, Undip, this research is conducted to prevent and control the possible hazards. The method used in this research are Hazard Identification, Risk Assessment, and Risk Control (HIRARC). HIRARC will show the risks and dangers that occur. So that, the places which has the most potential risks and dangers will be discovered. Laboratories that have higher risks and danger (high and very high-risk category) will be examined deeper on its OSH aspects. This research aims to create comfortable and safe activity and sustainable improvement in the laboratory of Faculty of Engineering, Undip.

2. Literature Review

2.1 Definition of Occupational Safety and Health (OSH)

Occupational safety is defined as efforts aimed to protect workers, the safety of others, equipment, workplaces and production materials, to maintain environment sustainability, and accelerate production process (Triyono, 2014). While occupational health is promotion and maintenance of physical, mental, social state of workers in any position as well as possible (Harrington & Gill, 2005). So, Occupational Safety and Health (OSH) is a form of effort to create a safe and healthy workplace which free from environmental pollution. So that, in the end, it will improve work efficiency and productivity.

2.2 Cause of Work Accident

According to Anizar (2009), generally, there are two factors causing work accident, i.e human factor (unsafe actions) and environment factor (unsafe conditions). Based on research, 80-85 percent of work accidents caused by unsafe action. It is a dangerous action of workers who may be motivated by various reasons (Tarwaka, 2014). Human factor or unsafe actions can be influenced by various things, including:

1. Unbalanced physical workforce, such as body position that causes fatigue, physical disability, temporary disability, and sensibility to something.
2. Lack of education, such as lack of experience, misunderstanding to an order, less skilled, misinterpreting the company operating standards and resulting on incorrect use of work tools.
3. Doing the job without having authority.
4. Doing the job that does not fit the skills.
5. Pretend to wear Personal Protective Equipment (PPE).
6. Carrying excessive loads.
7. Working excessively or exceed working hours.
8. Working under the influence of alcohol or drugs.

Unsafe condition is a condition that is not safe from machinery, equipment, aircraft, materials, work processes, environment, workplace, nature of the work and work system (Tarwaka, 2014). Environmental factor or unsafe conditions can be caused by various things, as follows:

1. Equipment that is no longer proper to be used.
2. Buildings that are non-standard.
3. Exposure to noise.
4. Exposure to radiation.
5. Insufficient or exaggerated lighting and ventilation.
6. Dangerous environmental conditions: gas, dust, steam, and fume.
7. Excessive security.
8. Inadequate warning system.
9. Hazard of explosion or fire.
10. Bad layout (housekeeping).
11. The nature of work that contains potential danger.

2.3 Hazard and Risk

Hazard is something that has potential in causing loss, damage, injury, illness, accident, or even death which is associated to work process and system. Meanwhile, according to AS/NZS 4360:2004, risk is a probability of something to have an impact towards target, measured by the law of cause and effect. Risk is measured by value of probability and consequences or severity. Formula used in risk calculations is:

$$Risk = P \times E \times S \quad \text{.....(2.1)}$$

with P = probability
E = exposure
S = severity

2.4 Hazard Identification Risk Assessment and Risk Control (HIRARC)

Hazard Identification Risk Assessment and Risk Control (HIRARC) is one of the methods usually used to identify hazard, risk assessment, and risk control in work activity. HIRARC is the most important first stage in risk

management of ISO 45001:2018. HIRARC preparation is divided into 3 stages, i.e hazard identification, risk assessment, and risk control (Ahmad, 2016).

1. Hazard Identification

   Based on ISO 45001:2018, there are some things that must be considered by management and workers in identifying hazard and assessing risk at workplace, including:

   a. Routine and non-routine activities at the workplace.
   b. Activities of all parties that enter workplace, including contractors, suppliers, visitors, and guests.
   c. Human behavior, abilities, and other human factors.
   d. Danger from outside the workplace.
   e. Danger emerged at the workplace.

2. Risk Assessment

   There are three main factors, i.e consequence or severity, exposure, and probability with predetermined rating or value. The value of these three factors are multiplied to determine the risk level. The following table describes semi-quantitative size criteria based on AS/NZS ISO 31000.

Table 1. Semi-quantitative size of severity

Category	Description	Rating
Significant Accident	Serious injury or death; need to be treated at the hospital. In nominal form, loss reach IDR 1,000,000,000.	40
Very High	Temporary disability; need to be treated at the hospital. In nominal form, loss reach IDR 100,000,000.	15
High	Injury causing absence of more than 3 days; no need to be treated at the hospital. In nominal form, loss reach IDR 50,000,000.	7
Medium	Injury causing absence of maximum 3 days; workers may not work normally after first aid treatment. In nominal form, loss reach IDR 10,000,000.	3
Low	Scratch, small incision. Workers still possible to work after receiving first aid treatment. No time lost. In nominal form, loss reach IDR 1,000,000.	1

Source: AS/NZS ISO 31000, 2009

Table 2. Semi-quantitative size of exposure

Category	Description	Rating
Continuously	Occur more than once a day	10
Frequently	Occur about once a day	6
Occasionally	Occur once a week until once a month	3
Infrequent	Once a month until once a year	2
Rare	Time of occurrence is unknown	1
Very rare	Time of occurrence is very unknown	0.5

Source: AS/NZS ISO 31000, 2009

Table 3. Semi-quantitative size of probability

Category	Description	Rating
Almost certain	Often occur; most likely to happen	10
Likely	Tend to occur; chance of accident is 50%:50%	6
Unusual but possible	Unusual to happen but possible	3
Conceivable	There has not been any accident for years, but it might occur	1

Source: AS/NZS ISO 31000, 2009

Table 4. Semi-quantitative risk level

Risk level	Comment	Action
>400	Very high	Stopping the activity, the risk is reduced to an acceptable limit
200-400	High	Need to be handled immediately
70-200	Medium	Require technical improvement
21-70	Low	Need to be monitored continuously
0-20	Slight	Activities intensity that pose a risk is reduced as minimum as possible

Source: AS/NZS ISO 31000, 2009

3. Risk Control

In risk control, the hierarchy that must be fulfilled are (Tarwaka, 2014):

1. Elimination
   Elimination is a permanent risk control and should be tried to be implemented as first option.
2. Substitution
   Substitution is defined as a control intended to replace a machine or machine work equipment with a safer one.
3. Engineering control
   Engineering is a controlling effort by changing the machine work object or machine work equipment.
4. Administrative control
   Administrative control is done by providing a work system that can reduce the possibility of someone to have direct contact with potential hazards.
5. Personal Protective Equipment (PPE)
   Types of PPE based on body parts that should be protected from contact with potential hazards including head, eye, ear, respiratory, hand, and foot.

3. Methods

3.1 Research Procedure

1. Literature and Field Study
   Literature study is conducted by collecting information from books and journals related to the definition of hazard, risk, ISO 45001:2018, Occupational Safety and Health (OSH), work accident both in terms of definition and causes, as well as the method used, i.e Hazard Identification, Risk Assessment, and Risk Control (HIRARC).
2. Data Collection
   The collected data is results of onsite visits conducted by OSH Team of Engineering Faculty, Undip, HIRARC collection for each department, completing documents through assistance in filling out HIRARC, as well as observations and interviews.
3. Data Processing
   Data processing is carried out using Hazard Identification, Risk Assessment, and Risk Control (HIRARC) to determine the potential hazards and risks in each laboratory at Faculty of Engineering, Undip. The first step in this process is identifying potential hazards and risks done in the laboratory. The identification includes any activities that may pose hazards or risks. Besides, the compatibility of existing equipment and work environment to OSH standards are also identified. The process will be resulting on formulation of potential hazards that may occur in the laboratory. From each risk potential, the risk value is calculated considering points of severity, exposure, and probability. By assessing the risk, category of risk value will be obtained. Then, the laboratory included in high risk category is selected. It will be recorded again based on the type of activity or facility that does not or less compatible and a proposal of safety laboratory design that match OSH aspects as well as control hierarchy proposal (elimination, substitution, engineering control, administrative control, and PPE (Personal Protective Equipment) will be given. Then, the processed data will be analyzed and interpreted.

4. Results

The following information in Table 5 are the results of hazard identification and risk assessment with risk included in high category.

Table 5. Identification of Hazards and Risk Assessment

	Risk	Assessment

No. of Risk		S	E	P	Risk Rating
Laboratory of Production System (Industrial Engineering)					
1.2.1	If it hits the limbs, it causes scratches, the limbs is pinched or trapped	40	1	6	240
1.4.1	Workpieces and chisels that can be thrown and hit the operator	40	1	6	240
1.6.1	If it hits the limbs, it causes scratches, the limbs is pinched or trapped	40	1	6	240
1.7.1	Workpieces and chisels that can be thrown and hit the operator	40	1	6	240
Laboratory of Microbiology (Chemical Engineering)					
1.3.1	Discomfort for breathing	3	10	10	300
2.2.1	The room is not fresh and seems unhealthy	3	10	10	300
Laboratory of Thermofluid (Mechanical Engineering)					
1.5.1	Vulnerable to explosions and fire	40	1	6	240
Laboratory of Electrical Energy Conversion and Power Systems (Electrical Engineering)					
1.2.1	There is residual stress that can causing electrocution	40	1	6	240
Non-routine activity					
Non-routine	Fall, to death	40	1	6	240
Non-routine	Got electric shock	40	1	6	240

Then, several risk controls were carried out. The following are some improvements that can be made:

- Laboratory of Production System
  1. Procurement of CNC turning and milling machines
  2. Procurement of virtual reality
  3. Safety guard on turning machines and conventional milling
  4. Regular maintenance on machine tools
  5. Procurement of Personal Protective Equipment, such as cut resistance gloves, safety helmet, safety shoes, and safety googles
  6. Form of experimental tools condition
  7. Form of overnight work permit
  8. Design of laboratory safety guide
- Laboratory of Microbiology
  1. Installation of exhaust fan
  2. Regular cleaning
  3. Procurement of medical masks, lab coats, and gloves
  4. Form of experimental tools condition
- Laboratory of Thermofluid
  1. Placing the fuel tank far from the engine
  2. Regular cleaning
  3. Procurement of PPE such as earplug. Availability of supporting equipment such as fire extinguishers and smoke detectors
  4. Form of overnight work permit
- Laboratory of Electrical Energy Conversion and Power System
  1. Large cage as a place for 100kV transformer
  2. Form of overnight work permit
  3. Form of experimental tools condition
  4. Procurement of PPE that consists of rubber shoes, gloves, and safety helmets.
- Non-Regular Activities
  1. Ergonomic folding ladder design
  2. Regular monitoring of the work environment
  3. Safety bell

5. Analysis and Discussion

5.1 Laboratory of Production System (Department of Industrial Engineering)

Hazards included in high category are those which come from turning machines and milling machines. The probable risks include, if the machine tool hits the operator's limbs, it can cause scratches, pinched or trapped limbs. Besides, the workpieces and chisels may be thrown and hit the operator. Each of both risks has a value of 240 for risk rating with the highest points obtained from severity section, which is 40 points. This is influenced by probable hazards that can cause serious injury, such as chuck key that is still on. It can spin and hit the operator, especially on the head. Besides, hand can also be easily pulled by that fast chuck spin.

To control the risk, several efforts are done by 5 hierarchies. The elimination stage can not be done considering that lathes and milling are important components in learning process at the laboratory. However, substitution can be made by changing conventional lathes with CNC machines. It is considered safer but still have advantages and disadvantages (Safitri, 2012). Besides being replaced with a CNC lathe, the learning can also be done through virtual reality (VR). Virtual reality is a technology that allows users to interact with the environment in cyberspace that is simulated by computer. So that, the users can feel that they are in the environment (Asfari, 2012). By using this technology, risks and hazards can be minimized.

If risk control can be implemented properly, the risk that may be occurred can also be minimized. By using CNC machines or VR, engineering control, administrative control, and PPE, the severity value can be reduced since the risk can be controlled better.

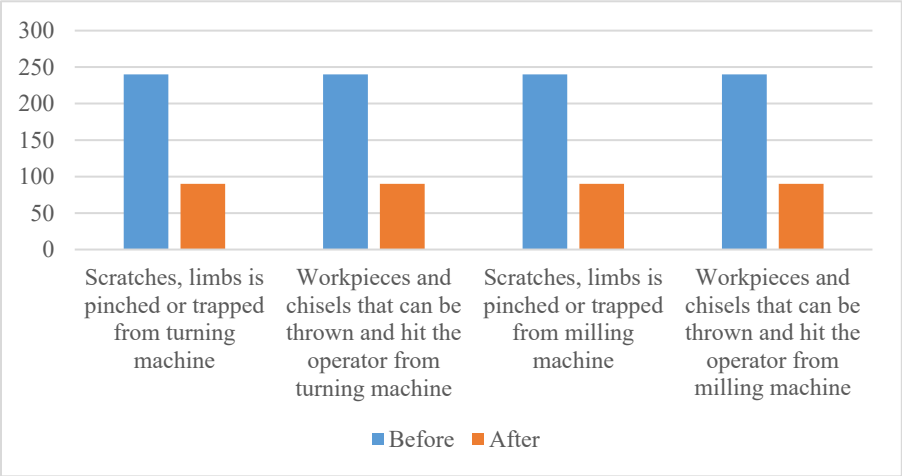

Figure 1. Chart of Risk Rating Comparison in Laboratory of Production System

5.2 Laboratory of Microbiology (Department of Chemical Engineering)

Laboratory of Microbiology is a laboratory used to conduct research related to fermentation and bacteria. This poses several risks such as odors that causing discomfort for breathing and rooms that are not fresh and seems unhealthy. Each of both risks has a value of 300 for risk rating due to the exposure and high probability of occurrence.

To control these risks, several controls are conducted such as exhaust fan installation. In the installation, the number can be determined, but since the width, length, and height of the room are unknown, the number can not be determined. In addition to exhaust fan installation, risk prevention can also be done by using PPE such as masks, lab coats, and gloves. Besides, there is a need for appropriate administrative control such as form to borrow equipment and picket schedule. If risk control can be implemented properly, the possibility of risk can be minimized so that the probability value can also be reduced.

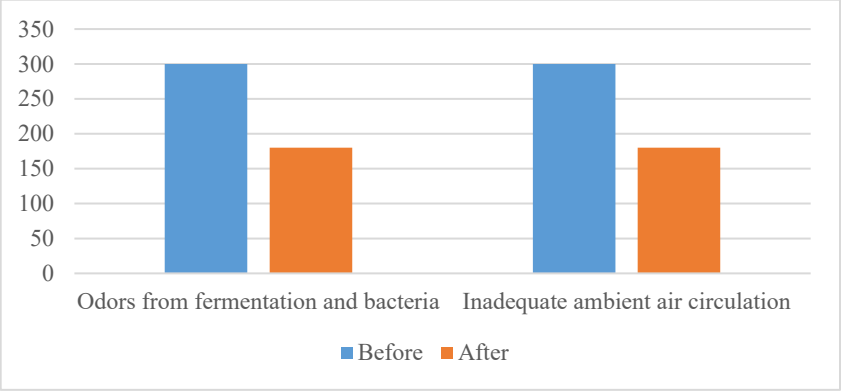

Figure 2. Chart Risk Rating Comparison in Laboratory of Microbiology

5.3 Laboratory of Thermofluid (Department of Mechanical Engineering)

Risk included in high risk category is machine block that can cause explosion and fire. This risk obtains high point due to its severity level that can cause serious injury to individuals who are affected, even the worst risk can cause death.

To control these risks, several controls are carried out such as placing the fuel tank further or not close to the engine (at least to the engine ignition) since fire occurs when there is fuel leak with ignition leak.
If the risk control can be implemented properly, the risk probability can be minimized.

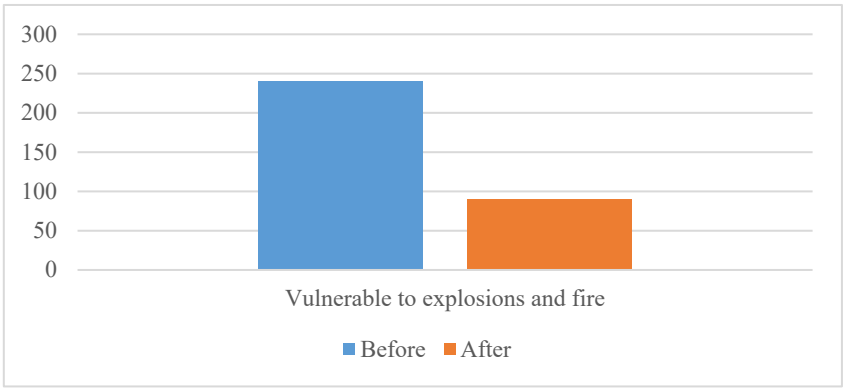

Figure 3. Chart Risk Rating Comparison in Laboratory of Thermofluid

5.4 Laboratory of Electrical Energy Conversion and Power Systems (Department of Electrical Engineering)

Result of hazard identification and risk assessment shows that there are five sources of danger in routine activity at the Laboratory of Electrical Energy Conversion and Power Systems. The risk that have highest value is the existence of residual stress that can cause electrocution. It obtains severity point of 40 since it categorized in high level of severity that can cause serious injury or even worst, death. However, the exposure categorized as minimum and rare in terms of probability. So, each value for exposure and probability are 1 and 6.

To control the risk, several efforts are done such as installation of transformer that is placed in large cage. It can reduce radiation or voltage that harms individuals around. In addition, individuals are advised to wear PPE that consist of rubber boots, gloves, and helmets. Rubber boot is chosen since it is an isolator that difficult or even unable to conduct electricity actively.

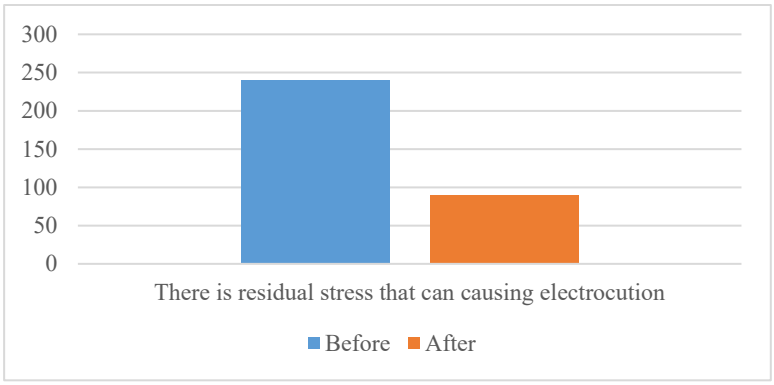

Figure 4. Chart Risk Rating Comparison in Laboratory of Electrical Energy Conversion and Power Systems

5.5 Non-Routine Activities

Results of hazard identification and risk assessment show that some laboratories have facilities such as air conditioners and projectors. Both of these facilities require maintenance and repair within certain period of time. Repairing air conditioners and projectors have potential hazard in the form of height. It can pose risk of falling, or worst, death. These risks obtain 40 points in severity category since it can cause serious injury and require a large amount of funds if the accidents really occur.

To control the risks, several efforts are carried out such as monitoring the work environment on a regular basis. So that, if repair is done, there should be assistance to make the process safer. Besides, ergonomic folding ladder design and the use of safety belts can also be done in controlling the possible risk.
If the risk control can be implemented properly, the possibility of risk to occur can be minimized since the level of severity that may be experienced by an individual could be reduced.

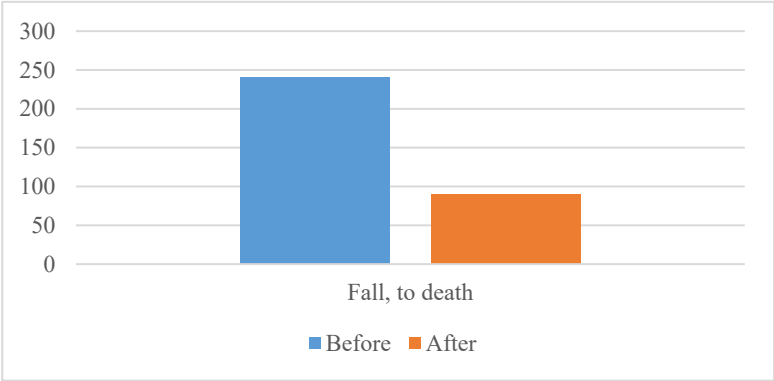

Figure 5. Chart Risk Rating Comparison in Non-Routine Activities

5. Conclusion

Based on the analysis results, it can be concluded that there is a decrease in the risk rating value between identified risk and controlled risk with several risk controlling efforts. Some of these risk controls are based on five hierarchies, i.e elimination, substitution, engineering control, administrative control, and personal protective equipment.

The recommended solutions given are procurement of several machines such as CNC-based turning and milling machines, virtual reality, safety guard, regular maintenance, Personal Protective Equipment (PPE) such as cut resistance gloves, safety helmets, safety shoes, safety googles, safety belts, and earplug adjusted to the need of each laboratory. In addition, several forms are needed to be prepared, such as form of experimental tools condition and overnight work permit. Besides, design of laboratory safety guide can also be done to maximize the risk control.

Acknowledgements

Authors thank for the research grant from Engineering Faculty of Diponegoro University, under the grant number 3178/S/industri/4/UN7.5.3.2/PP/2021.

References

Ahmad, A. C., Zin, I. N. M., Othman, M. K., and Muhamad, N. H. Hazard Identification, Risk Assessment and Risk Control (HIRARC) Accidents at Power Plant. *MATEC Web of Conferences*, vol. 66, pp. 00105, 2016.

Anizar, I., and Kes, M. *Teknik Keselamatan dan Kesehatan Kerja di Industri*. Graha Ilmu, Yogyakarta, 2009.

Asfari, U., Setiawan, B., and Sani, N. A. Pembuatan aplikasi tata ruang tiga dimensi gedung serba guna menggunakan teknologi virtual reality [studi kasus: Graha ITS Surabaya]. *Jurnal Teknik ITS*, vol. 1, no. 1, pp. A540-A544, 2012.

AS/NZS. *Risk Management Guidelines Companion to AS/NZS 4360:2004*. HB 436:2004, Standards Australia International, Sydney. Retrieved from Standards New Zealand Database.

Harrington & Gill. *Buku Saku Kesehatan Kerja*. EGC, Jakarta, 2005.

Muchtarom, A. *ISOLATOR Padat Bahan Karet. ISOLATOR Padat Bahan Karet*. 2017.

Pranolo, A., & Firmansyah, D. P. Identifikasi Tingkat Risiko Bencana Gempa Bumi Serta Arahan Tindakan Mitigasi Bencana Di Wilayah Kota Bengkulu. *Doctoral dissertation, Fakultas Teknik Unpas*, 2013.

Rudyarti, E. Hubungan Pengetahuan Keselamatan dan Kesehatan Kerja dan Sikap Penggunaan Alat Pelindung Diri Dengan Kejadian Kecelakaan Kerja Pada Pengrajin Pisau Batik Di PT. X. *UNS PRES*. Pp. 11, 2017.

Tarwaka, K. *Kesehatan Kerja Manajemen dan Implementasi K3 di Tempat Kerja.* 2014.

Triyono, M. B. *Buku Ajar Kesehatan dan Keselamatan Kerja (K3*). Fakultas Teknik Universitas Negeri Yogyakarta, 2014.

Biographies

Manik Mahachandra is an Assistant Professor in Industrial Engineering Department, Faculty of Engineering, Diponegoro University, Indonesia. She finished bachelor's degree in industrial engineering at Bandung Institute of Technology, Indonesia, master's degree in occupational health at Gadjah Mada University, Indonesia, and doctoral degree in industrial engineering and management at Bandung Institute of Technology, Indonesia. She has published journal and conference papers in industrial engineering, especially ergonomics and transportation safety. She is a member of Indonesian Ergonomics Association and secretary of Occupational Safety and Health Team of Faculty of Engineering, Diponegoro University. Her research interests are ergonomics, occupational safety and health, transportation safety, and work organization.

Heru Prastawa is an Associate Professor in Industrial Engineering Department, Faculty of Engineering, Diponegoro University, Indonesia. He earned bachelor's degree in production system at Sepuluh Nopember Institute of Technology, Indonesia, master's degree in information strategic at Universite d'Aaix Marseille III, France, and doctoral degree in industrial engineering and management at Sepuluh Nopember Institute of Technology, Indonesia. He has published journal and conference papers in industrial engineering. He is a member of Indonesian Ergonomics Association, where he acts as one of the board of trustee. His research interests are ergonomics, Kansei engineering, user experience, and work organization.

Dita Rizkiana is a fresh graduate student from Industrial Engineering Department, Faculty of Engineering, Diponegoro University, Indonesia. She finished her bachelor's degree in 2020 in occupational safety and health topic of thesis.