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# Hazard Identification, Risk Assessment and Control (HIRAC) on the Water Solid Contents Determination at the Environmental Chemistry Laboratory of President University

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ABSTRACT

This study conducted a Hazard Identification and Risk Assessment (HIRA) on the solid contents determination experiment activity at the Environmental Engineering Laboratory of President University. The main objective of this study is to identify potential hazards during the experiment, understand the risk level of hazards in the Environmental Engineering Laboratory, and propose strategies to improve the laboratory practices. The method used in this study is the Hazard Identification, Risk Assessment and Control (HIRAC) process. This study characterized 18 hazards, including slip and fall, respiratory hazard, fragile object, burn, physical injury, and electrical hazard. After priority sorting, 12 hazards were classified into high and medium. Activities that involve critical hazards include pouring the water sample into the vacuum using a volumetric glass. At the end, this study proposed steps that should be taken to improve the operational conditions of the laboratory safety and health aspects.

## 1. INTRODUCTION

Experimental laboratories are among the essential learning resources in higher education institutions, particularly in science and engineering programs, where practical, hands-on experiences complement theoretical knowledge. President University is a private university in Indonesia that offers a bachelor degree in Environmental Engineering. At the Environmental Engineering Study Program of President University, laboratory-based learning plays a vital role in fostering student competencies and bridging the gap between academic concepts and real-world applications. Well-equipped and efficiently managed laboratories enhance student learning, research outcomes, and technical skills development (Yarahmadi et al., 2016). However, the effectiveness of laboratory-based education also relies heavily on the implementation of proper health, safety, and environmental (HSE) practices. Ensuring safety and health protocols in the laboratory is crucial for protecting students and staff, maintaining research integrity, and preventing accidents, injuries, and environmental contamination (Aimi et al., 2022).

In Environmental Engineering programs, one of the core laboratories identified in the national curriculum formulated by the Indonesian Association of Environmental Study Program (BAKERMA-TL) is the Water and Wastewater Laboratory. Among the fundamental modules taught in this laboratory is Solid Content Determination. This experiment provides students with essential technical knowledge and analytical skills for water quality assessment and wastewater treatment processes.

However, several challenges have emerged, particularly related to HSE issues. As an instructional laboratory, the

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laboratory is administered by a limited number of technicians to serve students from different batches in meeting course learning objectives. The instructional module is accessible to all students, and provides basic safety instruction, such as emergency response protocols, and some instruments handling protocols.

One key concern lies in the multi-faceted nature of laboratory safety, especially for Solid Content experiments. Hazards can emerge not only during the measurement and heating phases but also post-experiment, such as during the cleaning of slippery porcelain glassware, which has been shown to cause safety incidents (Yarahmadi et al., 2016). To address this, a comprehensive HSE framework must be adopted. This begins with a clear understanding of the specific hazards present in the lab and a structured Hazard Identification, Risk Assessment, and Control (HIRAC) approach. The HIRAC framework classifies hazards into low, medium, and high-risk categories. Low-risk hazards require routine control and monitoring, medium-risk hazards demand corrective improvements, while high-risk hazards necessitate urgent intervention (Goetsch, 2011). Each risk is assessed based on likelihood and severity, enabling appropriate mitigation strategies to be developed.

With this experiment, we could identify that the disposal of polluted water with suspended solids has led to the pollution of surface water, groundwater, and natural water bodies (Yarahmadi et al., n.d.). In the process, we also conclude that there are hazards after the process, for example, washing the porcelain glass. It is proven that while washing the porcelain glass, it tends to get slippery from the soap and the water while rinsing the object (Yarahmadi et al., 2016)

The HIRAC itself has three levels of hazard. There are low risk levels, medium risk levels, and high risk levels. The low risk level needs existing control maintenance on the hazard, the medium risk level needs improvement on the hazard, while the high risk level needs urgent improvement on the hazard (Syfa Urrohmah & Riandadari, 2019). The objectives of this study are:

1. To identify and measure potential hazards that may occur during the Solid Content Determination experiment;
2. To understand the risk level of potential hazards that may occur during the Solid Content Determination experiment;
3. To propose strategies and improvements to minimize the risk level of potential hazards that may occur during the Solid Content Determination experiment.

## 2. METHODS

ISO 45001 is an international standard that provides guidelines in occupational health and safety management systems. This standard was issued by the International Organization for Standardization (ISO) in 2018 and replaces the previous standard, OHSAS 18001. The ISO 45001:2018 clauses that are being highlighted in this study are Planning, Operation, Performance Evaluation, and Improvement. The planning is determining the risks of doing the experiment mentioned in this study, the operation is to handle and manage the risks that may happen, the performance evaluation is finding the problem that caused the risk and then monitoring, measuring, analyzing and evaluating the performance of the safety management system, and the improvement is identifying and correcting the past mistakes that leads to accident in the Solid Content Determination Experiment (*Iso 45001 2018*, 2018). Fig.1 depicts the methodological framework of this study.


**Figure 1.** HIRAC Process Flowchart

### 2.1 Hazard Identification


**Figure 2.** Hazard Identification Information Sources

Hazard identification is the process of identifying all hazards in the workplace. There is no set method for grouping agricultural injury and illness hazards (Kabul & Yafi, 2022). Hazard identification analysis in solid content practicum is carried out to determine the risks that may occur and prevent accidents or other negative impacts (Henri Prasetyo et al., 2018). The hazard identification in this study was carried out systematically through direct observation of the laboratory environment and referring to accurate data. Hazard identification is the first step in risk management, which forms the basis for accident prevention or risk control

### 2.2 Risk Assessment

Once the hazards have been identified, it is necessary to assess what risk they pose to employees in the workplace, and then the risk should be evaluated and determined whether to be tolerated or not (Purohit et al., 2018). Risk assessment is carried out to identify and analyze hazards, the event sequences leading to hazards, and the risk associated with hazardous events. Risk assessment is necessary to assess what risk the hazardous events pose to employees in the workplace, and then the risk should be evaluated and determined whether to be tolerated or not (Purohit et al., 2018). Continual improvements in hazard modelling are required, both to correctly represent processes and to increase resolution (Ward et al., 2020). A tool used for assessing and evaluating risks is referred to in the OSH field as a risk table, risk grid, risk matrix, or (our preference) risk assessment matrix (RAM). RAM appears as a two-dimensional grid with one axis having categories of harmful consequence and the other axis with categories for likelihood or probability. The cells inside the grid are used to indicate risk (Jensen et al., 2022)

Risk assessment is performed by considering two main factors: likelihood (L) and severity (S). Risk value is obtained by multiplying likelihood with severity, which is formulated as (Eq. 1)

$$RV = L \cdot S$$

(Eq. 1)

The calculations for the cumulative value and cumulative risk are presented in this section to provide a comprehensive understanding of the overall hazard assessment outcomes. The cumulative value and cumulative risk are used for priority sorting in the HIRA process.

**Table 1.** Risk Matrix (Source: *QHSE Support, 2024*)

| | SEVERITY | | | |
|---|---|---|---|---|
| LIKELIHOOD | 4 | 8 | 12 | 16 |
| | 3 | 6 | 9 | 12 |
| | 2 | 4 | 6 | 8 |
| | 1 | 2 | 3 | 4 |

**Table 2.** Indication of Risk Level (Source: *QHSE Support, 2024*)

| RISK RATING | |
|---|---|
| 1 and 2 | LOW |
| 3 and 4 | MEDIUM LOW |
| 6, 8 or 9 | MEDIUM HIGH |
| 12 or 16 | HIGH |

### 2.3 Control

It is mentioned in the HIRAC flowchart process that the last step to identify HIRAC is to identify the Risk Control process and implement the result to the hazard identified. There are two ways to identify Risk Control: Severity and Likelihood (Salahuddin Araibi et al., 2024). Severity is used to identify the type of injury to happen, to identify type of illness to happen during activity, and financial loss due to the activity. While the Likelihood is used to identify the frequency of the hazard activity, frequency of the hazard occurrence, and the hazard length of exposure (Adiputra, 2015)

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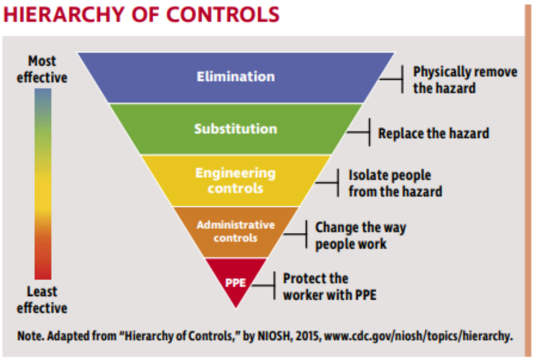


**Figure 3.** Hierarchy of Control (Source: Morris and Cannady, 2019)

## 3. RESULT AND DISCUSSION

In this study, the data were collected through interviews with laboratory assistants at the engineering laboratory of President University, observations during five visits while environmental engineering students conducted solid content experiments, and supplementary data from previous laboratory incident records. During these visits, conditions related to the laboratory environment, materials, equipment, devices, and ongoing experiments were carefully observed.

A total of 18 experimental steps commonly involved in solid content determination were identified. These procedures include tasks such as sample preparation, drying samples in an oven, weighing dried residues, and disposal of waste materials. Hazards associated with these activities, potential scenarios, consequences, and existing control measures were documented in the Hazard Identification and Risk Assessment (HIRA) (Table 3).

The likelihood and severity of each identified hazard were assessed using the collected data to calculate risk values. For example, the pouring of water samples into the vacuum using volumetric flask is determined to have a severity rating of 2. This is due to the potential risks of slipping and falling if the water spilled. However, the frequency of these accidents in the laboratory is medium. This results in a likelihood rating of 2, suggesting that the occurrence of an accident is possible.

By combining the likelihood (2) and severity (2.67), a risk value of 5.3 was calculated, as shown in Table. Using this same approach, risk values for all 18 experimental steps were evaluated. Some activities have high consequences, but their risk values remain medium due to their low likeliho

**Table 3.** HIRA Table

| No. | Main Process | Hazard Aspect | Hazard Scenario | Consequences | Existing Control | Initial Assessment | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Likelihood | | | | Severity | | | | Risk Value | Risk Level |
| | | | | | | FA | FO | LE | L | IN | IL | FL | S | | |
| | | | | | | Average | | | | Max | | | | | |
| 1 | Pouring the water sample into the vacuum using volumetric glass | Slipped and fall | Risk of slipping, falling, and handling when the water sample is spilled. | Body injury (cut) | Proper lifting equipment | 3 | 3 | 2 | 2.7 | 2 | 1 | 1 | 2 | 5.3 | Medium |
| 2 | Inhalation of the dried water sample | Respiratory hazard | After drying a water sample to measure TDS, TS, or TSS, you open the container or | Respiratory Infection | PPE (mask), ventilation | 2 | 2 | 2 | 2.0 | 1 | 1 | 2 | 2 | 4.0 | Medium |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | disturb the dried residue, releasing fine particles into the air. | | system | | | | | | | | | | |
| 3 | Pouring the water sample into the vacuum using volumetric glass | Slipped and fall, | While pouring water sample, spills could create slippery conditions on the lab floor, leading to potential slips and falls causing bodily injury. | Body Injury (bruise) | Proper lifting equipment | 3 | 3 | 2 | 2.7 | 1 | 1 | 1 | 1 | 2.7 | Medium |

The table above represents the HIRA table on the activity this study has done. In the number 1, which is pouring the water sample into the vacuum using volumetric glass, represents the critical actions of this activity, because the risk level of this activity places in the Medium level with the value 5.3. Then, there's an activity where inhalation of the dried water sample with the Medium risk level and the risk value itself is 4.0 which is lower than number one. For number three, there's pouring the water sample into the vacuum using volumetric glass with the Medium risk level. For further details on the HIRA table used in this experiment, please refer to **Appendix I**, where the complete HIRA table can be found.

Each practical process has potential hazards, such as water spills that cause slippery floors (risk of slipping), exposure to dry residue particles that are harmful if inhaled (risk of respiratory problems), and the use of fragile tools such as measuring cups that can break (risk of injury). These hazards are controlled by appropriate work procedures, the use of Personal Protective Equipment (PPE) for examples masks and gloves, and good laboratory conditions (e.g. good ventilation).

Based on the analysis, most of the risks in the laboratory fall into the medium risk category with scores between 2.0 and 5.3. Only a few risks are Low, such as turning on the vacuum device with a score of 1.0-1.7. Preventive measures such as training before practicum and additional supervision for high risks are still needed. The risk assessment refers to the HIRA method which is widely used in OHS (Occupational Health and Safety) management. Information was obtained from direct observation, laboratory analysis, as well as risk management guidelines from the AS/NZS 4360 standard and the HIRA method as described in ISO 45001.

**Table 4.** Priority Sorting Table

| No. | Main Process | Hazard Aspect | Hazard Scenario | Consequences | Existing Control | Initial Assessment | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Likelihood | | | | Severity | | | | Risk Value | Risk Level | Cumulative Value | % Cumulative of Risk |
| | | | | | | F | F | L | | I | I | F | | | | | |

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| | | | | | | A | O | E | L | N | L | L | S | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Average | | | | Max | | | | | | | |
| 1 | Pouring the water sample into the vacuum using volumetric glass | Slipped and fall | Risk of slipping, falling, and handling when the water sample is spilled and fragile objects | Body injury (cut) | Proper lifting equipment | 3 | 3 | 2 | 2.7 | 2 | 1 | 1 | 2 | 5.3 | Medium | 5.3 | 18% |
| 2 | Inhalation of the dried water sample | Respiratory hazard | After drying a water sample to measure TDS, TS, or TSS, you open the container or disturb the dried residue, releasing fine particles into the air. | Respiratory Infection | PPE (mask), ventilation system | 2 | 2 | 2 | 2.0 | 1 | 1 | 2 | 2 | 4.0 | Medium | 9.3 | 31% |
| 3 | Pouring the water sample into the vacuum using volumetric glass | Slipped and fall, | While pouring water sample, spills could create slippery conditions on the lab floor, leading to potential slips and | Body Injury (bruise) | Proper lifting equipment | 3 | 3 | 2 | 2.7 | 1 | 1 | 1 | 1 | 2.7 | Medium | 12.0 | 40% |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | falls causing bodily injury. | | | | | | | | | | | | | | |

The table above represents the Priority Sorting table on the activity this study has done. The priority Sorting table is used to prioritize an activity where it has the most critical hazard. For example, in number one, the activity has the highest cummulative value which is 5.3 and the cummulative risk is 18%. For further details on the Priority Sorting table used in this experiment, please refer to **Appendix II**, where the complete Priority Sorting table can be found.

The smaller cumulative percentage of risks that are prioritized for monitoring, the more serious the attention given to these risks. This is because prioritization is determined by the highest level of hazard based on cumulative risk analysis. Risks with smaller cumulative values indicate that the hazard requires more urgent control.

The Pareto principles was employed to identify the "vital few" hazards contributing to most of the total risk. This analysis revealed that the first 12 hazard scenarios accounted for approximately 80% of the cumulative risk, in line with the 80/20 rule. In the context of risk management, this principle states that most impacts (80%) are usually caused by a small number of root causes (20%) (Spasojević-Brkić et al., 2022). Therefore, prioritizing 80% of cumulative risks allows resources to be directed to the most significant hazards, thus providing maximum control impact. Most activities are in the medium risk category (M). Risks are evaluated based on their cumulative value, with processes that fall below 80% of the cumulative risk requiring priority attention. There are 12 priorities of hazard aspect, but these processes, particularly the first 9 activities involved medium hazards such as slips, respiratory problems, burns, and cuts. Processes with a lower cumulative risk, such as handling desiccators or other breakable equipment, still require monitoring but are considered less critical.

## Discussion

This section discusses the findings of the hazard identification and risk assessment, focusing on the controls implemented to mitigate the identified risks. The proposed control measures aim to reduce risk levels and ensure safety in the experimental process. A detailed summary of the control measures, categorized based on their priority and type, is presented in Table 5.

**Table 5.** Control Plan Table

| No | Hazard Scenario | Existing Control | Risk | Elimination | Substitution | Engineering Control | Administrative Control | PPE |
|---|---|---|---|---|---|---|---|---|
| 1 | Risk of slipping, falling, and handling when the water sample is spilled | Proper lifting equipment | 5.3 | Clean the spilled water | Replacing the floor surface with the anti-slip floor or adding an absorbent mat | Replacing the floor surface with the anti-slip floor or adding an absorbent mat | Provide Training for employees | Safety Shoes & Gloves |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | After drying a water sample to measure TDS, TS, or TSS, you open the container or disturb the dried residue, releasing fine particles into the air. | PPE (mask), ventilation system | 4.0 | Avoid physical handling | Replace conventional drying techniques with enclosed vacuum dryers that minimize particle release. | Perform drying and residue handling inside a laboratory fume hood to capture airborne particles. | Implement standard operating procedures (SOPs) | Respiratory Protective Equipment (RPE) |
| 3 | While pouring water sample, spills could create slippery conditions on the lab floor, leading to potential slips and falls causing bodily injury. | Proper lifting equipment | 2.7 | Clean the spilled water | Replacing the floor surface with the anti-slip floor or adding an absorbent mat | Replacing the floor surface with the anti-slip floor or adding an absorbent mat | Implement standard operating procedures (SOPs) | Safety shoes & Gloves |

The risk control table serves to summarize the mitigation strategies proposed to address identified hazards. It provides a clear overview of the control measures, their priority levels, and the type of actions required to reduce risks effectively. This table helps ensure that all necessary precautions are systematically implemented to maintain a safe and controlled environment during the experimental process. For example, the first hazard scenario of the control plan is risk of slipping, falling, and handling when the water sample is spilled. The existing control of this scenario is to do proper lifting equipment, the elimination of this scenario is cleaning the spilled water, the substitution is by doing a floor replacement, the engineering control is by doing a floor replacement, the administrative control is to provide training for employees, and the PPE is by wearing safety shoes & gloves. For further details on the Control Plan table used in this experiment, please refer to **Appendix III**, where the complete Control Plan table can be found.

## 4. CONCLUSION

Using the HIRA (Hazard Identification and Risk Assessment) method, the hazards occurring in the Environmental Engineering Laboratory of President University have been studied and evaluated. The study includes risks categorized into four categories: low, medium low, medium high, and high. Of these, most are in the medium low category and, therefore, should encourage the implementation of safety measures in the laboratory and a safe shelter from work.

The hazards mentioned in this study amount to be 18 in total. Priority sorting is then done to identify which hazard is high and medium in level and needs further caution, which turned out to be 12 medium low to high hazard. Thus, the hazard that is being mainly controlled are those 12 medium low to high hazards.

The study emphasizes the importance of improving safety measures in the laboratory. By identifying the effectiveness of the HIRA (Hazard Identification and Risk Assessment) method, steps are taken to improve the operational conditions of the laboratory. Monitoring, evaluation, and approval of methods can help reduce accidents. The most important aspect is used to update practical education afterwards by activating these powers.

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