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Analysis of Occupational Safety and Health Risks at Accident-Prone Beach Tourism Sites in Bangka Regency

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ABSTRACT

Background: Beach tourism involves occupational safety and health (OSH) hazards that may result in injuries, illness, disability, or death among tourists and tourism workers. This study aimed to assess OSH risks in beach tourism areas in Bangka Regency, Indonesia.
Subjects and Method: This qualitative case study was conducted at Pukan Beach, Parai Beach, Batu Belubang Beach, and Matras Beach in Bangka Regency. A total of 40 tourism workers were selected purposively as informants. Data were collected through observation, in-depth interviews, and document review. Risk assessment included hazard identification, risk analysis, risk evaluation, and risk control using the Tourism Risk Matrix and the Regulation of the Minister of Tourism No. 6 of 2025.
Results: Environmental, physical, biological, and unsafe behavioral hazards were identified across the four tourism areas. The highest risks were associated with swimming, fishing, water recreation, and extreme weather exposure. Extreme risks were identified for extreme weather at Pukan Beach (risk score=12), swimming at Parai Beach (risk score=16), fishing and swimming at Batu Belubang Beach (risk scores=16 and 12, respectively), and swimming at Matras Beach, which had the highest risk score (risk score=25). Several high-risk activities required immediate control measures due to their potential for severe injury or fatality.
Conclusion: OSH risks across the beach tourism areas ranged from low to extreme, with swimming and other water-related activities representing major safety concerns. Strengthening safety facilities, warning systems, lifeguard services, emergency preparedness, and periodic risk assessment is needed to reduce risks and improve beach tourism safety.

Keywords: occupational safety, risk assessment, beach tourism, hazard identification, tourism safety

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BACKGROUND

The tourism industry is an important contributor to economic and social development worldwide, but tourism activities are also associated with occupational safety and health (OSH) risks that may cause injuries, illness, disability, and death among tourists and tourism workers. Safety and health are important components of tourism service quality because accidents and health problems experienced at destinations may influence tourist satisfaction and perceptions

of destination management (Saptadi et al., 2021). These concerns are particularly relevant in coastal and beach tourism, where visitors and tourism workers are exposed to dynamic environmental conditions such as strong currents, high waves, slippery surfaces, extreme weather, marine organisms, and uneven coastal terrain. Previous research has indicated that accidents in tourism areas may occur because of inadequate safety standards, unsafe visitor behavior, and insufficient safety management by tourism operators (Koon et al., 2023). Travel-related health problems may also occur during tourism activities, indicating that tourism safety should be understood as a multidimensional issue involving environmental, behavioral, organizational, and health-related factors (Desty et al., 2020).

At the national level, Indonesia has substantial potential for coastal tourism because of its extensive coastline and diverse marine resources. The increasing development and utilization of beach destinations provide economic opportunities for local communities but also increase exposure to safety and health hazards. Tourism accidents may result from the interaction between unsafe actions and unsafe conditions, including inappropriate visitor behavior, inadequate supervision, hazardous environmental conditions, and insufficient safety facilities (Mawafasyah and Febriyanto, 2020). In addition, health risks may emerge through interactions between individuals, causal agents, and environmental conditions, as described by the epidemiological triangle (John and Kompithra, 2023). Therefore, tourism safety management requires a systematic approach that addresses both accident prevention and health protection. Risk management provides an important framework for identifying hazards, analyzing and evaluating risks, and implementing appropriate controls. ISO 31000:2018 emphasizes systematic processes of risk identification, analysis, evaluation, treatment, monitoring, and review, while HIRARC provides a practical approach for identifying hazards and prioritizing risks according to their likelihood and consequences.

Bangka Regency, Bangka Belitung Islands Province, has considerable potential for coastal tourism because of its beaches, white sand, granite formations, and marine environment. Among the destinations, Pukan Beach, Parai Beach, Batu Belubang Beach, and Matras Beach represent important tourism areas with different physical characteristics, tourism activities, visitor patterns, and management systems. Common tourism activities include swimming, boating, fishing, beach walking, culinary tourism, entertainment activities, interaction with marine animals, and tourism workers' activities. However, these activities are accompanied by different hazards, including strong currents, high waves, slippery surfaces, extreme weather, unsafe tourist behavior, marine animal exposure, coral injuries, and inadequate safety facilities. The characteristics of each destination may influence the magnitude and type of risk. Pukan Beach is characterized by open coastal waters, seasonal waves, and relatively limited safety facilities. Parai Beach is a privately managed tourism destination with intensive recreational activities and relatively high visitor numbers. Batu Belubang Beach has rocky and coral-dominated coastal areas that increase the potential for slips, falls, cuts, and wave-related incidents. Meanwhile, Matras Beach is a public beach with an extensive coastline, mass tourism activities, relatively large waves, and potential limitations in safety supervision.

The occurrence of accidents and the presence of potential hazards in these destinations demonstrate the need for systematic OSH risk assessment. Previous reports have documented incidents involving tourists

being swept away by waves, near-drowning, injuries associated with coastal environments, and sudden medical emergencies. Matras Beach, for example, experienced a fatal incident involving a child who was swept away by waves in 2023. Parai Beach has also experienced incidents involving visitors being carried away by waves while swimming, although they were successfully evacuated. Batu Belubang Beach presents particular concerns related to fishing and its rocky and coral coastal environment. Meanwhile, the absence of widely reported accidents at Pukan Beach cannot be interpreted as an absence of risk because hazards may remain undetected or underreported. Differences in management systems among the four beaches are also important because the availability of safety facilities, SOPs, trained personnel, supervision, and emergency preparedness may influence the effectiveness of risk control.

Previous studies have demonstrated the importance of systematic safety management in tourism destinations. Saptadi et al. (2021) emphasized the importance of OSH risk management in tourism areas, particularly through systematic hazard identification, risk assessment, and risk control. Zhu et al. (2023) further highlighted the role of rip currents, wave dynamics, and public awareness in beach drowning prevention. Manuele (2020) emphasized that effective safety management should combine hazard identification, risk assessment, and multiple layers of control rather than relying exclusively on individual behavior. In Bangka Regency, Veleriani et al. (2024) highlighted the potential for sustainable, community-based beach tourism development through community capacity building, infrastructure improvement, and adaptive coastal planning. These studies demonstrate that environmental conditions, human behavior, organizational capacity, and safety management are interconnected factors in tourism safety.

However, previous studies have generally focused on individual tourism destinations, specific hazards, accident prevention, or sustainable tourism development. Limited evidence is available on a comprehensive comparative assessment of OSH risks across multiple accident-prone beach tourism destinations within Bangka Regency. In particular, there remains a need to understand how differences in coastal characteristics, tourism activities, and management systems influence hazard patterns, risk levels, risk acceptability, and control priorities. This gap is important because safety interventions that are effective in one beach may not necessarily be appropriate for another destination with different environmental and organizational characteristics. A destination-specific and comparative risk assessment is therefore needed to provide evidence for prioritizing interventions and strengthening tourism safety management.

The present study addresses this gap by applying a HIRARC-based approach to four accident-prone beach tourism destinations in Bangka Regency: Pukan Beach, Parai Beach, Batu Belubang Beach, and Matras Beach. The study integrates hazard identification, risk analysis, risk evaluation, and risk control while considering hazards affecting tourism activities and tourism workers. The comparative approach enables the identification of activities with the highest risk levels and the development of control measures that are appropriate to the characteristics of each destination. This approach is expected to provide practical evidence for strengthening safety facilities, supervision, emergency preparedness, and OSH management in coastal tourism.

Therefore, this study aimed to analyze occupational safety and health risks in accident-prone beach tourism destinations in Bangka Regency. Specifically, the study sought to identify hazards associated with

tourism activities, analyze and evaluate their risk levels, determine activities requiring priority intervention, and formulate appropriate risk control measures for Pukan Beach, Parai Beach, Batu Belubang Beach, and Matras Beach. The findings are expected to support tourism managers and local authorities in developing destination-specific safety management strategies and improving the protection of both tourists and tourism workers.

SUBJECTS AND METHOD

1. Study Design

This study employed a qualitative case study design. The research was conducted at Pukan Beach, Parai Beach, Batu Belubang Beach, and Matras Beach in Bangka Regency during 2026. The four beaches were purposively selected because they represent coastal tourism destinations with distinct physical characteristics, tourism activities, and levels of accident risk, making them appropriate settings for investigating occupational safety and health risk management in beach tourism. Pukan Beach is characterized by open coastal waters, relatively strong seasonal waves, and limited safety facilities. Parai Beach is a privately managed commercial tourism destination offering comprehensive tourism facilities, intensive swimming and water recreation activities, and a high volume of visitors; however, it has also experienced accidents associated with strong sea currents and unsafe tourist behavior.

Batu Belubang Beach is characterized by rocky and coral-dominated coastal terrain, presenting a high risk of physical injuries, slips, falls, and wave-related accidents. In contrast, Matras Beach is a public beach with an extensive coastline, mass tourism activities, relatively large waves, and an increased potential for accidents due to high visitor density and limited safety supervision. The diversity of environmental characteristics, tourism activities, and management systems across these four beaches enabled a comprehensive comparison of occupational safety and health risks in accident-prone coastal tourism destinations.

2. Population and Sample

The study population consisted of tourism workers operating at the selected coastal tourism destinations. A purposive sampling technique was employed to recruit participants who were directly involved in the management and daily operational activities of each beach tourism destination and possessed relevant knowledge and experience regarding occupational safety and health (OSH) practices. A total of 40 respondents participated in the study, comprising 10 respondents from each beach destination. At each study site, the respondents consisted of one beach management coordinator (Head of Beach Management) and nine tourism workers.

3. Research Variables

The variables investigated included hazard identification, risk analysis, risk evaluation, and risk control of occupational safety and health risks in beach tourism activities.

4. Operational Definition

Hazard/risk identification referred to the process of recognizing potential sources of harm during tourism activities.

Risk analysis referred to the assessment of likelihood and severity of hazards.

Risk evaluation referred to the determination of risk acceptability.

Risk control referred to measures implemented to reduce or eliminate identified risks.

5. Study Instruments

Data were collected using observation checklists, interview guidelines, field notes, and documentation review based on the Minister of Tourism Regulation No. 6 of 2025.

6. Data Analysis

Data were analyzed using qualitative content analysis. Hazard identification and risk

assessment were conducted through a risk matrix approach combining likelihood and severity scores to determine risk levels.

7. Research Ethics

Ethical principles including confidentiality, anonymity, and informed consent were applied throughout the research process. Ethical approval was obtained from the authorized ethics committee before data collection. The research ethical clearance approval letter was obtained from the Health Research Ethic Committee at Poltekkes Kemenkes Semarang, Semarang, Indonesia, No. 165/EA/F.XXIII.38/2026, on February 11, 2026.

RESULTS

1. Sample Characteristics

A total of 40 tourism workers participated in this study. Respondents were equally distributed across the four study sites, including Pukan Beach, Parai Beach, Batu Belubang Beach, and Matras Beach, with 10 respondents recruited from each location (Table 1). This equal distribution was intended to ensure balanced representation of tourism workers from each beach destination, thereby facilitating a comprehensive assessment and comparison of occupational safety and health (OSH) risks across the study sites.

Table 1. Sample Characteristics of Tourism Workers

Study Site	Pukan Beach	Parai Beach	Batu Belubang Beach	Matras Beach
Length of Employment				
<7 Years	6	5	6	5
≥7 Years	4	5	4	5
Position				
Tourism Workers	9	9	9	9
Head of Management	1	1	1	1

2. Hazard/Risk Identification

Table 2 summarizes the main hazards and potential consequences associated with beach tourism activities. Water-based activities, including swimming, boating, and fishing, were associated with hazards such as strong currents, high waves, extreme weather, equipment failure, slippery rocks, and sharp coral. These hazards may result in drowning, capsizing, falls, lacerations, injuries, and fatalities. Other tourism activities presented different safety concerns. Beach walking was associated with slippery surfaces and uneven terrain, while marine animal interaction involved exposure to jellyfish, sea urchins, and other marine animals, potentially resulting in stings, allergic reactions, and injuries. Culinary and entertainment activities were associated with poor food hygiene, hot equipment, crowd density, and environmental exposure, with potential consequences including foodborne illness, burns, minor injuries, and fatigue.

Tourism work activities also involved occupational hazards, including heat exposure, sharp tools, heavy lifting, and long working hours, which may contribute to heat stress, occupational injuries, and fatigue. In addition, extreme weather exposure, including heavy rain, storms, high winds, extreme heat, and lightning, represented an important environmental hazard with potentially serious consequences, such as heat-related illness, hypothermia, lightning injury, and fatality. Overall, the identified hazards varied according to the type of tourism activity and exposure, indicating the need for activity-specific risk assessment and appropriate safety control measures.

Table 2. Main Hazards Identified in Tourism Activities at Accident-Prone Beaches

Tourism Activity/ Exposure	Identified Hazards	Potential Consequences
Swimming	Strong currents, high waves, unsafe tourist behavior	Drowning, injury, fatality
Boating	High waves, extreme weather, equipment failure	Capsizing, injury
Fishing	Slippery rocks, strong currents, sharp coral	Falls, drowning, lacerations
Culinary activities	Poor food hygiene, hot equipment	Foodborne illness, burns
Entertainment activities	Crowd density, environmental exposure	Minor injuries, fatigue
Beach walking	Slippery surfaces, uneven terrain	Slips, falls, minor injuries
Marine animal interaction	Jellyfish, sea urchins, other marine animals	Stings, allergic reactions, injuries
Tourism work activities	Heat exposure, sharp tools, heavy lifting, long working hours	Heat stress, occupational injuries, fatigue
Extreme weather exposure	Heavy rain, storms, high winds, extreme heat, lightning	Heat-related illness, hypo-thermia, lightning injury, fatality

3. Risk Analysis

In Table 3, the risk analysis showed considerable variation in risk levels across tourism activities and study sites. Swimming presented some of the highest risk levels, with the highest overall risk score recorded at Matras Beach (risk score=25; extreme), followed by Parai Beach (risk score=16; extreme) and Batu Belubang Beach (risk score= 12; high). In contrast, swimming at Pukan Beach was classified as low risk (risk score= 4).

Fishing activities also varied across the four beaches. The highest risk was identified at Batu Belubang Beach (risk score=16; extreme), while fishing at Pukan and Matras Beaches was classified as high risk (risk score=12). At Parai Beach, fishing was categorized as moderate risk (risk score=6). Boating was consistently classified as high risk across all study sites, with risk scores of 12 at Pukan, Parai, and Matras Beaches and 9 at Batu Belubang Beach.

Among other activities, beach walking and tourism work activities were consistently classified as high risk across all four beaches, with scores ranging from 9 to 12. Extreme weather exposure was also categorized as high risk at all study sites, with a risk score of 12 at Pukan and Batu Belubang Beaches and 9 at Parai and Matras Beaches. Culinary and entertainment activities generally showed low to moderate risk levels. Marine animal interaction ranged from low to high risk, with the highest risk identified at Batu Belubang Beach (risk score=12; high), while the corresponding risk was moderate at Pukan and Parai Beaches (risk score=6) and low at Matras Beach (risk score=4).

Overall, the highest risk levels were identified for swimming at Matras and Parai Beaches and fishing at Batu Belubang Beach, all of which were classified as extreme risk. Several other activities, including boating, beach walking, tourism work activities, and extreme weather exposure, consistently remained within the high-risk category. These findings indicate that risk control measures should prioritize activities classified as extreme and high risk, particularly through appropriate safety facilities, hazard communication, supervision, emergency preparedness, and activity-specific preventive measures.

Table 3. Highest Risk Scores Identified by Beach and Tourism Activity

Activity	Pukan		Parai		Batu Belubang		Matras	
	Score	Category	Score	Category	Score	Category	Score	Category
Swimming	4	Low	16	Extreme	12	High	25	Extreme
Boating	12	High	12	High	9	High	12	High
Fishing	12	High	6	Moderate	16	Extreme	12	High
Culinary activities	4	Low	6	Moderate	4	Low	6	Moderate
Entertainment activities	4	Low	6	Moderate	4	Low	4	Low
Beach walking	9	High	9	High	12	High	12	High
Marine animal interaction	6	Moderate	6	Moderate	12	High	4	Low
Tourism work activities	9	High	9	High	9	High	12	High
Extreme weather exposure	12	High	9	High	12	High	9	High

4. Risk Evaluation

Risk evaluation indicated that several identified hazards required immediate intervention because they were classified as high and extreme risk, reflecting an unacceptable level of occupational safety and health (OSH) risk. Extreme-risk activities were predominantly associated with water-based tourism, particularly swimming at Matras Beach (R = 25), swimming at Parai Beach (R = 16), fishing and swimming at Batu Belubang Beach (R = 16 and R= 12), and extreme weather exposure at Pukan Beach (R = 12). These activities presented the greatest potential for serious injuries or fatalities due to strong waves, rip currents, slippery rocky surfaces, rapidly changing weather conditions, and inadequate safety management systems. The evaluation further demonstrated that the absence of sufficient lifeguards, limited safety equipment, incomplete standard operating procedures (SOPs), and insufficient budget allocation for safety programs significantly contributed to the elevated risk levels across the study sites.

Activities classified as high risk, including boat tours, beach walking, tourism worker activities, and fishing in several locations, required immediate corrective actions because existing control measures were insufficient to reduce risks to an acceptable level. Engineering controls, administrative improvements, enhanced supervision, and increased availability of safety facilities are therefore necessary to minimize the likelihood of accidents. Meanwhile, activities categorized as moderate risk, such as interaction with marine animals, culinary tourism at Parai Beach, and recreational beach walking in lower-exposure areas, required continued management attention through routine supervision, safety education, and periodic review of control measures.

In contrast, culinary tourism and entertainment attractions at most study locations were generally classified as low risk because they involved limited exposure to hazardous coastal environments and existing control measures were considered adequate to maintain acceptable safety conditions. Nevertheless, routine monitoring and continuous improvement remained necessary to ensure that these activities continued to meet occupational safety and public health standards (Table 4). Overall, the risk evaluation demonstrated that the level of risk varied according to the characteristics of each tourism activity and beach environment. Water-based tourism activities consistently represented the highest OSH risks across all

four beaches and should therefore receive the highest priority for risk control, continuous safety monitoring, and systematic implementation of the HIRARC-based safety management system.

Table 4. Distribution of Risk Evaluation by Activity Category

Risk Category	Description	Activities Commonly Included
Low	Routine monitoring required. Existing control measures are generally adequate; periodic inspection and continuous monitoring should be maintained to ensure risks remain at an acceptable level.	Culinary tourism, entertainment attractions, and other low-exposure tourism activities (Pukan, Batu Belubang, and Matras Beaches).
Moderate	Management attention required. Additional preventive measures, safety education, and routine supervision are needed to prevent risks from increasing.	Beach walking, interaction with marine animals, fishing and culinary tourism at Parai Beach, and other activities with moderate exposure.
High	Immediate corrective actions required. Existing controls are insufficient; engineering and administrative controls should be strengthened before activities continue.	Boat tours at Pukan, Parai, and Matras Beaches; beach walking at Pukan, Batu Belubang, and Matras Beaches; tourism worker activities at Pukan, Parai, and Matras Beaches; extreme weather at Parai Beach; swimming at Batu Belubang Beach.
Extreme	Immediate intervention and comprehensive risk control required. Activities should be suspended or strictly restricted until effective control measures are implemented because the risk is unacceptable.	Swimming at Matras Beach (R = 25); swimming at Parai Beach (R = 16); fishing and swimming at Batu Belubang Beach (R = 16); extreme weather at Pukan Beach (highest-priority hazards); fishing at Matras Beach where risk remained high and required immediate intervention.

5. Risk Control

Risk control at Pukan Beach should prioritize hazards classified as high and extreme risk through a combination of engineering, administrative, and management measures. These include installing an early warning system (EWS), weather information boards, evacuation route signage, assembly points, safety barriers, and adequate safety equipment such as life jackets, lifebuoys, first aid facilities, and personal protective equipment (PPE). Administrative controls should focus on developing and implementing standardized Standard Operating Procedures (SOPs) for all tourism activities, including weather emergency procedures, routine safety inspections, mandatory safety briefings before boating activities, regular monitoring of weather conditions, supervision of high-risk activities, and periodic emergency drills. In addition, continous safety education should be provided to tourists and tourism workers to improve awareness of coastal hazards and emergency response. Adequate financial support is also required to ensure the procurement and maintenance of safety facilities, implementation of OSH programs, and regular monitoring and evaluation. Collectively, these control measures are expected to strengthen the occupational safety and health management system and reduce the likelihood of

accidents and work-related health risks at Pukan Beach.

Risk control at Parai Beach should prioritize hazards associated with high- and extreme-risk activities, particularly swimming, boating, walking along the beach, tourism workers' activities, and extreme weather conditions. Control measures should include strengthening engineering controls through the installation of additional warning signs, sea condition flags, lifeguard towers, ring buoys, life jackets, first aid facilities, safe walking routes, safety barriers, and an early warning system for adverse weather conditions. Administrative controls should focus on developing and consistently implementing standardized Standard Operating Procedures (SOPs) for swimming area closures, boating operations, fishing activities, food safety, emergency response, and occupational safety, accompanied by routine inspections of safety equipment, mandatory safety briefings, continuous weather monitoring, and regular emergency drills. In addition, increasing the number and competency of trained lifeguards and safety personnel, providing continuous safety education for tourists, ensuring the consistent use of personal protective equipment (PPE) by tourism workers, and allocating sufficient financial resources for safety infrastructure, equipment maintenance, training, and occupational safety and health (OSH) programs are essential to strengthen the safety management system and reduce the likelihood of accidents and work-related health risks at Parai Beach.

Risk control at Batu Belubang Beach should prioritize hazards associated with extreme- and high-risk activities, particularly fishing, swimming, walking on rocky coastal areas, interacting with marine organisms, and tourism workers' activities. Control measures should include engineering controls through the establishment of designated safe fishing and swimming zones, installation of safety barriers, warning signs, evacuation routes, rescue equipment, first aid facilities, life jackets, and lifebuoys at high-risk locations. Administrative controls should focus on developing and implementing standardized Standard Operating Procedures (SOPs) for fishing, swimming, emergency response, marine animal injuries, and occupational safety, supported by routine inspections, continous supervision by trained safety personnel, regular tourist safety education, and emergency simulation exercises. The consistent use of appropriate personal protective equipment (PPE), such as non-slip footwear for workers and visitors in rocky areas and life jackets for water-based activities, should also be enforced. Furthermore, adequate financial resources are required to support the procurement and maintenance of safety facilities, personnel training, and the implementation of occupational safety and health (OSH) programs. These integrated control measures are expected to strengthen the safety management system and reduce the incidence of accidents and work-related health risks at Batu Belubang Beach.

Risk control at Matras Beach should prioritize hazards associated with extreme- and high-risk activities, particularly swimming, boating, fishing, walking along the beach, tourism workers' activities, and adverse weather conditions. Engineering controls should include the installation of additional lifeguard towers, early warning systems (EWS), evacuation routes, warning signs, sea condition flags, lifebuoys, life jackets, first aid facilities, and clearly designated safe zones for water-based activities. Administrative controls should emphasize the consistent implementation

of standardized Standard Operating Procedures (SOPs), routine monitoring of sea and weather conditions, temporary closure of hazardous areas during unsafe conditions, regular safety inspections, mandatory safety briefings, visitor capacity management, continuous safety education, and periodic emergency drills. Increasing the number and competency of trained lifeguards and ensuring the consistent use of personal protective equipment (PPE) by tourism workers and visitors participating in water activities are also essential. In addition, sufficient financial support should be allocated for maintaining safety infrastructure, upgrading rescue equipment, strengthening occupational safety and health (OSH) programs, and improving emergency preparedness. Collectively, these control measures are expected to reduce accident risks and enhance the overall safety management system at Matras Beach.

DISCUSSION

This study demonstrated that occupational safety and health (OSH) risks in beach tourism destinations differed according to the characteristics of the coastal environment, tourism activities, and the effectiveness of existing safety management systems. The HIRARC approach enabled a comprehensive assessment by systematically identifying hazards, analyzing risk levels, evaluating the acceptability of risks, and determining appropriate control measures for each beach. The findings indicate that coastal tourism safety is influenced not only by natural environmental conditions but also by organizational preparedness and visitor behavior. This finding is consistent with Chen et al. (2020), who proposed a dynamic coastal water safety risk-management system that integrates hazard identification, threshold determination, real-time assessment, and early warning. Similarly, Negara et al. (2023) emphasized that tourist safety should be an important component of tourism destination management because safety conditions influence both visitor protection and destination quality. Therefore, integrating systematic risk management into beach tourism operations is essential to minimize accidents while supporting sustainable tourism development in Bangka Regency.

Hazard identification revealed that strong currents, high waves, slippery surfaces, extreme weather conditions, unsafe tourist behavior, marine animal exposure, coral reef injuries, and inadequate safety facilities were the dominant hazards across the four beaches. These findings are consistent with studies demonstrating that environmental and hydrodynamic conditions are major contributors to coastal recreational risk. Zhang et al. (2021) identified rip currents as a primary coastal hazard and demonstrated their important contribution to variations in beach drowning statistics. Likewise, Pitman et al. (2021) reported that rip currents are a major cause of drowning on recreational beaches and found that only a small proportion of beachgoers could correctly identify rip currents in real beach conditions. More recently, Yuan et al. (2023) demonstrated that rip-current variability and associated hazard conditions can change considerably within a beach environment, reinforcing the importance of site-specific hazard monitoring. The present findings therefore suggest that hazard prevention should not only focus on improving the physical environment but also on strengthening visitor awareness, compliance with safety regulations, and continous supervision by beach management personnel.

Risk analysis demonstrated that water-based tourism activities consistently presented the highest occupational safety and health risks across the study locations. Swimming at Matras Beach produced the

highest overall risk score, while swimming at Parai Beach and fishing at Batu Belubang Beach were also classified as extreme-risk activities because of the combination of high hazard probability and severe consequences. These findings indicate that the physical characteristics of each beach, including wave height, sea currents, rocky shorelines, and visitor density, substantially influence the magnitude of risk. Koon et al. (2023) demonstrated that oceanographic conditions, including tidal characteristics, are associated with fatal drowning risk at surf beaches and have implications for beach safety management. Similarly, Chen et al. (2020) demonstrated the importance of incorporating hydrodynamic conditions into coastal recreational risk assessment and proposed real-time monitoring to support decisions regarding the opening or restriction of recreational areas. These findings support the present study by demonstrating that water-based tourism risks should be assessed according to the specific environmental characteristics of each destination rather than assuming that all beaches present equivalent levels of risk. Furthermore, the application of the ISO 31000:2018 risk assessment framework in this study demonstrates that evaluating both likelihood and consequence provides a practical basis for prioritizing occupational safety interventions in tourism settings.

The results also showed considerable variation in risk levels among the four beaches despite the similarity of tourism activities. Pukan Beach was characterized by relatively lower risks for several activities but showed an extreme level of risk associated with adverse weather conditions. In contrast, Batu Belubang Beach exhibited higher risks during fishing activities because of coral reefs, uneven rocky terrain, and slippery coastal surfaces that increased the probability of falls and drowning. These differences emphasize that environmental characteristics are important determinants of tourism safety and should be incorporated into destination-specific risk management strategies. This interpretation is supported by Uebelhoer et al. (2020), who found substantial differences in beachgoer safety knowledge and behavior at unpatrolled surf beaches and highlighted the importance of local beach conditions and the availability of safety services. In addition, Surisetty et al. (2023) demonstrated the feasibility of identifying rip-current hotspots through beach monitoring technologies, indicating that safety assessment can benefit from location-specific environmental information. Consequently, identical safety interventions may not be equally effective across different coastal tourism destinations, highlighting the need for location-specific hazard assessment and control planning.

Risk evaluation demonstrated that several identified hazards remained unacceptable because existing control measures were insufficient to reduce the risks to an acceptable level. Extreme-risk activities, particularly swimming at Matras Beach and Parai Beach, fishing at Batu Belubang Beach, and exposure to extreme weather at Pukan Beach, required immediate intervention because they presented a substantial risk of severe injury or fatality. These findings indicate that current safety management systems have not fully addressed the complexity of hazards encountered in accident-prone coastal tourism areas. Evidence from Koon et al. (2023) indicates that beach safety management needs to consider changing environmental conditions when making operational safety decisions. Furthermore, Kamstra et al. (2023) found that beach-based drowning prevention can benefit from participatory engagement with beachgoers, indicating that safety interventions should extend beyond infrastructure and involve active communication and community engagement. Therefore,

the identification of extreme risks in the present study provides an important basis for prioritizing immediate intervention and strengthening existing safety management systems.

Another important finding was that organizational factors contributed substantially to elevated risk levels across the study sites. Limited numbers of trained lifeguards, inadequate rescue equipment, incomplete standard operating procedures, and insufficient financial support for safety programs reduced the effectiveness of hazard prevention and emergency response. This finding is supported by Koon et al. (2020), who emphasized the importance of lifeguard data for beach safety operations, drowning prevention, and understanding beach hazards. Furthermore, Sonmez et al. (2020) demonstrated that lifeguard drowning-detection performance can decline over time and is influenced by factors such as bather numbers and the duration of a drowning event, emphasizing the importance of adequate staffing, vigilance, and competency. The importance of organizational capacity is also consistent with Tastam and Goksal (2020), identified occupational safety and health risks among tourism workers and highlighted the need to address multiple workplace risk factors. These findings indicate that improving organizational capacity is equally important as addressing natural hazards in reducing accident risks. Consequently, tourism managers should adopt a comprehensive occupational safety management system that integrates planning, implementation, monitoring, staff competency development, and continuous evaluation.

The proposed risk control measures focused on implementing engineering controls, administrative controls, emergency preparedness, and continuous safety education. Engineering improvements such as lifeguard towers, warning signs, evacuation routes, early warning systems, designated swimming zones, rescue equipment, and first-aid facilities were identified as priority interventions for reducing exposure to hazards. Administrative measures, including standardized standard operating procedures (SOPs), routine inspections, weather monitoring, visitor capacity management, emergency drills, and regular safety briefings, are equally important for strengthening preventive efforts. According to Manuele (2020), combining engineering controls with administrative measures provides greater effectiveness than relying solely on individual behavior because hazards are controlled at multiple levels. Therefore, integrating both approaches is expected to reduce accident frequency and improve emergency preparedness across all beach tourism destinations.

An important contribution of this study is the application of the HIRARC framework to occupational safety management in Indonesian beach tourism destinations. Previous tourism safety studies have generally focused on accident occurrence or visitor safety, whereas the present study provides a more comprehensive assessment by integrating hazard identification, risk analysis, risk evaluation, and risk control for both tourists and tourism workers. In addition, comparing four beaches with different environmental characteristics demonstrated that occupational safety risks vary considerably depending on local geographical conditions, tourism activities, and management practices. These findings provide practical evidence that risk management strategies should be tailored to the characteristics of each tourism destination rather than applying standardized interventions uniformly across all beaches. Such an approach may improve the effectiveness of safety programs while supporting sustainable tourism management.

The relationship between environmental change and tourism safety also

deserves attention, particularly because extreme weather can alter the exposure and vulnerability of coastal tourism destinations. Scott (2021) emphasized that climate change increasingly affects tourism-sector planning, investment, operations, and destination preparedness. Similarly, Kurleto (2022) discussed the increasing challenges that climate change presents for tourism management and emphasized the importance of risk-management and recovery strategies. These perspectives strengthen the interpretation of the present findings, particularly the extreme risk associated with adverse weather conditions at Pukan Beach. Consequently, beach tourism managers should incorporate weather and climate-related hazards into routine risk assessments and establish clear criteria for restricting or suspending tourism activities during hazardous conditions.

This study has several limitations that should be considered when interpreting the findings. The qualitative case study design focused on four beach tourism destinations in Bangka Regency, which may limit the transferability of the results to other coastal regions with different environmental and management characteristics. Furthermore, the risk assessment was conducted during a specific observation period and may not fully capture seasonal variations in weather conditions, visitor numbers, and tourism activities that influence accident risks. Future studies are therefore recommended to incorporate longitudinal monitoring, quantitative accident surveillance data, and evaluations of implemented control measures to strengthen evidence-based tourism safety management. Despite these limitations, the present study provides valuable information for improving occupational safety and health management and supports the implementation of HIRARC as an effective framework for reducing accident risks in coastal tourism destinations.

AUTHOR CONTRIBUTION

All authors contributed to the conception and design of the study, data collection and analysis, interpretation of the findings, and preparation and revision of the manuscript. All authors reviewed and approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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