

Assessment of Occupational Safety and Health Implementation and Preventive Measures in Dry Dam Operations: A Case Study of the Sukamahi Dry Dam

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Abstract

Background: Dry dams serve as flood-control mechanisms in urban regions subjected to extreme hydrometeorological conditions. The Sukamahi Dry Dam, the first dry dam in Indonesia, has been operational since 2022 and mitigates peak discharges toward Jakarta. This study assessed the implementation of occupational health and safety (OHS) measures, identified potential hazards, and evaluated risk levels associated with the dam's operational activities.

Method: Hazard identification and risk assessment methodology was applied to categorize hazards and compute risk scores on the basis of consequence, exposure, and likelihood. Data collection involved field observations, interviews with 26 personnel, and a review of operational documents at the Sukamahi Dry Dam in 2024.

Results: Six primary operational tasks, most notably crane hoist operations and work conducted at heights, presented significant risks, with consequence scores of 100. Major deficiencies were identified, including the absence of fall protection systems, undocumented inspections of lifting equipment, outdated standard operating procedures (SOPs), and inconsistent use of protective equipment. Irregular training, the absence of safety officers, limited emergency preparedness, and a reactive safety culture exacerbate these hazards.

Conclusion: Current OHS practices are inadequate for ensuring safe operations. Such practices can be improved through competency-based training, the establishment of risk-based SOPs with clear standards, safety audits, improved emergency response, and the integration of digital monitoring technology to enhance worker protection and ensure the reliability of flood control measures.

Keywords: Dry dam, Hazard identification, Occupational safety, Risk assessment.

INTRODUCTION

Indonesia, characterized by its tropical climate and significant annual precipitation, is particularly vulnerable to flooding, especially in densely populated urban centers such as Jakarta and its surrounding areas.¹ A principal factor contributing to flooding in Jakarta is excessive runoff from upstream regions of the Ciliwung River, which is inadequately managed, particularly during episodes of intense rainfall.^{2,3} The government has implemented a range of flood mitigation strategies, including river normalization and the development of flood control infrastructure. Among these innovative infrastructural solutions is the Dry Dam, which temporarily retains surplus water during extreme rainfall events and subsequently releases it downstream in a regulated manner.^{4,5,6} Unlike traditional dams, which permanently store water, dry dams are activated only when water volumes surpass the channel's capacity.

The Sukamahi Dry Dam, located in the Megamendung District of Bogor Regency, West Java, is one of Indonesia's pioneering flood-control infrastructure projects utilizing this technology. This structure functions as a runoff-retention system, engineered to mitigate peak discharges and reduce flood risk in downstream regions without sustaining a permanent water column. Additionally, this infrastructure forms part of the National Strategic Project (PSN) initiated by the Indonesian government

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to address flooding issues in the capital city, particularly along the Ciliwung River corridor. The concept for this facility has evolved since the 1990s, with construction commencing in 2016 and the facility officially inaugurated on December 23, 2022. Overall, its implementation exemplifies an adaptive and sustainable approach to natural resource management, aligned with modern technologies such as environmental sensors and water quality monitoring systems, to support ecosystem sustainability and regional resource resilience.^{7,8}

Occupational health and safety (OHS) is an essential component of the effective management of such infrastructure. The functional complexity and technical attributes of the Sukamahi Dry Dam, including hydrological monitoring, structural inspections, and spillway maintenance, inherently pose various potential hazards that necessitate the rigorous, risk-based application of OHS principles. This transition is crucial because the sustainability and operational efficacy of contemporary flood control technologies are determined not only by the reliability of hydrological and structural systems but also by the ability to ensure the safety of personnel responsible for managing these facilities.

The implementation of OHS practices in dam operations throughout Indonesia exemplifies a dynamic interaction between effective practices and ongoing on-site challenges.⁹ Several national strategic projects, such as the Bener Dam in Purworejo and the Bagong Dam in Trenggalek, have exhibited a proactive commitment to OHS implementation through competency certification programs for workers and structured OHS socialization initiatives involving relevant stakeholders, including the Regional Disaster Management Agency (BPBD).¹⁰ These practices have contributed not only to enhanced workplace safety but also to improved productivity and professionalism within the water resource infrastructure sector.

However, efforts to implement OHS management systems in various infrastructure projects in Indonesia, including dam construction and operation, remain suboptimal.^{11,12,13} Numerous studies have identified several constraints in this sector, such as inadequate systematic documentation, insufficient periodic risk assessments, inconsistent safety training programs, and low compliance with personal protective equipment (PPE) use. Furthermore, a comprehensive safety culture has not been fully internalized at either the worker or project management level, resulting in a persistently high risk of occupational accidents that may jeopardize both the operational continuity and structural integrity of dams. Occupational accidents at the Jenelata Dam project and issues related to labor social security at the Temef Dam further highlight the deficiencies in supervision and compliance with OHS standards in the field.

In the realm of Dry Dam infrastructure, conditions become increasingly critical because operational characteristics differ fundamentally from those of conventional dams. This type of system operates intensively, primarily during extreme rainfall or hydrometeorological events, subjecting routine activities, such as hydrological data monitoring, structural inspections, spillway maintenance, sediment accumulation management, and emergency preparedness, to more dynamic and situational risk profiles. Previous studies focusing on the construction-related risks of conventional dams have not adequately addressed OHS aspects during the operational phase, particularly for Dry Dams, which possess unique risk characteristics and remain underexplored in the academic literature. The absence of comprehensive studies examining the interrelationships among hydrological dynamics, facility operations, and occupational safety risks highlights this significant research gap.

An in-depth evaluation is necessary to assess the implementation of OHS management systems in Dry Dam operations, with a focus on hazard identification, field-based risk assessment, and the efficacy of existing mitigation measures. This approach is crucial to ensure that facility operations are technically reliable, safe, and sustainable. Consequently, this study aims to evaluate the implementation of OHS in the operation of the Sukamahi Dry Dam, with an emphasis on identifying occupational risks, analyzing the effectiveness of the implemented mitigation measures, and formulating strategic recommendations to enhance safety management systems in this sector. Through this investigation, it is anticipated that a more comprehensive understanding of the challenges, opportunities, and necessary improvements in OHS within the water resources sector will be achieved, thereby contributing to the development of more adaptive, risk-based, and sustainable occupational safety standards.

METHOD

The research was conducted at the Sukamahi Dry Dam, located in Sukamahi Village, Megamendung Subdistrict, Bogor Regency, West Java Province, Indonesia. Geographically, it is located

at 106°52'53.17" E - 6°40'10.16" S. The Sukamahi Dry Dam covers 40 hectares and comprises the main structure and supporting infrastructure. Its maximum storage capacity is 1.68 million cubic meters, with the inundated area ranging from 5.23 to 10 hectares, depending on the prevailing hydrological conditions.

Functionally, this dam is designed to reduce peak flood discharge by up to 15.47 m³/s, which is a significant contribution toward decreasing flood risk in downstream areas, particularly Jakarta and its surroundings along the Ciliwung watershed. In addition to its primary role as a flood mitigation infrastructure, the Sukamahi Dry Dam provides ecological and social benefits for environmental conservation in the upstream region.



Figure 1. Location of Sukamahi Dry Dam

Participants and Study Design

The research employed a descriptive qualitative approach, using the Hazard Identification and Risk Assessment (HIRA) method to evaluate the implementation of occupational health and safety measures during dam operations. A total of 26 participants were involved, including 20 operational workers, three field supervisors, and three managerial personnel responsible for daily operational decisions. Participants were selected based on their direct involvement in high-risk work activities, such as operating stoplogs, maintaining structures, lifting loads with crane hoists, cleaning the dam body, and monitoring hydrometeorological parameters. These work activities were selected not only for their high risk level but also because of the steep terrain around the dam, which necessitates effective monitoring and management to prevent accidents and ensure occupational safety during dam operation. Participation provided relevant empirical data to identify working risk conditions.

Measurements and Procedure

The research procedure began with the methodological preparation stage, which included determining the scope of the analysis, identifying high-risk operational activities, and coordinating with the Dam Management Unit to obtain access to observations, interviews, and technical documents. The next stage was the initial field observation to map critical work zones, including the crane hoist area, stoplog room, inspection routes, and inlet-outlet channels, to determine the focus of data collection.

After the initial mapping, the research continued with the main data collection, which was conducted through systematic observation of operational activities, semi-structured interviews with key workers, and document analysis, including standard operating procedures (SOPs), equipment inspection logs, and incident reports. These three techniques were used in a triangulated approach to obtain a comprehensive picture of work practices, equipment conditions, and risk history.

The final stage was the identification and assessment of risks using the HIRA method in accordance with the AS/NZS 4360:2004 standard.^{14,15,16} The HIRA method was selected due to the

complexity and operational dynamics of the Dry Dam, which involve multiple simultaneous hazards, thus requiring a more comprehensive analytical approach than the Job Safety Analysis (JSA). JSA only assesses routine activities with well-defined work steps, whereas HIRA, through qualitative and quantitative assessments based on three main parameters (severity, exposure, and likelihood), can evaluate risks at the system level for various tasks, including emergency conditions such as operating stoplogs during peak rainfall or conducting inspections during extreme precipitation. At the same time, HIRA provides a framework commonly used in public infrastructure risk management and flood control, making it more suitable for producing accurate and relevant risk evaluations.¹⁷

The evaluation procedure using the HIRA method includes several processes: (1) systematic identification of all potential hazards for each type of activity; (2) identification of the groups of workers exposed; (3) assessment of the severity, level of exposure, and likelihood of incidents occurring; and (4) classification of risk levels using a standard risk matrix. The resulting risk categories, ranging from acceptable to very high, were used as the basis for establishing control priorities. To maintain the focus of the article, technical details regarding the assessment scale, basic risk and existing risk formulas, and the complete risk matrix are presented as supplementary material.

RESULT

Field observations indicate that the operational activities at the Sukamahi Dry Dam encompass a range of high risk tasks. Certain activities—such as the installation process and the operation of the crane hoist to lift, move, and lower the stoplog—involve multiple workers, thereby increasing the potential for hazards (Fig. 2). These activities pose risks, including falls from heights, electric shocks during the installation of the crane hoist power grid, and being struck by heavy objects. An inspection of the work area revealed the absence of permanent fall protection measures, such as safety railings or anchor points, at locations where work was conducted at a height.

The terrain at the Sukamahi Dry Dam, characterized by steep, rocky terrain, exacerbates the risk of slips and injuries from sharp objects during routine maintenance or dam operations under flood conditions. Additionally, sediment excavation work in the boulder rack area poses a drowning risk because of its proximity to the inlet channel.



Figure 2. Operational, Maintenance, and Monitoring Activities of the Sukamahi Dry Dam

Risk Identification

Risk identification for K3 was conducted through interviews and field observations of workers and supervisors (Table 1). The interview findings indicated that most operational activities in the Dry Dam area were carried out without documented SOPs or technical inspection protocols for heavy machinery. Furthermore, workers reported inconsistent use of PPE, particularly during tasks that required body harnesses and safety helmets. Additionally, OHS training is not administered regularly; most workers receive it only during their initial placements.

In accordance with the Minister of Manpower Regulation No. 9 of 2016 and OSHA 3146-05R of 2015, all work conducted in areas with a potential risk of falls from heights must be equipped with fall protection systems, including guardrails, safety nets, and personal fall arrest systems.^{18,19} The

observed discrepancy between field practices and regulatory requirements highlights a substantial risk to worker safety that necessitates immediate attention.

Various operational activities in the Dry Dam area, particularly those associated with the installation and operation of stoplogs and the maintenance of structures, pose a relatively high risk. Activities such as installing the crane hoist electrical system and lifting, shifting, and lowering stoplogs occur in work areas at significant heights and involve direct interactions with heavy equipment (Table 1). These conditions present potential hazards, including electric shock, falls from heights, being struck by heavy objects, and being pinched by metal components. Potential consequences range from minor injuries, such as bruises and sprains, to serious burns and fatal injuries.

Additional risks were identified in the inspection and maintenance of stoplogs, particularly because of the potential for slips on narrow or slippery work surfaces. Instrument monitoring activities and dam structure maintenance pose similar hazards, given the steep, rocky, and unstable terrain, which increases the likelihood of falling, slipping, or injury from sharp objects. During sediment excavation in the boulder rack and inlet channel areas, the risk of drowning becomes a primary concern because of the proximity to deep-water flows and the potential for loss of balance while working.

Table 1. Identification of Occupational Health and Safety Hazards (OHS)











No	Figure	Source of Hazard	Potential Hazard	Risk
1		Installation of electrical wiring, crane hoists, and stoplogs	Electrocution and falls from elevations	Positions can result in sprains, cellular damage due to electric shock, burns, and even fatalities
2		Crane hoist motor installation	Falling from a height or being struck by heavy equipment	Sprain, bruise, death
3		Connecting the stoplog to the crane hoist	Falling from a height or being trapped by a metal object	Sprain, bruise
4		Stoplog lifting operation	Falling from a height or crushed by a heavy object	Sprain, bruise, death
5		Stoplog shifting operation	Falling from a height or being crushed by a heavy object	Sprain, bruise, death
6		Stoplog operation lowering	Falling from a height or being crushed by a heavy object	Sprain, bruise, death
7		Stoplog and conduit inspection	Slip	Sprain, bruise

Table 1. Identification of Occupational Health and Safety Hazards (OHS)

No	Figure	Source of Hazard	Potential Hazard	Risk
8		Monitoring of dam instrumentation	Falling from a height	Sprain, bruise
9		Dam body maintenance	Falling from a height or being scratched by a sharp object	Sprain, bruise, death
10		Sediment excavation in the boulder rack of the dam	Falling into the dam inlet channel	Drowning

Operational activities at dams expose workers to a diverse range of high-risk hazards, particularly those related to working at heights, operating heavy machinery, and navigating complex environments. Consequently, the integration of comprehensive OSH risk management, consistent implementation of safety training, utilization of appropriate PPE, and strict compliance with safe work procedures are essential components at every operational stage to mitigate the risk of injuries, occupational illnesses, and fatal incidents in the construction industry.

Risk Assessment

Risk assessment was conducted as a systematic procedure to evaluate the potential hazards associated with each work activity at the Sukamahi Dry Dam. This process is designed to assess the severity of consequences, frequency of exposure, and likelihood of incidents, thereby enabling the objective prioritization of control measures. The methodology employed in this study adheres to the HIRA approach, which encompasses three primary assessment parameters: consequence (C), exposure (E), and likelihood (L).

These three parameters were derived from questionnaires completed by workers and field supervisors, thereby reflecting risk perceptions grounded in operational experiences. The values of C, E, and L were subsequently integrated to compute the basic risk (BR), which was then categorized into a risk level (LR) to ascertain the urgency of implementing control measures. The comprehensive results of the risk assessment are presented in Table 2.

Table 2 indicates that most activities related to the installation of electrical networks, operation of crane hoists, and handling of stoplogs have BR values of 100 and are classified under the "Substantial" risk category. This classification underscores the significant potential hazards associated with these activities, which may lead to severe injuries, including falls from heights, electric shocks, and impacts from heavy objects. Given this level of risk, it is imperative to implement both technical and administrative control measures promptly to prevent fatal accidents.

Conversely, activities such as stoplog and conduit inspections have been assigned BR values of 15, categorizing them as "Acceptable." However, it remains crucial to implement safe working procedures to prevent any escalation of risk owing to environmental changes or human error. In contrast, other activities, including dam instrumentation monitoring, dam structure maintenance, and sediment excavation work in the boulder rack area, were assigned BR values of 63, placing them in the "Priority 3" category. These activities pose a moderate level of risk and require consistent control and monitoring, although they are not as urgent as those classified under the "Substantial" category.

Table 2. Results of Risk Assessment Based on HIRA











No	Figure	Source of Hazard	Risk	Value				
				C	E	L	BR	LR
1		Installation of electrical wiring, crane hoists, and stoplogs	Electrocution and falls from elevations	100.0	1.0	1.0	100.0	Substantial
2		Crane hoist motor installation	Falling from a height or being struck by heavy equipment	100.0	1.0	1.0	100.0	Substantial
3		Connecting the stoplog to the crane hoist	Falling from a height or being trapped by a metal object	100.0	1.0	1.0	100.0	Substantial
4		Stoplog lifting operation	Falling from a height or being crushed by a heavy object	100.0	1.0	1.0	100.0	Substantial
5		Stoplog shifting operation	Falling from a height or being crushed by a heavy object	100.0	1.0	1.0	100.0	Substantial
6		Stoplog lowering operation	Falling from a height or being crushed by a heavy object	100.0	1.0	1.0	100.0	Substantial
7		Stoplog and conduit inspection	Slip	15.0	1.0	1.0	15.0	Acceptable
8		Monitoring of dam instrumentation	Falling from a height	7.0	3.0	3.0	63.0	Priority 3

Table 2. Results of Risk Assessment Based on HIRA

No	Figure	Source of Hazard	Risk	Value				
				C	E	L	BR	LR
9		Dam body maintenance	Falling from a height or being scratched by a sharp object	7.0	3.0	3.0	63.0	Priority 3
10		Sediment excavation in the boulder rack of the dam	Falling into the dam inlet channel	7.0	3.0	3.0	63.0	Priority 3

The findings of this risk assessment serve as a crucial foundation for dam managers to prioritize OSH initiatives. It is imperative to focus on high-risk activities, which require enhancing SOPs, providing appropriate PPE, and developing workers' skills through regular training. Concurrently, medium- and low-risk activities require ongoing management to ensure that the work environment remains safe and stable over the long term.

Assessment of Potential Hazard Classification

Potential hazards were classified to categorize sources of danger based on their characteristics and causes. This classification was derived from the identification and risk assessment results of all work activities at the Sukamahi Dry Dam. The categorization of hazards aligns with the primary groups commonly utilized in occupational safety studies—namely work attitude, work procedures, workplace, and the physical work environment. This classification aids in more specific mapping of accident-causing factors, thereby enabling the design of more accurately targeted control measures.²⁰

a. Work Attitude

This category encompasses potential hazards associated with worker behavior, including noncompliance with PPE usage, engagement in unsafe work practices, and execution of tasks that deviate from established work procedures.

b. Work Procedures

Hazards in this category arise from work systems or operational phases that inherently pose risks to worker safety. The absence of appropriate procedures, unavailability of standard operating procedures (SOPs), or implementation of non-standardized work practices can substantially increase the risk of harm.

c. Workplace

Potential physical hazards in the work environment include confined spaces, unstable areas, restricted access, and surface conditions that may lead to slips or loss of balance.

d. Physical Work Environment

This category encompasses environmental conditions that may influence worker safety and comfort, including temperature, air quality, noise levels, lighting intensity, and work surface configuration. These factors can increase the risk of accidents if not adequately managed.

Table 3 indicates that most hazard sources in the dry dam area are categorized as having a substantial risk level, particularly those associated with work procedures and attitudes. Activities such as installing crane hoist components; operating cranes; and lifting, shifting, and lowering the stoplog are included in this category because they involve working at heights and interaction with heavy equipment. The primary consequences include falls from heights, being struck by heavy objects, and electric shock, all of which necessitate immediate control measures if a work-related risk materializes.

Table 3. Classification of Potential Hazards

No	Source of Hazard	Potential Hazards	Risk Level	Hazard Classification
1	Installation of electrical wiring, crane hoists, and stoplogs	Electrocution and falls from elevations	Substantial	Standard Operating Procedures
2	Crane hoist motor installation	Falling from a height, being struck by heavy equipment	Substantial	Standard Operating Procedures
3	Connecting the stoplog to the crane hoist	Falling from a height, being trapped by a metal object	Substantial	Standard Operating Procedures
4	Stoplog lifting operation	Falling from a height, being crushed by a heavy object	Substantial	Working Postures
5	Stoplog shifting operation	Falling from a height, being crushed by a heavy object	Substantial	Working Postures
6	Stoplog lowering operation	Falling from a height, being crushed by a heavy object	Substantial	Working Postures
7	Stoplog and conduit inspection	Slip	Acceptable	Physical Work Environment
8	Monitoring of dam instrumentation	Falling from a height	Priority 3	Physical Work Environment
9	Dam body maintenance	Falling from a height, being scratched by a sharp object	Priority 3	Physical Work Environment
10	Sediment excavation in the boulder rack of the dam	Falling into the dam inlet channel	Priority 3	Standard Operating Procedures

Furthermore, several activities—including stoplog inspection, instrumentation monitoring, and dam body maintenance—were classified as having a priority of 3 or an acceptable risk level, with hazard sources primarily originating from the physical work environment. Factors such as slippery work floors, confined spaces, and steep or unstable terrain increase the risk of accidents, including slips and falls.

This classification of hazard potential serves as a critical foundation for developing risk control strategies. By specifically identifying the root causes of hazards, management can ascertain the most appropriate interventions, whether through improvements in work behavior, refinement of standard operating procedures, modification of the work environment, or enhancement of the supervision system, to prevent workplace accidents.

Hazard Control

The management of OHS hazards at Dry Dam Sukamahi is carried out by evaluating the urgency and risk characteristics of each operational activity. This approach seeks to minimize potential hazards by implementing control strategies that adhere to a risk control hierarchy. Given the nature of the work, which involves mechanical and electrical activities as well as direct interaction with the dry dam structure, risk mitigation efforts focus on technical and administrative controls and the use of PPE.

Overall, Table 4 indicates that eliminating or substituting hazards is currently infeasible, as all work stages are essential components of dry dam operation. Consequently, risk management focuses on engineering controls, administrative controls, and personal protective measures. Engineering controls include the use of standardized operational equipment, deactivation of electrical power sources during installation, and scheduling work hours to minimize exposure to extreme environmental conditions such as high temperatures or heavy rainfall. This strategy is consistent with engineering-based risk mitigation recommendations for the operation of hydrological infrastructure. Administratively, all activities must adhere to SOPs designed to ensure the consistent application of safe working practices. The SOPs encompass maintenance procedures; equipment inspections; instrumentation monitoring; and the operation of lifting, shifting, and lowering the stoplogs. Various engineering safety studies have demonstrated the efficacy of SOPs in mitigating human-error risks in high-risk work environments.

Furthermore, the use of PPE, including gloves, safety helmets, body harnesses, safety boots, and life jackets, is obligatory for activities that pose a risk of falling into the water. Although PPE is positioned at the lowest tier in the hierarchy of controls, it remains an essential component for tasks involving mechanical loads, lifting systems, and potential exposure to water at dry dams. This systematic control strategy is intended to reduce the probability of injuries—including sprains, bruises, burns from electrical contact, and even fatalities—during stoplog operations. The consistent application of controls

at each stage of work facilitates the attainment of an acceptable level of safety, in alignment with risk management principles for flood control infrastructure such as dry dams.^{15,21}

Table 4. The Results of Hazard Control

No	Source of Hazard	Risk	Hazard Control
1	Installation of electrical wiring, crane hoists, and stoplogs	Electrocution and falls from elevations	<ul style="list-style-type: none"> - Elimination: none - Substitution: none - Technical controls: switch off the switch during the installation process - Administrative controls: create SOP for work - PPE: gloves, helmet, body harness, boots
2	Crane hoist motor installation	Falling from a height or being struck by heavy equipment	<ul style="list-style-type: none"> - Elimination: none - Substitution: none - Technical control: use standardized operating equipment - Administrative control: create SOP - PPE: gloves, helmets, body harnesses, boots
3	Connecting the stoplog to the crane hoist	Falling from a height or being trapped by a metal object	<ul style="list-style-type: none"> - Elimination: none - Substitution: none - Technical control: use standardized operating equipment - Administrative control: create SOP - PPE: gloves, helmets, body harnesses, boots
4	Stoplog lifting operation	Falling from a height or being crushed by a heavy object	<ul style="list-style-type: none"> - Elimination: none - Substitution: none - Technical control: use standardized operating equipment - Administrative control: create SOP - PPE: gloves, helmets, body harnesses, boots
5	Stoplog shifting operation	Falling from a height or being crushed by a heavy object	<ul style="list-style-type: none"> - Elimination: none - Substitution: none - Technical control: use standardized operating equipment - Administrative control: create SOP - PPE: gloves, helmets, body harnesses, boots
6	Stoplog lowering operation	Falling from a height or being crushed by a heavy object	<ul style="list-style-type: none"> - Elimination: none - Substitution: none - Technical control: use standardized operating equipment - Administrative control: create SOP - PPE: gloves, helmets, body harnesses, boots
7	Stoplog and conduit inspection	Slipping	<ul style="list-style-type: none"> - Elimination: none - Substitution: none - Technical control: none - Administrative control: create SOP - PPE: gloves, helmets, body harnesses, boots
8	Monitoring of dam instrumentation	Falling from a height	<ul style="list-style-type: none"> - Elimination: none - Substitution: none - Technical control: ensure that work is not performed during the day/in hot sun or in rainy conditions - Administrative control: create SOP - PPE: gloves, helmets, body harnesses, boots
9	Dam body maintenance	Falling from a height or being scratched by a sharp object	<ul style="list-style-type: none"> - Elimination: none - Substitution: none - Technical control: ensure that work is not performed during the day/in hot sun or in rainy conditions - Administrative control: create SOP - PPE: gloves, helmets, body harnesses, boots

Table 4. The Results of Hazard Control

No	Source of Hazard	Risk	Hazard Control
10	Sediment excavation in the boulder rack of the dam	Falling into the dam inlet channel	<ul style="list-style-type: none"> - Elimination: none - Substitution: none - Technical control: ensure that excavation work is not performed during the rainy season - Administrative control: create SOP - PPE: life jackets

DISCUSSION

Most operational activities at the Sukamahi Dry Dam are classified as having substantial risk, with a BR score of 100. High-risk tasks include lifting, lowering, and shifting stoplogs using a crane hoist, as well as activities with the potential for falls from heights. Although the probability and exposure levels are relatively low, the high severity of potential incidents results in significant overall risk. According to AS/NZS 4360:2004, activities with risk scores exceeding 70 require immediate mitigation without awaiting senior management intervention. In the field, the lack of permanent fall protection such as lifelines, anchor points, or guardrails increases the likelihood of serious injury or fatality, while crane hoists lack up-to-date technical inspection documentation and have not undergone regular load testing as mandated by Permenaker No. PER.01/MEN/1980.

OHS implementation at Sukamahi Dam does not fully comply with national standards, including Permen PUPR No. These findings are consistent with studies conducted at the Jragung Dam, which indicate that the absence of HIRA and written SOPs contributes to higher accident rates during embankment and heavy equipment operations, while low PPE compliance is closely related to insufficient direct supervision and limited SOP dissemination.¹² These findings are consistent with studies conducted at Jragung Dam, which indicate that the absence of HIRA and written SOPs contributes to higher accident rates during embankment and heavy equipment operations, while low PPE compliance is closely related to insufficient direct supervision and limited SOP dissemination.¹² The International Labour Organization (ILO) emphasizes the importance of a preventive culture, active worker engagement, regular training, and technological integration to establish an effective OHS system, particularly for high-risk tasks such as water infrastructure management.²³

Deficiencies in OHS implementation endanger workers and have broader implications for flood control systems and public health. The Sukamahi Dam is critical infrastructure designed to regulate water flow in Jakarta, and operational disruptions caused by accidents or technical negligence could compromise its functionality, increase the risk of downstream flooding, and expose the population to waterborne diseases, such as leptospirosis, diarrhea, and skin infections. Improperly managed workplace accidents also exacerbate the health burden on the workforce and reduce public-sector productivity. From an occupational public health perspective, these conditions reflect a lack of integration between OHS systems and environmental risk management, despite their interrelated roles in safeguarding community health.

The analysis of the underlying causes of low OHS effectiveness at the Sukamahi Dam revealed several key factors. First, worker training was limited to a single initial session, leaving technical knowledge outdated. Second, the absence of written SOPs and risk maps, particularly for heavy equipment maintenance and high-risk work areas, undermined the functionality of the OHS management system. Third, the lack of permanent OHS personnel meant that supervision was performed on an ad hoc basis by the operational unit head, who also carried administrative responsibilities. Fourth, budget constraints delayed requests for additional training, new PPE, and equipment maintenance. Finally, a non-preventive work culture persisted, with some workers perceiving accidents as an inherent part of the job.

Based on these findings, several recommendations are proposed to strengthen OHS during the operational phase of the dam. Periodic OHS training should be conducted at least twice annually, covering topics such as lockout-tagout (LOTO), heavy equipment operation, working at heights, and emergency response procedures. Risk-based SOPs should be developed and complemented by visual risk maps at all high-risk locations. The placement of certified permanent OHS personnel with a stop-work authority is essential for direct supervision. Digital systems for equipment monitoring, daily reporting, and integration with management dashboards can enhance transparency and accountability.

Quarterly internal audits of PPE use, equipment readiness, and SOP compliance, alongside periodic external audits by BBWSSC or other independent agencies, are necessary to ensure system sustainability. Emergency evacuation routes and assembly points should be marked with permanent signage, and crane hoists and other heavy equipment must undergo independent inspections and load testing every three months. Annual emergency response drills for all personnel are also recommended. Implementing these measures is expected to improve OHS performance at the Sukamahi Dam, reduce the risk of workplace accidents, and maintain the reliability of flood control systems.

CONCLUSION

The OHS system implemented in the operations of the Sukamahi Dry Dam has not yet achieved compliance with the normative standards set by national regulations and international best-practice guidelines. A hazard identification and risk assessment conducted using the HIRA method indicates that six out of ten primary operational activities—including the installation of the crane hoist electrical network; crane motor installation; and the lifting, shifting, and lowering of stoplogs—have BR risk index values of 100, categorized as substantial, and pose potential fatal risks, such as falls from heights, electric shock, and being struck by heavy loads.

Inspection activities related to stoplogs and conduits were associated with a BR value of 15, which was deemed acceptable. In contrast, three other activities—namely instrument monitoring, dam body maintenance, and sediment excavation—each exhibited a BR value of 63, categorized as Priority 3. Notably, 60% of activities were classified as having substantial risk, whereas only 10% fell within the acceptable range. This distribution indicates that the OHS conditions at the site present a high risk profile and have not been effectively managed. The findings suggest that current mitigation efforts predominantly rely on administrative controls and lack sufficient technical measures, such as permanent fall protection systems, regular inspections of lifting equipment, or risk-based SOPs. The absence of regular training, dedicated OHS personnel, and comprehensive risk evaluation documentation further underscores that the OHS system remains reactive rather than preventive. This situation not only increases the risk of accidents among workers but also threatens the operational integrity of the Sukamahi Dry Dam as flood control infrastructure, with significant implications for the safety of downstream communities.

Given these findings, it is imperative to enhance the OHS management system as a strategic priority. Recommended actions include establishing a dedicated OHS unit, developing SOPs based on HIRA values, conducting training sessions at least biannually, completing regular inspections and testing of heavy equipment, providing permanent fall protection systems, and integrating real-time monitoring technology for equipment conditions and work activities. The implementation of these measures is anticipated to reduce high-risk activities, strengthen the safety culture, and ensure the operational reliability of the Sukamahi Dry Dam, a critical component of the flood mitigation system and public health protection plan.

ETHICS APPROVAL

This study involved human participants through interviews with dam management personnel. Ethical approval was obtained prior to conducting the research, and all participants provided informed consent before participating in the interviews. The study was conducted in accordance with applicable ethical standards to ensure confidentiality and voluntary participation.

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COMPETING INTEREST

All authors declare that there are no conflicts of interest.

FUNDING

This study received no external funding.

UNDERLYING DATA

The data supporting the findings of this study were derived primarily from structured interviews conducted with dam management personnel. The collected qualitative data were analyzed and interpreted to support the research objectives.

DECLARATION OF ARTIFICIAL INTELLIGENCE USE

This article includes the use of artificial intelligence (AI) tools in the following capacity:

Manuscript writing support: AI was used solely for language refinement and grammatical editing during the manuscript preparation process. AI tools were not used for data collection, data analysis, visualization, interpretation of results, simulation, forecasting, or generation of scientific conclusions. All scientific content, analysis, and findings presented in this study were developed independently by the authors.

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