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Occupational Health and Safety Risk Assessment of Surabaya Pump Houses using the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) Method

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Abstract

Heavy rainfall caused by climate change has led many Indonesian cities to build pump houses to remove excess water and prevent flooding. While pump performance is critical for protecting urban communities, the health and safety of pump house workers has received little attention. Because their work is seasonal, occupational health and safety (OHS) in pump houses is often overlooked, even though protecting workers is essential for ensuring reliable pump operations during emergencies. This study applies the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method, commonly used in manufacturing, to assess risks in pump house operations. Field data were collected from four representative pump houses in Surabaya, with findings intended for broader application to 61 pump houses in the city. The results highlight urgent actions needed to improve worker safety and propose practical measures to strengthen OHS practices. These findings provide valuable insights for other Indonesian cities seeking to enhance their safety culture and ensure the resilience of flood control infrastructure.

Keywords: HIRARC, occupational health and safety, pump house, risk analysis, Surabaya city

1. Introduction

Surabaya is the second-largest city in Indonesia with a strong commitment to achieve its vision of becoming an advanced, humane, and sustainable world class city. To realize this vision, Surabaya has adopted a mission to achieve inclusive economic growth to enhance residents' well-being, develop high-quality human resources, integrate world-class urban spatial planning, and foster social harmony alongside transparent bureaucratic transformation [1]. However, as experienced by all cities with similar geographic conditions to Surabaya, heavy rain triggered by climate change has exposed the city to the threat of flooding [2]. Therefore, the Surabaya City Government continues to implement policies focused on sustainability, infrastructure quality enhancement, and community empowerment. One of the key agencies supporting these efforts is the Surabaya Department of Roads and Drainage, which is responsible for public works and spatial planning, particularly in sustainable water management, including drainage, flood prevention, and road infrastructure.

Surabaya is particularly vulnerable to flooding because of its low-lying topography, which ranges from 3 to 6 meters above sea level [1]. Heavy rainfall significantly contributes to flooding, as evidenced by data from the National Disaster Management Agency (BNPB), which recorded 12 flooding incidents caused by intense rainfall [3]. River overflows due to continuous heavy rain has led to flooding in multiple locations across Surabaya. In addition, rapid land-use changes increase the risk of flooding [4]. Therefore, pump houses play a critical role in the city's drainage system by regulating water levels and mitigating flood risks. The Surabaya Drainage Master Plan 2018 acknowledged the significance of pump houses as an integral component of the city's flood mitigation strategy. Thus, effective monitoring and reliable operations of pump houses are crucial for the Surabaya City government to prevent and manage floods effectively.

Currently, Surabaya has 65 pump houses distributed across five districts: Genteng, Jambangan, Gubeng, Tandes, and Wiyung. In total, these stations have 270 pump units. The power sources for these pump houses are categorized into 3 (three) types, which are electricity from the national grid, generator sets (gensets), and a combination of both. The total number of gensets installed at Surabaya's pump houses was approximately 100 units. In addition, several pump houses have automatic trash screens, including mechanical and rotary screens,

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with 47 units in total. Although the design of each pump house varies slightly by region, their operational systems are generally standardized.

To optimize the operation of all pump houses across the city, the Surabaya Department of Roads and Drainage together with the researcher team from Institut Teknologi Sepuluh November (ITS) conducted an intense observation. The observations have identified several occupational safety hazards, such as slippery floors and the absence of safety signs in the pump houses. These factors require urgent attention to minimize the risks to pump house workers, which in the end end will affect the pump house operations.

This paper presents the results of immediate action taken after the observation, which was the implementation of HIRARC (Hazard Identification, Risk Assessment, and Risk Control) to improve the health and safety management in the pump houses. The HIRARC method is commonly used in manufacturing or commercial companies to identify, evaluate, and mitigate risks related to the health and safety. Unfortunately, in public services provided by a city government across Indonesia, the implementation of scientific management like HIRARC has not been widely utilized. Thus, the results presented in this paper are expected to inspire other city governments in Indonesia to start using scientific management methods to improve the condition of their public services.

2. Theoretical Basis

Occupational safety refers to the protection of workers' physical well-being to prevent accidents and injuries in the workplace [5]. Workforce safety is a critical element in any organization's operations because human resources play an essential role in maintaining efficiency and productivity. In addition to safety, worker health is also a significant concern because it directly affects overall productivity. Occupational health is defined as a state of well-being aimed at ensuring employees' optimal physical, mental, and social health, preventing occupational diseases, and addressing work-related health conditions [6]. According to [7], occupational health involves the application of health sciences to prevent work-related illnesses and improve employee well-being to enhance efficiency. Therefore, Occupational Safety and Health (OSH) encompasses all conditions and factors that may influence workers' safety and health in the workplace. OSH regulations in Indonesia are governed by Indonesia's Law No. 1/1970 on Occupational Safety, which defines workplaces as any enclosed or open area, stationary or mobile, where workers perform their duties.

Risk is defined as an uncertain condition that carries potential hazards or adverse consequences [8, 9]. To anticipate risks, organizations must implement risk management strategies. Risk management refers to systematic approaches for identifying, assessing, and controlling risks to prevent or minimize losses [10, 11]. The primary objective of risk management is to accurately predict potential hazards and make informed decisions based on initial assessments to mitigate adverse impacts. One of the fundamental components of risk management is risk analysis, which can be conducted using a risk assessment matrix. This matrix is a project management tool used to evaluate risks and determine whether specific risks require managerial intervention [12]. The matrix categorizes risks according to likelihood (probability of occurrence) and severity (impact level). These two parameters are used to determine the overall risk level, which is presented in a structured table format (Figure 1). The operational definition of each likelihood level and severity level are defined in Table 1 and 2 respectively, while the consequences of each risk level are interpreted in Table 3. Understanding these tables and risk assessment matrix is important for establish an accurate risk management.

The Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method is a systematic approach to preventing and mitigating workplace accidents. HIRARC involves a series of OSH implementations, starting from hazard identification, which involves recognizing potential hazards associated with specific work activities [13]. The next phase, risk assessment, evaluates whether the risks associated with processes, operations, or activities are within acceptable limits [14]. The final phase, risk control, focuses on minimizing exposure to workplace hazards through appropriate mitigation measures [13]. An effective risk control strategy requires the prioritization of hazards based on their potential impact, which subsequently informs the selection of risk mitigation methods. The HIRARC framework serves as a guideline for OSH implementation within organizations, enabling them to independently address safety management challenges [15].

		Severity				
		Insignificant	Minor	Moderate	Major	Severe
Likelihood	Almost Certain	Medium	High	High	Extreme	Extreme
	Likely	Medium	Medium	High	Extreme	Extreme
	Possible	Low	Medium	Medium	High	Extreme
	Unlikely	Low	Low	Medium	High	High
	Rare	Low	Low	Low	Medium	High

Figure 1. Risk Assessment Matrix
Source: [16]

Table 1. Likelihood Level

Likelihood	
Almost Certain	The event is expected to occur in most cases when the activity is performed (likelihood of occurrence above 90%).
Likely	The event may occur in most cases when the activity is performed (likelihood of occurrence between 51% and 90%).
Possible	The event may occur when the activity is performed (likelihood of occurrence between 21% and 50%).
Unlikely	The event could occur at some point when the activity is performed (likelihood of occurrence between 1% and 20%).
Rare	The event may occur only in exceptional circumstances when the activity is performed (likelihood of occurrence below 1%).

Source: [16]

Table 2. Severity Level

Severity	
Severe	Severe injury or illness requiring life support, potential or actual fatality, or work leave exceeding 250 days.
Major	Significant medical treatment (e.g., surgery), major to permanent illness or injury, or sick leave exceeding 10 days.
Moderate	Multiple medical treatments, non-permanent injury, or work leave of fewer than 10 days.
Minor	Requires a single instance of medical treatment, minor injury, no work leave required.
Insignificant	Only first aid treatment, minor injury, and no work leave required.

Source: [16]

Table 3. Risk Level

Risk Level	
Extreme	The risk must be immediately mitigated. Additional effective control measures must be introduced to reduce risk.
High	The risk is generally unacceptable. It should only be tolerated temporarily and only during the planning of further control measures to reduce risk.
Medium	The risk is generally acceptable. Further risk reduction efforts should be undertaken if feasible.
Low	The risk may be monitored and reviewed periodically to ensure that it does not escalate.

Source: [16]

3. Methodology

The Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method was employed to investigate occupational health and safety risks in pump houses throughout Surabaya. The research adopted a case study design to develop a risk mitigation framework intended as a reference for pump houses in Surabaya and other Indonesian cities. Of the seven major pump houses in Surabaya (Dinoyo, Kenari, Semampir, Kalidarmo, Greges, Pesapen, and Bozem Morokrembangan), four were purposively selected as research sites. Selection was conducted in collaboration with the Surabaya City Government through a Focus Group Discussion (FGD) and was based on three criteria: pump capacity, completeness of facilities, and flood risk level. This sampling strategy ensured representation of diverse operational scales and occupational risk levels.

Data collection integrated qualitative and quantitative methods, including on-site observation, semi-structured interviews, direct technical measurements, and expert discussions. Key personnel interviewed included the sub-coordinator of drainage infrastructure, regional pump house supervisors, engineers, technicians, and operators. Observations were supplemented with documentation reviews and technical data from the Department of Water Resources and Spatial Planning. The three-month data collection period ensured comprehensive coverage of operational conditions across the selected sites.

Hazard identification utilized two complementary frameworks. The Risk Breakdown Structure (RBS) categorized hazards into environmental, technical, and safety aspects, while a Preliminary Hazard List (PHL) mapped specific hazards, their causes, and potential effects on workers and operations. Risk assessment was subsequently conducted using a semi-quantitative risk matrix, classifying risks as extreme, high, medium, or low. Likelihood and severity were determined using available quantitative data or, when unavailable, expert judgment and descriptive reasoning.

The risk control phase adhered to the internationally recognized Hierarchy of Controls. Recommendations were prioritized for effectiveness, starting with elimination and substitution, followed by engineering and administrative controls, and concluding with personal protective equipment (PPE) as the final measure. Proposed occupational safety and health mitigation measures emphasized engineering solutions and administrative protocols that could be sustainably implemented by pump house management.

The proposed control strategies were validated through consultations with senior decision-makers, including the Head and Deputy Head of the Surabaya City Water Resources and Spatial Planning Department. Stakeholder feedback was incorporated into the final recommendations to ensure technical feasibility and alignment with the city's occupational health and safety policies.

4. Results and Discussion

The risk analysis and Occupational Health and Safety (OHS) assessment in Surabaya pump houses were conducted in four stages: Hazard Identification, Risk Assessment, Risk Control, and Risk Mitigation. The detailed results of each stage are explained in the following subsections.

4.1. Hazard Identification

The first step in applying the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) approach is to identify activities that pose potential hazards in operational processes. The primary objective of hazard identification is to recognize all possible hazards arising from a working system [17]. Hazard risk identification in pump houses uses the Risk Breakdown Structure (RBS), which categorizes risks into three main categories: technical, environmental, and safety risks. These categories are outlined in Table 4, which classifies potential hazards according to risk type. Furthermore, Table 5 presents a detailed analysis of the hazards identified at the pump houses, including an overview of the risks, causes, and effects associated with each hazard.

Table 4. Risk Breakdown Structure (RBS)

RISK BREAKDOWN STRUCTURE (RBS)				Description
Pump House Management Risks	Environment	A.1	Complaints from the Surrounding Community	Noise complaints from the surrounding community due to the loud sound of pump machines when turned on.
	Technical	B.1	Pipe or Pump Leakage	Risk of pipe or pump leakage caused by corrosion or other factors.
		B.2	Damaged Operator Panel	Potential damaged of the pump or mechanical screen, which may disrupt operations.
		B.3	Power Outage	Power outages affecting the pump house's power supply.
	Safety	C.1	Slipping	Slipping hazards due to slippery floors.
		C.2	Drowning	Risk of falling and drowning for operators, especially in pump houses located near rivers.
		C.3	Caught in Machinery	Potential entrapment in mechanical screens while operating equipment.
		C.4	Struck by Heavy Objects	Hazards such as falling from heavy equipment, such as hanging iron chains, which can be dropped onto operators.
		C.5	Electrocution	Risk of electrocution due to the use of electricity as the pump house's primary energy source.
		C.6	Falling into Uneven Floors or Open Holes	Tripping hazards from uneven floors or open drainage holes, which increase the risk of workers falling.

Table 5. Preliminary Hazard List (PHL) for Surabaya Pump Houses

Preliminary Hazard List (PHL)				
Item	**Hazard**	**Risk**	**Causes**	**Effect**
1	Short Circuit	Fire	Chewed or peeled electrical cables by rodents	Damaged equipment, financial losses, potential injuries or fatalities
2	Slippery Floor	Slipping and Falling	Water puddles on the floor during manual screening	Injuries to the workers
3	Hanging Heavy Objects	Struck by Heavy Objects	Falling objects from above, such as chains and hooks	Injuries or loss of life
4	Exposed Electrical Cables	Electrocution	Messy cable placement and rodents' presence	Burns and/or fatalities
5	Unprotected Moving Machinery	Caught in a Mechanical Screen Machine	Operator carelessness during operation (human error)	Injuries or loss of life
6	Wide Open Holes in Several Areas of a Pump House	Falling into a Hole	Lack of regular monitoring of the facilities	Injuries or loss of life

4.2. Risk Assessment

In this stage, the risks and hazards identified in the previous stage were assessed based on their likelihood and severity. The assessment was conducted through discussions and brainstorming with key stakeholders. The evaluation involved calculating the mean score from the survey responses for each performance assessment indicator related to the safety programme and its activities. The risk value was then computed by multiplying the severity with the likelihood.

The risk value calculations are presented in Table 6. Each identified risk was then classified according to a risk level criterion ranging from low to extreme, from acceptable to unacceptable. For risk categorization, a risk level matrix was used to determine the severity of potential hazards (Table 7). The risk severity levels are divided into four categories: Low Risk (minimal impact, requiring only monitoring), Moderate Risk (requires mitigation measures), High Risk (requires immediate corrective action), and Extreme Risk (unacceptable and must be addressed urgently).

Moreover, Table 8 describes the risk level categorization for each risk that has been identified and listed in Table 4. It can be seen that 40% of the identified risks fall into the low risk category, while 30% of the identified risks fall into the medium risk category and 30% into the high risk category. Fortunately, none of the risks are categorized as extreme risks. However, risks at any level should be addressed and mitigated properly.

To ensure the reliability and objectivity of the findings, the results of the risk scoring, risk matrix, and risk level classification were validated by a certified safety expert. This validation process was conducted through a Focus Group Discussion (FGD) involving multiple stakeholders, including pump house operators, researchers, independent occupational safety experts, and representatives from the Surabaya City Government. Through this participatory approach, expert feedback was integrated into the analysis, enabling the refinement of risk categorizations and the strengthening of the proposed mitigation strategies.

Table 6. Risk Value Calculations for Surabaya Pump House

Risk	Severity	Likelihood	Risk Value
A.1	2	1	2
B.1	2	1	2
B.2	4	2	8
B.3	3	1	3
C.1	3	3	9
C.2	1	1	1
C.3	4	1	4
C.4	5	1	5
C.5	4	3	12
C.6	3	2	6

Table 7. Risk Matrix of Surabaya Pump House

Likelihood	Weight	Risk = Severity x Likelihood				
Very Likely	5					
Likely	4					
Possible	3			C.1	C.5	
Unlikely	2			C.6	B.2	
Very Unlikely	1	C.2	A.1;B.1	B.3	C.3	C.4
Weight		1	2	3	4	5
Severity		Minor	Moderate	Less Serious	Serious	Major

Table 8. Risk Level Categorization in Pump House Management Risks

RISK BREAKDOWN STRUCTURE (RBS)			Risk Level
Pump House Management Risks	Environment	Complaints from the Surrounding Community	Low
	Technical	Pipe/Pump Leakage	Low
		Damaged Operator Panel	High
		Power Outage	Low
	Safety	Slipping/Falling	High
		Drowning	Low
		Caught in Machinery	Medium
		Struck by Heavy Objects	Medium
		Electrocution	High
		Falling into Uneven Floors or Open Holes	Medium

4.3. Risk Control

Risk control is a systematic process aimed at managing all potential hazards in the workplace while ensuring continuous reassessment and improvement. The primary objective of risk control is to mitigate potential hazards and ensure that work operations are safe [18]. Risk control follows the hierarchy of control approach (as shown in Figure 2) which outlines a structured sequence of hazard prevention and mitigation measures [19] including elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE). Elimination means removing the hazardous substance entirely by discontinuing the use of hazardous equipment or sources. Substitution replaces hazardous sources with safer alternatives that pose lower risks). Engineering controls reduce risk levels by modifying workplace design, equipment, and operational processes to enhance safety. Administrative controls implement workplace policies, such as Standard Operating Procedures (SOPs), to minimize exposure to hazards. Personal Protective Equipment (PPE) is a measure implemented to reduce the severity of harm caused by hazards through protective gear [20].

Based on the risk assessment results compiled in Table 8, three high risks have been identified as high-priority hazards requiring immediate control measures. They include malfunctioning of operator panel, slipping hazards, and the risk of electrocution. The recommended control measures for each risk are summarized in Table 9.

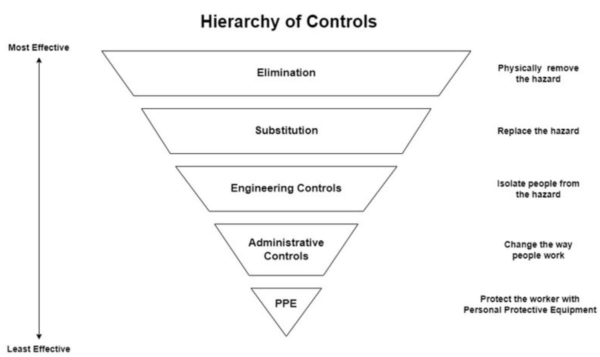

Figure 2. Hierarchy of Controls

Table 9. Risk Control for Surabaya Pump House

Risk	Hierarchy of Controls	Risk Control
Malfunctioning of Operator Panel	Engineering Control	Regular Maintenance and Repairs of the Operator Panel *A structured maintenance schedule is implemented to ensure that the operator panel remains functional and in optimal condition.*
	Administration	Developing and Enforcing Standard Operating Procedures (SOPs) *Establish clear SOPs for pump house operations, including safety protocols for handling critical components.*
	Personal Protective Equipment (PPE)	Provide Personal Protective Equipment (PPE) for Workers/Operators *Equip workers/operators with rubber gloves and safety shoes to prevent electrical hazards and workplace injuries.*
Slipping Hazards	Personal Protective Equipment (PPE)	Provide PPE for Workers/Operators and Cleaning Personnel *Supply workers/operators and cleaning staff with rubber boots to reduce slipping hazards in wet environments.*
Electrocution Risk	Personal Protective Equipment (PPE)	Ensuring PPE Compliance for Workers/Operators *Equip workers/operators with rubber gloves and safety shoes to enhance the protection against electrical hazards.*

4.4. Risk Mitigation

After completing the first three stages of the HIRARC method, several risk mitigation measures were proposed for Occupational Safety and Health (OSH) aspects at pump houses in Surabaya. The risk mitigation efforts that can be implemented include:

1) Placing fire extinguishers at the more appropriate place

   Based on the field observations, each pump house was equipped with a fire extinguisher. However, the fire extinguishers are not correctly placed, either unseen or hidden or mounted on the walls too high or too low. Therefore, to ensure easy access, it should be positioned at a visible and easily accessible location, and mounted on walls at a height of about 1 meter.

2) Installing an appropriate fire extinguisher

   Selecting an appropriate type of fire extinguisher is essential. Based on the risk analysis at pump houses, the recommended types of fire extinguisher are powder and carbon dioxide. These two types are considered effective in extinguishing fires in Class B (flammable liquid) and Class C (high-voltage electrical installation) fires, which are potential hazards in the pump house area [21, 22].

3) Adding adequate safety signs at the pump house area

Figure 3. Proposed Safety Signs for the Pump House Area

Observations of the sample pump houses found that essential safety and hazard risk signs were missing. Some necessary safety signs that should be provided in pump houses including electrical hazard safety signs (placed near panels and generators), PPE usage safety signs (posted on walls to remind workers or operators to wear appropriate PPE while working), and slippery floor hazard signs (placed near areas prone to slips and falls). The example of required signs are shown in Figure 3.

4) Strict supervision of OSH implementation

During the observations, workers and field supervisors did not wear adequate PPE while performing their duties, posing risks to themselves and others. Therefore, safety awareness should be promoted and even formally taught. Moreover, field and area supervisors should enforce strict supervision of safety aspects. Neglect of proper PPE use should result in a warning, and repeated or serious breaches of safety regulations should be subject to sanctions.

5. Conclusion and Recommendation

Based on the HIRARC analysis at 4 selected pump houses in Surabaya city, 10 hazard risks have been identified and categorized into environmental, technical, and safety groups. These risks include complaints from the surrounding community, pipe or pump leakage, damaged operator panels, power outages, slipping, drowning, getting caught in machinery, being struck by heavy objects, and electric shocks. According to the risk assessment matrix, 3 risks fall into the high level, which are damaged operator panels, slipping, and electric shocks. For each of those high risk categories, risk control measures based on the hierarchy of control have been developed.

Furthermore, to mitigate all identified risks, several measures have been formulated, such as providing adequate and properly managed safety equipment and ensuring the presence of safety signs in the pump houses. Additionally, strict supervision of occupational safety aspects is necessary to ensure that operators and field workers adhere to safety protocols. Regular maintenance and scheduled repairs of equipment should also be conducted to prevent damages that could compromise the safety of operators and personnel.

In a nutshell, the study presented in this paper highlights the importance of scientific management approaches, in this case is HIRARC method, to be implemented in public sectors provided by City Government. The implementation of science management methods could provide more effective, efficient, safer, and more sustainable services. Therefore, it is strongly recommended that the findings presented in this paper can be implemented in other pump houses in Surabaya and other cities in Indonesia. Even, in other developing countries with similar level of safety awareness as in Indonesia, this study can be used as a benchmark for continuous improvement.

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