From Risk to Safety: Applying Job Safety Analysis in Organic Chemistry Practicals for Future Chemistry Educators

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ABSTRACT

Purpose of the study: This study aims to determine the use of Job Safety Analysis in analyzing potential hazards in Organic Chemistry practicums as an effort to implement occupational safety and security for chemistry education students.

Methodology: The method used is descriptive qualitative. The sample of this study was 41 students of the Chemistry Education Study Program. The instruments used were the Job Safety Analysis observation sheet and semi-structured interviews. The stages in analyzing potential hazards using the Job Safety Analysis method are (1) choosing a job, (2) determining the work steps, (3) identifying and analyzing potential hazards in each step of the work and (4) making efforts to control potential hazards.

Main Findings: The results of the study showed 16 potential hazards identified using the Job Safety Analysis method. The results of the analysis of the risk level value (Risk Level) of potential hazards in all work steps divided into four stages of the practicum showed that 19% were (Extreme Risk-Very High Risk), 27% were (High Risk-High Risk), 19% were (Moderate Risk-Moderate Risk) and 35% were (Low Risk-Low Risk). Work safety and security efforts that can be made to overcome the risk of potential hazards are by using PPE according to procedures, knowing the use of SOP for laboratory equipment and MSDS of chemicals and understanding examples, causes, impacts and prevention of work accidents during Organic Chemistry practicum activities.

Novelty/Originality of this study: This study provides an innovative contribution to the development of occupational safety culture in educational environments by integrating JSA as a preventive measure based on practical risk analysis.

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1. INTRODUCTION

Chemistry is a science that is closely related to laboratory experiments and practices [1], [2]. Practical activities in chemistry learning provide students with direct experience in understanding chemical theories and concepts [3], [4]. Chemistry is an experimental science that most of its knowledge is obtained from research in the laboratory [5], [6]. Therefore, the chemistry learning process will be more effective if it is equipped with experimental activities in the laboratory. The laboratory itself must be a safe environment because it is directly related to risky materials and equipment.

Some chemistry courses that require laboratory practicums include Organic Chemistry, Inorganic Chemistry, and Physical Chemistry [7]-[9]. Organic Chemistry practicums often involve hazardous chemicals such as methyl ether, chloromethyl, and dichloromethane. These materials are carcinogenic and can be dangerous if not used properly. Most students do not know the properties of the chemicals used in practicums [10]-[12]. This lack of knowledge can increase the risk of work accidents in the laboratory.

Various types of accidents that occur in the laboratory, such as exposure to chemicals, slipping, and skin irritation [13]-[15]. Some types of accidents even have a high percentage of occurrence, such as contact with heat and complaints of dizziness. The main cause of this accident is student negligence and the use of inappropriate tools and materials. In addition to chemicals, laboratory equipment can also be a source of danger if not managed properly [16], [17]. Therefore, it is important for students to understand and apply the principles of occupational safety in every practicum activity [18]-[20].

One form of implementing the Occupational Health and Safety principle is to recognize potential hazards through the risk analysis method [21]-[23]. Job Safety Analysis is one method used to identify potential hazards based on each work step [24]-[26]. Job Safety Analysis is effective in controlling hazards that may occur in a work activity including practicums [27]-[29]. This method has been proven to help in planning safe and systematic work activities. With Job Safety Analysis, students can understand the risks and design control measures to prevent accidents.

The use of the Job Safety Analysis method in practicum activities provides benefits in identifying and controlling work risks [30], [31]. For example, in Organic Chemistry practicums such as the manufacture of nitrobenzene which involves hazardous chemicals such as benzene and sulfuric acid. If the work procedure is not carried out properly, potential hazards such as explosions or irritation can occur [32]-[34]. The application of Occupational Health and Safety in chemical mixing procedures is still low. This reinforces the need for the application of the Job Safety Analysis method to create safe practicums for students.

Each step in the practicum procedure has its own potential hazards that need to be recognized from the start. Job Safety Analysis allows students to analyze the hazards and create control strategies [26], [35]. With the many variations of tools and materials in each lab title, risk recognition becomes very important. Knowledge of Occupational Health and Safety is also an important part in preparing students to face the world of work in the fields of education and chemical industry [36]-[38]. Therefore, this study was conducted to explore the use of Job Safety Analysis in identifying potential hazards in labs as an effort to implement occupational safety for chemistry education students.

Research conducted by Zaroushan and Khajehnasiri [39] highlighted the application of Job Safety Analysis in improving occupational safety in healthcare centers during the COVID-19 pandemic, focusing on mitigating biological and procedural risks in emergency situations. Meanwhile, Palega [40] applied the Job Safety Analysis method to assess occupational risks in an industrial environment, specifically for laser cutter operators, emphasizing the identification of technical and operational hazards in a manufacturing context. Both studies demonstrated the effectiveness of Job Safety Analysis in different professional contexts, but there has been no study that specifically applies the Job Safety Analysis method in an educational context, especially in organic chemistry laboratory practices in a college environment. The current study aims to fill this gap by applying Job Safety Analysis as a potential risk analysis tool in organic chemistry practicums, in order to increase awareness and application of occupational safety among chemistry education students as prospective professional educators.

This research has novelty because it applies the Job Safety Analysis method, which is commonly used in the industrial and health care sectors, to the context of higher education, especially in organic chemistry practicums for chemistry education students. This approach has not been widely studied in the educational realm, even though laboratory activities in academic environments also have significant potential hazards. The urgency of this research lies in the importance of instilling a culture of occupational safety and health from an early age to prospective chemistry teachers, so that they not only understand the theoretical aspects, but are also able to instill safety practices in students in the future. With the increasing complexity of laboratory materials and procedures, risk analysis using Job Safety Analysis is a strategic step in preventing accidents and creating a safe and professional learning environment.

Based on the explanation above, this study aims to determine the use of Job Safety Analysis in analyzing potential hazards in Organic Chemistry practicums as an effort to implement occupational safety and security for chemistry education students.

2. RESEARCH METHOD

2.1. Types of research

The method used in this study is descriptive qualitative. Descriptive is a study that uses observation, interviews or questionnaires regarding the current situation and/or the subject we are studying [41], [42]. This study aims to determine the use of Job Safety Analysis in analyzing potential hazards in Organic Chemistry practicums. And describe the results obtained using the Job Safety Analysis method as a recommendation for efforts to implement work safety and security for chemistry education students during Organic Chemistry practicums.

2.2. Research Subject

Population is all objects or subjects that have certain qualities and characteristics that researchers determine to be studied [43], [44]. The population in this study were students of the Chemistry Education Study Program. The sample is part of the number and characteristics possessed by the population. The sample of this study was 41 students of the Chemistry Education Study Program. The selection of the number of samples follows the conditions in the implementation of the Organic Chemistry practicum with the title Making Nitrobenzene.

2.3. Research Procedures

This research begins with a preparation stage that includes a literature study to formulate problems and analyze needs based on all titles of Organic Chemistry 1 and 2 practicums in the Chemistry Laboratory of the Faculty of Tarbiyah and Teacher Training, Syarif Hidayatullah State Islamic University. The practicum that is specifically analyzed is the Manufacture of Nitrobenzene, by grouping hazardous chemicals and equipment according to the Regulation of the Minister of State for the Environment Number 03 of 2008. The work procedures in the practicum are then divided into four stages, namely the preparation stage, preparation, core activities, and final activities.

The next stage was the preparation of research instruments consisting of Job Safety Analysis observation sheets and semi-structured interview guidelines for laboratory managers and student practicums. The instruments were validated by experts and revised based on the input provided. Furthermore, observations were made on the implementation of the Nitrobenzene Making practicum by students with the help of four observers to record potential hazards at each work step.

At the implementation stage, the practicum was carried out by 3rd and 5th semester students, where researchers and observers observed and documented activities to support data analysis. The final stage included the analysis of the Job Safety Analysis observation sheet by calculating the Risk Rating Number based on the frequency of occurrence and severity. The results of this analysis, together with the results of interviews and documentation, were used to describe efforts to implement the safety and security of chemistry education students in practicum activities.

2.4. Data Collection Technique

The data source is the subject from which the data is obtained. The data collection technique is carried out by conducting observations and interviews. The data obtained in this study came from the researcher's observations with the Job Safety Analysis observation sheet during the Organic Chemistry practicum entitled Making Nitrobenzene and structured interviews with the Chemistry Education Laboratory Manager and student practicums. Documentation, notes, and literature studies during the research implementation process can be used as secondary data.

The data sources in this study consist of primary data. Primary data were obtained through the Work Safety Analysis observation sheet which was carried out directly during the Organic Chemistry practicum entitled Making Nitrobenzene. This observation includes identification and analysis of potential hazards at each work step using an observation sheet modified from previous research with columns covering work stages, potential hazards, risks, and control efforts.

The analysis of the Job Safety Analysis observation sheet begins with filling in the Job Safety Analysis format adapted from several sources, to identify potential hazards during the Nitrobenzene Making practicum. Each potential hazard is analyzed by determining the frequency of occurrence (Likelyhood) based on the AS/NZS 4360 (2004) standard, which is categorized from "Almost Certain" to "Rare". Then, the severity (Consequence) of the potential hazard is also analyzed using a scale from 1 (Insignificant) to 5 (Catastrophic).

2.5. Data Analysis Technique

The next step is to calculate the risk level value using the Risk Rating Number formula, which is the result of multiplying the Likelihood and Consequence values. This RRN value is then matched with the risk level matrix from the AS/NZS 4360 standard to classify the risk level into Low, Moderate, High, or Extreme. This classification is important to determine the urgency of risk management at each work step in the practicum.

After the risk level is known, the researcher prepares recommendations for preventive measures to reduce the potential for work accidents. The final results of this identification and analysis are then described systematically to show efforts to implement occupational safety and security for Chemistry Education students during the practicum activities.

3. RESULTS AND DISCUSSION

The potential hazards that may occur during the Organic Chemistry practicum process vary, depending on the situation and type of activities carried out by the student practicum at each stage of the practicum. The results of the analysis of potential hazards using the Job Safety Analysis (JSA) method in the organic chemistry practicum (Nitrobenzene Production) can be seen in the table below:

Table 1. Analysis of Potential Hazards Using the Job Safety Analysis (JSA) Method in Organic Chemistry Practicals (Nitrobenzene Production)

No	Practical Stage	No	Work Steps	Potential Hazards
A.	Preparation	1.	Wearing Personal Protective Equipment	Exposure to residual substances from previous practicum on the practicum clothes
		2.	Preparing the tools to be used	Broken tools, damaged tools, slipping
		3.	Preparing the chemicals to be used	Spill materials, skin irritation, exposure to materials, slipping
B.	Preparation	1.	Measuring the volume of concentrated nitric acid as much as 18 ml using a measuring pipette and carried out in a fume hood	Broken tool, broken tool, spilled material, eye and skin irritation, shortness of breath, slipping
		2.	Measuring the volume of concentrated sulfuric acid as much as 20 ml using a measuring pipette and carried out in a fume hood	Spilled material, broken tool, broken tool, eye and skin irritation, slipping
		3.	Measuring the volume of benzene as much as 15 ml using a measuring pipette and carried out in a fume hood	Spilled material, broken tool, broken tool, eye and skin irritation, slipping
		4.	Making 10% NaOH reagent as much as 10 ml	Eye and skin irritation, shortness of breath, spilled material, broken tool, broken tool, slipping
		5.	Weighing 3 grams of CaCl2 solid	Electrocution, broken tool, spilled material, slipping, skin irritation
C.	Core activities	1.	Put 20 ml of concentrated sulfuric acid into a round flask, place it in an ice bath.	Skin contact, skin irritation, spilled material, broken equipment
		2.	Add 18 ml of concentrated nitric acid to a round flask containing concentrated sulfuric acid in an ice bath.	Spilled material, skin irritation, broken equipment, thermal injury, slipping
		3.	Slowly add 15 ml of benzene into a mixture of concentrated sulfuric acid and concentrated nitric acid	Spilled material, eye and skin irritation, thermal injury, shortness of breath, slipping, carcinogenic, excess gas, dizziness and nausea, highly reactive
		4.	The solution mixture is shaken slowly	Broken equipment, spilled material, eye and skin irritation, shortness of breath, highly reactive
		5.	Make a water bath at a temperature of 60oC as much	Electrocution, slipping, broken equipment, spilled

			as 150 ml using a 250 ml beaker	material, fire, thermal exposure, skin irritation
		6.	Heat the solution in a water bath for 1.5 hours (2 layers are formed; the upper layer is dark orange and the lower layer is orange)	Heat exposure, electric shock, broken equipment, spilled material, tripping, fire, slipping, skin irritation
		7.	Cool the solution to room temperature	Spilled material, broken tools, slipping, skin irritation
		8.	Put the solution into a separating funnel, shake and separate 2 layers (the lower layer is dark yellow)	Dropped & broken tools, spilled material, eye & skin irritation, shortness of breath, slipping, dizziness & nausea, excess gas
		9.	Add 50 ml of water into the separating funnel, shake and separate 2 layers (the upper layer remains in the separating funnel and the lower layer is yellow)	Spilled material, broken tools, slipping, skin irritation
		10.	Add 10 ml of 10% NaOH into the separating funnel, and shake the solution until it forms a layer (the lower layer is light yellow)	Spilled material, broken tools, skin irritation, slip, gas
		11.	Transfer the upper layer into a beaker	Spilled material, broken tools, slip, skin irritation
		12.	Add 3 grams of CaCl2 to the solution in the beaker Chemistry	Spilled material, broken tools, skin irritation, slip
		13.	Filter the solution, then observe the residue and filtrate	Spilled material, broken tools skin irritation, slip
D.	Final Activities	1.	Dispose of chemical waste from the lab to a special waste disposal site.	Eye and skin irritation, broken tools, environmental pollution, slipping, excess gas
		2.	Cleaning and returning the tools that have been used	Broken tool, hit by material, slipped
		3.	Returning the remaining chemicals to their storage places	Spilled material, slipping
		4.	Cleaning the area/work table where the practicum will be conducted	Skin irritation, broken tools, remaining and spilled lab materials, slipping
		5.	Cleaning the waste from the practicum activities to the waste disposal site	Contact with residual substances, skin irritation

3.1. Preparation Stage

The preparation stage in the Organic Chemistry practicum entitled Making Nitrobenzene based on table data is divided into 3 work steps. The potential hazards that occur in the preparation stage are identified as being exposed to residual substances, broken & damaged tools, spilled materials, irritation and slipping. The following are the results of the analysis for the frequency value (Likelyhood) of potential hazards in the preparation stage based on table 1 explained as in figure 1.

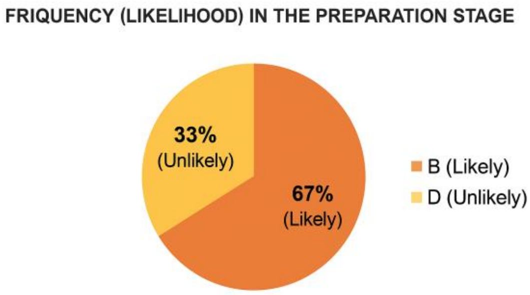

Figure 1. Number of Potential Hazards Based on the Frequency Value (Likelyhood) of the Preparation Stage

Based on the analysis of the frequency value (Likelyhood) of potential hazards at the preparation stage as shown in Figure 4.4, it is known that most of the work steps are in the category of a fairly high frequency. As many as two of the three work steps, namely steps 2 and 3 (around 67%), are categorized as having a potential hazard frequency value of B (Likely), which means it is very likely to occur. Meanwhile, one work step, namely the first step (around 33%), is categorized in the potential hazard frequency value of D (Unlikely), which means the possibility of the hazard occurring is relatively low. This finding indicates that the majority of activities at the preparation stage require special attention to the potential risks that are quite high.

Next are the results of the analysis of the severity value (Consequence) of potential hazards at the preparation stage based on table 1 as explained in Figure 2.

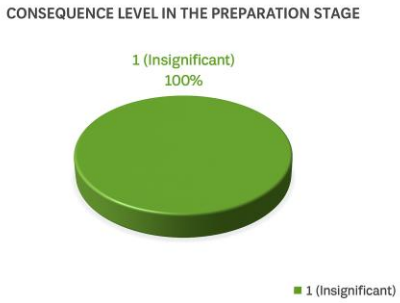

Figure 2. Number of Potential Hazards Based on the Severity Level (Consequence) Value of the Preparation Stage

Based on the research results presented in Table 4.1, the analysis of the severity value (Consequence) of potential hazards at the preparation stage shown in Figure 4.5 shows that all work steps (1, 2, and 3) or 100% have a severity level with a value of 1 (Insignificant–No Injury). This indicates that the potential hazard at this stage is classified as very low and does not pose a significant risk of injury. Furthermore, the analysis of the risk level assessment (Risk Level) for potential hazards at the preparation stage by knowing the RRN (Risk Rating Number) value by multiplying the frequency value (Likelyhood) and severity level (Consequence) contained in the potential hazard at the preparation stage. The results of the analysis of the risk level value (Risk Level) at the preparation stage based on table 1 are explained as in figure 3.

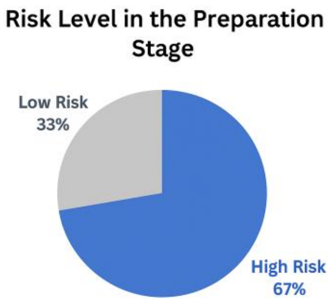

Figure 3. Number of Potential Hazards Based on Risk Level (Risk Level) Preparation Stage

Based on the research results listed in Table 1, the analysis of the risk level value (Risk Level) of potential hazards at the preparation stage shown in Figure 3 shows that of the three work steps analyzed, two work steps (namely steps 2 and 3) have a high potential hazard risk level value (H), which covers 67% of the total existing work steps. Meanwhile, one work step (step 1) has a low potential hazard risk value (L), which covers 33% of the total work steps.

The potential hazards that occur at the preparation stage can be caused not only by the tools and materials used by students, but also by the students' attitudes during the start of the practicum preparation stage. Based on the results of documentation during the implementation of observations in the field, in the first work step, namely the use of personal protective equipment (PPE), students were still found not to use personal protective equipment (PPE) properly and correctly.

3.2. Preparation Stage

The preparation stage in the Organic Chemistry practicum entitled Making Nitrobenzene based on data in table 1 is divided into 5 work steps. The potential hazards that occur in the preparation stage that are identified include falling and breaking tools, spilled materials, eye and skin irritation, shortness of breath, electric shock and slipping. The following are the results of the analysis for the frequency value (Likelyhood) of potential hazards in the preparation stage based on table 1 explained as in figure 4.

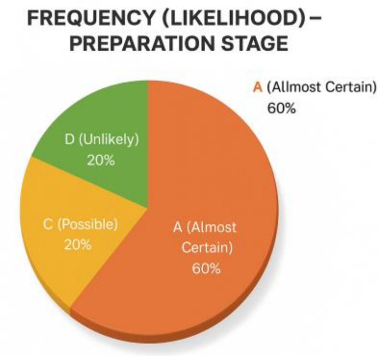

Figure 4. Number of Potential Hazards Based on the Frequency Value (Likelyhood) of the Preparation Stage.

Based on the research results presented in Table 1, the analysis of the frequency value (Likelihood) of potential hazards at the preparation stage shown in Figure 4 shows that as many as three work steps (steps 1, 2, and 3) out of a total of five work steps (60%) have a potential hazard frequency value of category A (Almost Certain). Meanwhile, one work step (step 4) or 20% is included in the potential hazard frequency category C (Possible), and one other work step (step 5) or 20% is in category D (Unlikely).

The following are the results of the analysis of the severity value (Consequence) of potential hazards at the preparation stage based on table 1 as explained in figure 5.

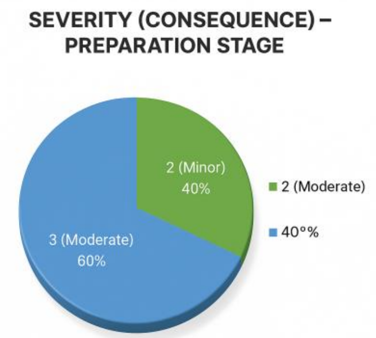

Figure 5. Number of Potential Hazards Based on the Severity Level (Consequence) Value of the Preparation Stage

Based on the research results listed in Table 1, the analysis of the severity level (Consequence) of potential hazards at the preparation stage shown in Figure 5 shows that two work steps (steps 4 and 5) out of five work steps or 40% have a potential hazard severity level of category 2 (Minor - Minor Injury). Meanwhile, three work steps (steps 1, 2, and 3) or 60% are included in the potential hazard severity category 3 (Moderate - Moderate Injury).

Furthermore, the analysis of the risk level assessment (Risk Level) for potential hazards at the preparation stage by knowing the RRN (Risk Rating Number) value by multiplying the frequency value (Likelyhood) and severity level (Consequence) contained in the potential hazard at the preparation stage. The results of the analysis of the risk level value (Risk Level) at the preparation stage based on table 1 are explained as in Figure 6.

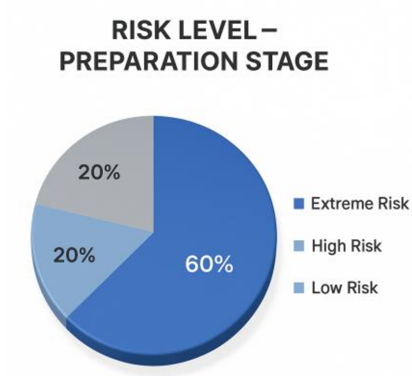

Figure 6. Number of Potential Hazards Based on Risk Level (Risk Level) Preparation Stage

Based on the research results presented in Table 1, the analysis of the risk level value (Risk Level) of potential hazards at the preparation stage as shown in Figure 6 shows that three work steps (steps 1, 2, and 3) out of a total of five work steps, or 60%, have a risk level of potential hazards category E (Extreme Risk - Very High Risk). Meanwhile, one work step (step 4) or 20% is included in category H (High Risk - High Risk), and one other work step (step 5) or 20% is in category L (Low Risk - Low Risk).

The findings in the field during observation activities, the potential hazards that can occur at the preparation stage come from each student activity which is divided into 5 work steps. An accident at the preparation stage occurred by one of the groups in the chemistry education class while taking benzene in the fume cupboard. The volume pipette used by students during the process of taking the material fell and broke.

3.3. Core Activity Stage

The core activity stage in the Organic Chemistry practicum with the title Making Nitrobenzene based on table 1 data is divided into 13 work steps. The potential hazards found in core activities such as falling and breaking tools, spilled materials, eye and skin irritation, shortness of breath, slipping, electric shock, heat exposure, carcinogenic, dizziness, nausea, excess gas, easily reactive and fire. The following are the results of the analysis for the frequency value (Likelyhood) of potential hazards at the core activity stage based on table 1 explained as in figure 7.

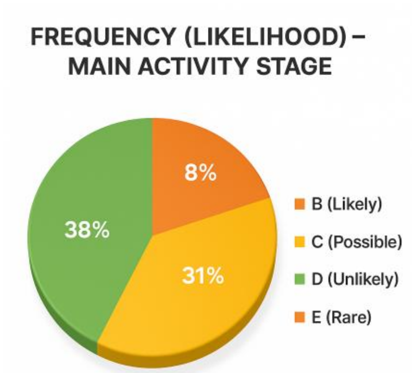

Figure 7. Number of Potential Hazards Based on the Frequency Value (Likelyhood) of the Core Activity Stage

Based on the research results presented in Table 1, the analysis of the frequency value (Likelihood) of potential hazards at the core activity stage presented in Figure 7 shows that three work steps (steps 3, 8, and 13) out of a total of thirteen work steps or 23% have a frequency value of potential hazards in category B (Likely - Very Possible). Furthermore, four work steps (steps 2, 4, 7, and 10) or 31% are in category C (Possible - Possible), while five work steps (steps 1, 5, 6, 11, and 12) or 38% are included in category D (Unlikely - Less Likely). One work step (step 9) or 8% is included in category E (Rare - Rare). Furthermore, the results of the analysis of the severity value (Consequence) of potential hazards at the core activity stage based on table 1 as explained in figure 8.

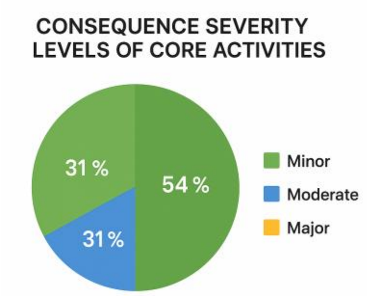

Figure 8. Number of Potential Hazards Based on the Severity Level (Consequence) Value of the Core Activity Stage

Based on the research results presented in Table 1 and analyzed in Figure 8, the severity (Consequence) of potential hazards at the core activity stage shows the following results. A total of 7 work steps (namely steps 5, 7, 9, 10, 11, 12, and 13) out of a total of 13 work steps, or equivalent to 54%, have a potential hazard severity category 2 (Minor-Slight Injury). Furthermore, 4 work steps (namely steps 1, 4, 6, and 8) out of a total of 13 work steps, or 31%, are classified as having a potential hazard severity category 3 (Moderate-Moderate Injury). Meanwhile, 2 work steps (namely steps 2 and 3) out of a total of 13 work steps, or around 15%, have a potential hazard severity category 4 (Major-Severe Injury). This analysis provides an overview of the risk distribution based on the severity level at the core activity stage.

Next, the analysis of the risk level assessment (Risk Level) for potential hazards at the core activity stage by knowing the RRN (Risk Rating Number) value by multiplying the frequency value (Likelyhood) and severity level (Consequency) contained in the potential hazards at the core activity stage. The results of the risk level analysis (Risk Level) at the core activity stage based on table 1 are explained as in Figure 9.

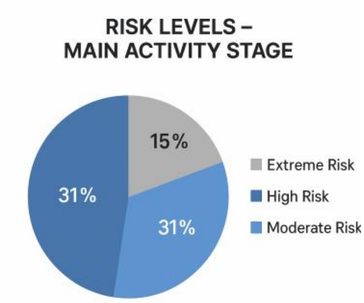

Figure 9. Number of Potential Hazards Based on Risk Level (Risk Level) Core Activity Stage

Based on the research results in Table 1, the analysis of the risk level value (Risk Level) of potential hazards at the core activity stage presented in Figure 9 shows that out of 13 work steps, there are different distributions of risk level values. First, two work steps (steps 2 and 3) out of 13 work steps (15%) have a potential hazard risk level value of E (Extreme Risk - Very High Risk). Second, three work steps (steps 4, 8, and 13) out of 13 work steps (23%) have a potential hazard risk level value of H (High Risk - High Risk). Furthermore, four work steps (steps 1, 6, 7, and 10) out of 13 work steps (31%) have a potential hazard risk value of M (Moderate Risk - Medium Risk). Finally, four work steps (steps 5, 9, 11, and 12) out of 13 work steps (31%) have a potential hazard risk value of L (Low Risk - Low Risk).

At the core activity stage, students begin to react various chemicals that have been prepared with various laboratory equipment to become a product, namely Nitrobenzene. During the process at the core activity stage, in addition to the dangers of the tools and materials used, the results of the reaction process between chemicals can also potentially cause work accidents. So that with the increasing number of activities that students do at the core activity stage, the potential hazards that have been successfully identified and analyzed using the Job Safety Analysis (JSA) method at the core activity stage are very diverse.

3.4. Final Activity Stage

The final activity stage in the Organic Chemistry practicum entitled Making Nitrobenzene based on data from table 1 is divided into 5 work steps. The potential hazards in the core activities include falling and breaking tools, spilled materials, eye and skin irritation, excess gas, slipping, and environmental pollution. The following are the results of the analysis for the frequency value (Likelyhood) of potential hazards in the final activity stage based on table 1 explained as in Figure 10.

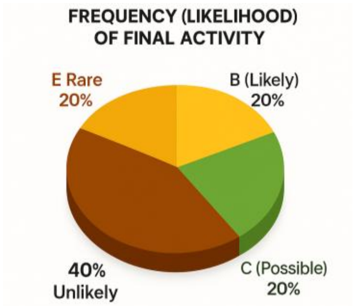

Figure 10. Number of Potential Hazards Based on the Frequency Value (Likelyhood) of the Final Activity Stage

Based on the research results presented in Table 1 and Figure 10, the analysis of the frequency value (Likelihood) of potential hazards at the final activity stage shows variations in the level of likelihood of hazards occurring. As many as 1 work step (step 4) out of a total of 5 work steps or 20% has a frequency value of potential hazards in category B (Likely/Very Likely). Furthermore, there is 1 work step (step 1) out of 2 work steps or 20% which is included in the frequency category C (Possible/Possible). Then, 2 work steps (steps 2 and 5) out of 5 work steps or 40% are categorized in frequency D (Unlikely/Less Likely). Finally, as many as 1 work step (step 3) out of 5 work steps or 20% is in the frequency category E (Rare/Rare). These data illustrate that most work steps have a low level of likelihood of hazards occurring, with a dominance of category D (Unlikely).

Next are the results of the analysis of the severity value (Consequence) of potential hazards at the core activity stage based on table 1 as explained in Figure 11.

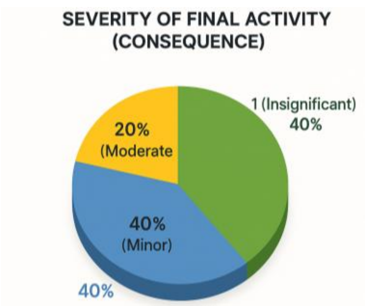

Figure 11. Number of Potential Hazards Based on the Severity Level (Consequence) Value of the Final Activity Stage

Based on the research results listed in Table 1, the analysis of the severity level (consequence) of potential hazards at the final activity stage as shown in Figure 11 shows that two work steps (steps 3 and 5) out of a total of five work steps (40%) have a potential hazard severity level in category 1 (Insignificant—No Injury). Furthermore, the other two work steps (steps 2 and 4) or 40% are in the severity category 2 (Minor—Minor Injury). Meanwhile, one work step (step 1) out of five work steps (20%) has a potential hazard severity level in category 3 (Moderate—Moderate Injury). These data show that the majority of potential hazards at the final activity stage have an impact that is classified as mild to non-injury.

Furthermore, the analysis of the risk level assessment (Risk Level) for potential hazards at the final activity stage by knowing the RRN (Risk Rating Number) value by multiplying the frequency value (Likelihood) and severity level (Consequence) contained in the potential hazards at the final activity stage. The results of the analysis of the risk level value (Risk Level) at the final activity stage based on table 1 are explained as in Figure 12.

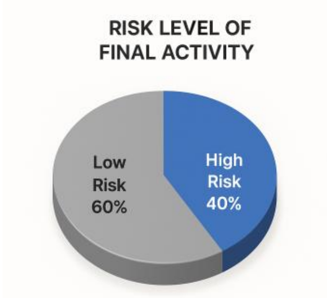

Figure 12. Number of Potential Hazards Based on Risk Level (Risk Level) Final Activity Stage

Based on the research results in Table 1, the analysis of the risk level value (Risk Level) of potential hazards at the final activity stage shown in Figure 12 shows that there are 2 work steps, namely steps 1 and 4 (40%), which have a potential hazard risk level of H (High Risk). Meanwhile, as many as 3 work steps, namely steps 2, 3, and 5 (60%), have a potential hazard risk level of L (Low Risk). This shows that the majority of work steps are classified as low risk, although there are still work steps with a high risk level that need more attention in implementing hazard control measures.

At this final activity stage, students carry out various activities before they leave the laboratory. The results of documentation during observation activities when students are cleaning tools and materials and disposing of waste and garbage from the practicum produced during the practicum process can also cause potential hazards.

This study has a positive impact in efforts to increase awareness and understanding of chemistry education students regarding the importance of work safety in the laboratory through the application of the Job Safety Analysis method. With this approach, students are not only able to identify potential hazards in organic chemistry practicums, but can also apply systematic preventive measures, thereby encouraging the creation of a safer and more responsible work culture in the academic environment. However, this study has several limitations, including the scope of the sample which is limited to one educational institution and only covers aspects of organic chemistry practicums, so that the results cannot be generalized widely to other courses or to different institutions. In addition, the analysis conducted is descriptive and has not been accompanied by measuring the effectiveness of JSA implementation in the long term.

4. CONCLUSION

Based on the results of the research and discussion that has been done, it can be concluded that there are 16 potential hazards in the Organic Chemistry practicum with the title Making Nitrobenzene which are identified and analyzed using the Job Safety Analysis (JSA) method. The stages in using the Job Safety Analysis (JSA) method are (1) choosing a job, (2) determining the work steps, (3) identifying and analyzing potential hazards in each work step and (4) making efforts to control potential hazards. The results of the identification of potential hazards such as tools falling and breaking, being exposed to materials, eye and skin irritation, dizziness, nausea, slipping, electric shock, carcinogenic, flammable, environmental pollution, shortness of breath, excess gas, easily reactive, exposed to heat, fire and blistered hands. The results of the analysis of the risk level value (Risk Level) of potential hazards in all work steps divided into four stages of the practicum showed that 19% were (Extreme Risk Very High Risk), 27% were (High Risk), 19% were (Moderate Risk) and 35% were (Low Risk). Work safety and security (Occupational Health and Safety) efforts that can be made to overcome the risk of potential hazards are by using good and correct PPE in accordance with procedures, knowing the use of SOP for laboratory equipment and MSDS of chemicals before starting the practicum and understanding examples, causes, impacts and prevention of work accidents during Organic Chemistry practicum activities. Further research is suggested to involve more institutions and study programs so that the results are more representative and can be generalized. In addition, a quantitative approach is needed to measure the effectiveness of Job Safety Analysis implementation on changes in students' work safety behavior and knowledge more objectively.

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