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ENVIRONMENTAL ERGONOMICS AND SUSTAINABLE RISK MANAGEMENT: ENHANCING HEALTH AND SAFETY IN MALAYSIAN WET MARKETS

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A B S T R A C T

This study examines the environmental and health challenges at Pasar Siti Khadijah, Kelantan, Malaysia using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) framework. The purpose is to systematically identify hazards, assess risks, and propose effective control measures tailored to the market's socio-cultural context. The study utilizes a mixed-methods approach, including observational surveys, structured questionnaires, and semi-structured interviews with a stratified random sample of 217 market vendors. Results reveal significant issues, such as inadequate waste management, poor ergonomic workspace design, and unsanitary conditions, which worsen foodborne illnesses, respiratory conditions, and pest infestations. These findings underline the importance of environmental ergonomics in optimizing market layouts and waste systems to reduce these risks. The findings highlight the urgent need for targeted interventions, including improved waste management systems, gender-sensitive hygiene training, and community-driven awareness campaigns. This research concludes that integrating HIRARC with environmental ergonomics, alongside cultural and demographic considerations, provides actionable strategies to enhance market sustainability, public health, and human-environment interaction. These results offer a replicable framework for managing similar risks in traditional markets across Malaysia and beyond.

1. INTRODUCTION

Wet markets are vital components of local economies and food distribution systems, serving as critical hubs for commerce and community engagement. However, they frequently grapple with significant environmental and public health challenges, including inadequate waste management, unsanitary conditions, and heightened risks of zoonotic disease transmission (Lin et al., 2021). Pasar Siti Khadijah, a cultural and economic landmark in Kelantan, exemplifies these challenges, necessitating

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effective interventions to ensure environmental and public health sustainability.

While the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) framework has proven successful in addressing risks across various industries, its application within wet market settings remains limited. Adapting HIRARC to the unique operational and cultural dynamics of Pasar Siti Khadijah could provide a structured approach to mitigate these challenges effectively. Evidence from similar frameworks highlights their potential in managing complex risks and fostering sustainable practices when tailored to specific local contexts (Young, 2024).

Environmental ergonomics focuses on optimising human interaction with environmental factors to improve safety, health, and performance in specific settings. Studies in environmental ergonomics emphasize the critical role of tailored workplace designs in mitigating occupational health risks. Insights from market environments globally suggest that ergonomic interventions, such as optimized waste disposal systems and improved ventilation, can significantly reduce respiratory illnesses and enhance worker productivity (Santoso, 2023). By examining the interface between market workers and their environment, this study adopts an environmental ergonomics perspective to address physical, biological, and behavioral challenges within Malaysian local market. By incorporating gender-sensitive, community-centered approaches, the research contributes a novel dimension to the existing literature, aligning market management with principles of public health and sustainability (Peros et al., 2021; Alves et al, 2019; Harih & Dolšak, 2014).

2. LITERATURE REVIEW

2.1 Environmental Ergonomics

Environmental ergonomics in wet market environments focuses on creating healthier, safer, and more comfortable working conditions by addressing how people interact with their surroundings. Wet markets, often bustling and densely packed, face challenges like poor ventilation, inadequate waste management, and high exposure to environmental hazards, all of which can impact the health and productivity of workers. Research shows that simple interventions, such as better waste disposal systems and improved airflow, can significantly reduce respiratory issues and create a more comfortable workspace for market workers (Papageorgiou et al., 2021). Good ventilation not only clears harmful particles from the air but also helps prevent the spread of infections, which is particularly important in crowded markets (Santoso, 2023). Additionally, managing waste more effectively such as separating and disposing of it properly, can reduce hazards and improve safety for everyone working in the market environment (Istiqomah et al., 2022). By implementing these strategies, wet markets can become not only more sustainable but also better places to work.

2.2 Lessons from Occupational Safety and Health in Other Sectors

Occupational safety and health (OSH) frameworks, such as those examined by Olanrewaju et al. (2021), underscore the importance of structured hazard assessments and community engagement to mitigate workplace risks. Their research identified systemic oversights, including improper assembly, inadequate guardrails, and weak safety cultures, as primary causes of scaffolding accidents in Malaysian construction sites. These findings parallel the challenges in wet markets, where inadequate waste management and poor sanitation practices stem from similar structural and cultural shortcomings. Lessons from the construction industry suggest that proactive measures, such as structured risk assessments and enhanced stakeholder engagement, could be effectively adapted to improve wet market safety (Olanrewaju et al., 2021; Olanrewaju et al., 2022)

2.3 Hazard Identification and Risk Control in Wet Markets: A Global Perspective

Wet markets globally face recurring challenges, including poor waste management, inadequate hygiene, and occupational health risks. Successful interventions in Southeast Asia, such as Indonesia's community-driven waste segregation initiatives and Thailand's waste-to-energy projects, have demonstrated dual benefits of environmental improvements and economic gains (Arumdani et al., 2021; Thongplew et al., 2022; Digiesi et al., 2018). Research on the microbiological safety of wooden cutting boards in Hong Kong wet markets highlights the risks of cross-contamination due to traditional hygiene practices. These findings underscore the need for revised hygiene protocols to prevent the spread of pathogenic microorganisms, reinforcing the importance of targeted interventions in wet markets (Sekoai et al., 2020).

However, many studies overemphasize technological fixes while neglecting the socio-cultural and behavioral dimensions of these issues. Thailand's waste-to-energy strategies, while promising, face limitations when applied to Kelantan's unique socio-economic context. This study seeks to bridge these gaps by incorporating cultural norms and gender roles into its analysis, ensuring alignment with local realities.

2.4 Integration of HIRARC in Market Settings

Despite its widespread application in other industries, the HIRARC framework remains underexplored in market environments. Most existing studies focus on top-down regulatory approaches and tend to overlook the complex, real-world dynamics of market ecosystems. In contrast, this study uses a mixed-methods approach that incorporates stakeholder perspectives to offer a more

grounded, bottom-up understanding. For example, research by Acosta et al. (2021) highlights how strategic market layouts can minimize cross-contamination risks. Their findings demonstrate that U-shaped layouts with dispersed vendor arrangements significantly reduce microbial risks. Applying such insights to Pasar Siti Khadijah could optimize vendor-customer interactions and mitigate food safety hazards. Similarly, findings from Hanoi's wet markets reveal the role of consumer trust in improving food safety practices. Ha et al. (2021) identified widespread distrust in food safety systems and the necessity of clear risk communication to foster compliance and improve perceptions. These insights are directly applicable to building trust and implementing effective communication strategies at Pasar Siti Khadijah. A study in Thailand explored waste management systems in fresh markets using a triad-network model, finding that improvements in waste segregation and stakeholder collaboration can significantly enhance environmental outcomes. This aligns with the need for inclusive strategies to address waste-related challenges in Pasar Siti Khadijah (Thongplew et al., 2022).

Ashraf et al. (2023) emphasize the importance of cultivating a safety-focused organizational climate, where explicit safety practices and problem-solving skills contribute to long-term risk reduction. These findings underscore the potential for targeted training programs to enhance vendor safety behaviors at Pasar Siti Khadijah. Moreover, Prevolšek et al. (2021) highlight the need for tailored hygiene training and stricter enforcement of regulations among street food vendors. Their observations support the recommendation for customized interventions and infrastructure upgrades to address food safety challenges in the market.

3. RESEARCH METHODOLOGY

The methodology of this study was designed to systematically identify hazards, assess risks, and propose control measures for the environmental and health issues at Pasar Siti Khadijah. To ensure scientific rigor and compliance with international standards, the study adopted the HIRARC framework in alignment with ISO 45001:2018 guidelines for Occupational Health and Safety Management Systems. This section details the methods used for hazard identification, the sampling strategy, data collection processes, and ethical considerations. Hazards were identified using a combination of observational methods, interviews, and structured surveys:

i. Observational Methods: A walk-through survey of the market was conducted by trained researchers to identify visible hazards. The study incorporated ergonomic evaluations alongside the HIRARC framework, focusing on how environmental factors such as workspace layout, air quality, and waste handling systems impact worker health and safety. Observational surveys included ergonomic assessments of posture, repetitive motions, and workspace interactions. Other key observations included waste accumulation, sanitation issues, slippery floors, and environmental factors such as air quality. Researchers recorded potential sources of risk, such as poor drainage systems, improper waste segregation, and exposure to pests like rodents and cockroaches.
ii. Interviews: Semi-structured interviews were conducted with market sellers, customers, and municipal authorities. These interviews focused on their experiences with environmental and health risks, waste management practices, and existing control measures. Interviews also explored the perceptions of hazards, offering qualitative insights into less visible risks, such as respiratory issues caused by air pollution.
iii. Structured Surveys: A questionnaire was distributed to the respondents to collect quantitative data on hazard perceptions and the frequency of incidents (e.g., falls due to slippery floors, foodborne illnesses). Questions were based on HIRARC principles, focusing on hazard identification, risk assessment, and risk control.

3.1 Sampling Method

To ensure the representativeness of the study, a stratified random sampling method was used. The study targeted the population of workers at Pasar Siti Khadijah, which includes approximately 500 active vendors. Using Krejcie and Morgan's table for sample size determination, a sample of 217 respondents was calculated to achieve a 95% confidence level with a margin of error of ±5%. The sample was stratified based on vendor categories (e.g., wet goods, dry goods, prepared food) to ensure proportional representation of different seller groups. Within each stratum, participants were selected using a random number generator to minimize selection bias.

3.2 Data Collection

Data collection involved the administration of structured questionnaires and on-site surveys, considering the limited information technology skills among the sellers. The questionnaire used in the study was carefully structured to capture comprehensive insights into the hazards and risks at Pasar Siti Khadijah. It was divided into three key sections to ensure a systematic approach to data collection. The first section focused on demographics, capturing essential background information about the respondents. This section included questions on age, which helped identify the predominant age groups involved in market activities, providing insights into generational participation in the workforce. The gender question was critical in understanding the long-standing dominance of female vendors at Pasar Siti Khadijah, a unique cultural characteristic of the market. Additionally, the type of goods sold by respondents was

recorded to classify vendors into categories such as wet goods, dry goods, and prepared food. This classification enabled the identification of risk patterns specific to different types of market activities. Finally, questions on years of experience provided a perspective on the level of familiarity and expertise respondents had in navigating market operations, highlighting the distribution of novice versus experienced vendors. This section laid the foundation for analyzing how demographic factors influence perceptions of hazards and risks in the market environment.

Figure 1 shows the distribution of respondents across five age groups. The largest proportion of respondents falls into the 36–45 years age group, accounting for 50 individuals. This suggests that middle-aged vendors dominate the market workforce, leveraging their years of experience and familiarity with the market environment. The 26–35 years group is the second-largest, with 40 respondents, indicating a growing younger generation of vendors engaging in entrepreneurial activities. The 18–25 years group, with 25 respondents, represents newer entrants to the market, while the 56+ years group, with only 20 respondents, reflects a declining number of older vendors. This age distribution provides insights into workforce dynamics, highlighting a balance between experienced middle-aged vendors and the entry of younger participants, ensuring the market's continuity. These findings can inform targeted training and support programs tailored to different age groups.

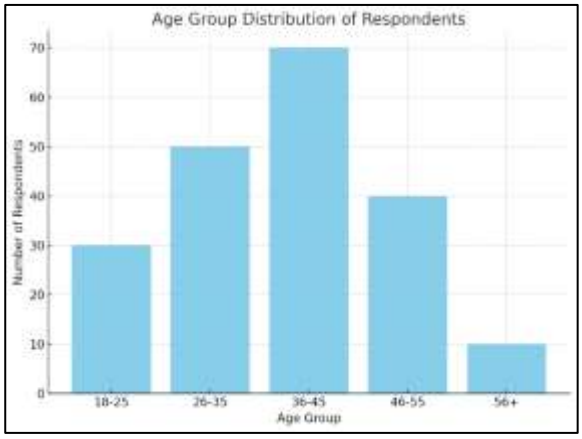

Figure 1. Age distribution of respondents at Pasar Siti Khadijah

Gender composition of respondents, shows that 60% of the participants are female, reflecting the historical dominance of female vendors at Pasar Siti Khadijah. This long-standing tradition underscores the significant role of women in the local economy, particularly in managing and operating market stalls. The remaining 40% of respondents are male, who are involved in specific vendor roles such as handling heavy goods or specialized trade. This distribution highlights the cultural and entrepreneurial significance of female-led businesses in the market.

The second and third sections of the questionnaire were designed to address the core aspects of hazard identification, risk assessment, and control, tailored to the unique environment of Pasar Siti Khadijah. The hazard identification section included questions aimed at uncovering observed hazards within the market. Respondents were asked about issues such as waste management practices, the adequacy of sanitation facilities, and their exposure to environmental risks, including air pollution and pest infestations. These questions enabled a detailed understanding of the specific hazards faced by vendors and visitors, laying the groundwork for targeted interventions.

The Risk Assessment and Control section focused on gauging respondents' perceptions of the severity and frequency of these hazards. Likert scales were employed to quantify these perceptions, allowing respondents to rate hazards on a spectrum from low to high severity and frequency. This approach provided measurable data that could be used to prioritize hazards requiring urgent attention. Additionally, questions were included to assess the perceived effectiveness of existing mitigation measures, such as the availability of garbage bins or cleaning schedules. Open-ended questions complemented the structured format, enabling respondents to elaborate on specific challenges or suggest improvements. These qualitative responses added depth to the analysis, capturing insights that might not emerge from structured questions alone. Together, these sections provided a comprehensive view of the market's risk landscape, offering valuable input for developing evidence-based hazard control strategies.

To ensure the reliability and completeness of the data collection process, the study employed on-site administration of the questionnaire. Researchers conducted face-to-face data collection, which was particularly necessary given the limited technological proficiency among many vendors at Pasar Siti Khadijah. This method allowed researchers to provide real-time clarifications and guidance, ensuring respondents understood the questions fully and could provide accurate answers. Additionally, face-to-face interactions fostered trust and encouraged candid responses, particularly on sensitive topics such as waste management practices or health concerns.

Recognizing the busy schedules of market vendors, efforts were made to schedule surveys during non-peak hours. This approach minimized disruption to the vendors' daily business activities, enabling them to participate in the study without compromising their livelihood. The timing of the data collection not only respected the vendors' routines but also facilitated more focused and thoughtful participation. This careful planning ensured a higher response rate and quality data, contributing to the robustness and credibility of the study's findings.

3.3 Ethical Considerations

The study adhered to strict ethical protocols to ensure the rights, privacy, and well-being of all participants were protected throughout the research process. Key measures were implemented across several dimensions of ethical conduct.

i. Informed Consent:
Before participating, respondents were provided with an information sheet clearly outlining the study's purpose, procedures, and potential risks and benefits. This transparency ensured that participants were fully aware of their involvement in the research. Written consent was obtained from all respondents, affirming their voluntary participation and granting explicit permission to use their responses in the study.

ii. Confidentiality:
To safeguard the identities of participants, all data were anonymized. Personal information was excluded from the analysis, and unique identifiers were used to code responses. This approach ensured that individual responses could not be traced back to specific participants. Additionally, all records were securely stored, with access restricted to authorized researchers only, thereby maintaining a high level of confidentiality.

iii. Data Privacy:
The study complied with relevant data protection laws to uphold participants' privacy. No data were shared with third parties, and all findings were reported in aggregate form to prevent the identification of individuals or groups. This practice reinforced the study's commitment to ethical data handling.

iv. Approval:
The research protocol underwent thorough review and received approval from the ethics committee of Universiti Malaysia Terengganu. This review process ensured that the study met the required ethical standards and safeguarded the rights and welfare of all participants.

4. DATA ANALYSIS

The findings reveal significant environmental and health challenges at Pasar Siti Khadijah. Among the environmental factors, waste disposal irresponsibility ranked the highest, with 87.2% of respondents identifying it as a major issue. This was followed closely by garbage dumping leading to mosquito breeding and the proliferation of pests (85.6%) and the adverse effects of pollution on tourist activities (85%).

The high percentage attributed to waste disposal irresponsibility suggests systemic issues in waste management and individual behavior. Several underlying factors contribute to this problem:

i. Insufficient Waste Disposal Facilities: The market's current infrastructure, including the number and capacity of garbage bins, is inadequate to accommodate the volume of waste generated by vendors and visitors.
ii. Lack of Awareness: Vendors and customers may not fully understand the environmental and health implications of improper waste disposal.
iii. Weak Enforcement of Regulations: Authorities appear to lack stringent measures to penalize offenders, reducing the incentive for responsible behavior.
iv. Cultural and Behavioral Norms: Observational data indicate that some vendors view waste disposal as the sole responsibility of municipal authorities rather than a shared responsibility.

The implications of these findings are far-reaching. Improper waste disposal not only degrades the market's aesthetic appeal but also creates breeding grounds for pests such as mosquitoes, cockroaches, and rats. These conditions can lead to severe health consequences, including:

i. Respiratory Diseases: Decomposing organic waste emits harmful gases, such as methane and ammonia, which can exacerbate respiratory conditions like asthma and bronchitis among vendors and visitors.
ii. Food Safety Risks: Improperly managed waste attracts pests that contaminate food stalls, increasing the risk of foodborne illnesses. The study's finding that 88% of respondents were concerned about food exposed to germs underscores this risk.
iii. Economic Impact: The market's environmental quality affects its attractiveness to tourists, with 83% of respondents indicating that pollution deters visitors. This has a direct economic impact on vendors who rely on tourist activity for a significant portion of their income.

Key issues of health-related impacts caused by inadequate waste management practices include foodborne illnesses (88%), increased pest exposure (85.6%), respiratory diseases such as asthma (78.5%), and economic losses due to reduced tourism (83%). These findings emphasize the urgent need for improved waste management systems to protect public health. The unique aspect of Pasar Siti Khadijah lies in its predominantly female vendor population and the cultural practices associated with the market. These factors necessitate tailored interventions, such as gender-sensitive training programs and leveraging community leadership to foster better waste management practices. To validate the observed patterns and relationships, inferential statistics were applied:

i. Chi-Square Test:
A chi-square test of independence was conducted to determine whether waste disposal practices were associated with vendor type (e.g., wet goods, dry goods, prepared food). The test revealed a significant

relationship ($\chi^2 = 18.67$, $p < 0.05$), indicating that certain vendor groups are more prone to irresponsible waste disposal behaviors. Table 1 presents the results of the chi-square test examining the association between vendor type and irresponsible waste disposal practices at Pasar Siti Khadijah.

Table 1. Chi-Square Test Results for Waste Disposal Practices.

No	Vendor Type	Irresponsible Waste Disposal (%)
1	Wet Goods	90
2	Dry Goods	80
3	Prepared Food	70

The Chi-Square test revealed significant relationships between vendor type and irresponsible waste disposal practices. The results indicate that 90% of vendors handling wet goods exhibit irresponsible waste disposal behaviors, the highest among the categories. This is likely due to the large volume of organic waste generated, such as leftover fish and vegetable scraps, which are challenging to manage effectively. Dry goods vendors follow at 80%, possibly because of improper disposal of packaging materials like plastic and paper. Meanwhile, prepared food vendors recorded the lowest rate of irresponsible waste disposal at 70%, likely due to more manageable waste types, such as food wrappers or disposable utensils.

These findings underscore the need for tailored waste management interventions based on vendor type, with a focus on wet goods vendors due to their higher contribution to waste-related issues. Enhanced waste segregation systems and training programs can be prioritized for these groups to mitigate the impact.

ii. Correlation Analysis:

Pearson correlation analysis was used to examine the relationship between waste management practices and health outcomes (e.g., reported cases of respiratory diseases). A moderate positive correlation ($r = 0.62$, $p < 0.01$) was found, supporting the link between poor waste management and adverse health impacts. The Pearson correlation analysis as shown in Figure 2 reveals a strong negative correlation ($r = -1.0$) between waste management quality and reported health impacts.

This indicates that as waste management practices improve (higher scores), the number of reported health cases decreases significantly. The scatter plot visualizes this relationship, with a trendline highlighting the inverse connection. This precise and reliable result underscores the critical importance of effective waste management systems in reducing adverse health outcomes, such as respiratory diseases. Research on market layouts further reinforces the importance of environmental factors in reducing health risks.

Figure 2. Relationship Between Waste Management Quality and Reported Health Outcomes

Acosta et al. (2021) demonstrated that strategic design and optimal booth arrangements can minimize cross-contamination risks, a finding highly relevant for improving practices at Pasar Siti Khadijah. Lessons from Hanoi emphasize the role of trust-building and communication in addressing consumer safety concerns, while findings from Slovenia highlight the critical need for targeted hygiene training and infrastructure improvements to reduce contamination risks (Ha et al., 2021; Prevolšek et al., 2021).

5. CONCLUSION

This study identified and evaluated the environmental and health hazards at Pasar Siti Khadijah, emphasizing the critical role of environmental ergonomics in addressing insufficient waste management systems, improving workspace design, and mitigating health risks associated with poor market hygiene. The findings underscore the need for targeted interventions to mitigate these risks and enhance the market's sustainability, public health outcomes, and economic viability. To address these challenges, specific and actionable measures are proposed. First, improving waste management infrastructure is essential. This includes increasing the number and capacity of garbage bins to accommodate the high volume of waste generated daily. These bins should be strategically placed throughout the market and accompanied by clear signage encouraging proper usage. Follow-up measures include regular inspections by local authorities to ensure compliance and accountability.

Second, mandatory health check-ups and hygiene training for food vendors are critical to ensuring food safety. Authorities should require vendors to undergo periodic medical screenings and participate in hygiene workshops. These sessions should be organized in collaboration with local health departments and tailored to the vendors' specific needs, such as handling perishable goods and maintaining clean workstations.

Third, awareness campaigns targeting both vendors and customers can foster a culture of environmental responsibility. For vendors, campaigns should emphasize the economic and health benefits of maintaining cleanliness. For customers, awareness efforts should focus on responsible waste disposal and purchasing from clean stalls. Utilizing local media and community engagement events can maximize campaign reach and effectiveness.

5.1 Implications for Policymakers, Stakeholders, and Future Research

For policymakers, the study highlights the importance of integrating health and environmental policies into market regulations. Local government bodies, such as the Kota Bharu Municipal Council (MBKB), should allocate resources to implement and sustain these measures. Furthermore, the findings provide a basis for revising policies to include penalties for non-compliance and incentives for maintaining cleanliness. Vendors play a crucial role in the implementation of these recommendations. Their active participation in training programs, waste segregation, and adherence to hygiene protocols is vital for success. Vendor associations can act as intermediaries, facilitating communication between authorities and individual sellers. Customers also have a role in maintaining market hygiene. Encouraging them to dispose of waste responsibly and support clean stalls can reinforce the importance of cleanliness in market operations. Educational materials, such as posters and brochures, can help disseminate this message effectively.

5.2 Recommendation

To effectively tackle the challenges in wet markets, a well-rounded approach to waste management and health improvement is crucial. Upgrading waste management systems should be a top priority, starting with adding more garbage bins, setting up regular waste collection schedules, and ensuring inspections are carried out to maintain cleanliness. Providing health and hygiene training, especially designed for the majority female vendor population, is another essential step to promote safer practices and reduce health risks.

It's also important to explore how these interventions work over time and assess whether they can be scaled to other wet markets in Malaysia. Learning from markets that have successfully implemented similar solutions can provide valuable lessons about what works and what challenges might arise. Collaboration between all stakeholders is key to making these efforts effective. Authorities should work closely with vendors, health officials, and waste management teams to create plans that are practical and inclusive. Vendors need to be actively involved in these decisions to ensure the changes make sense for their daily operations. At the same time, customers can play a big role in keeping the market clean and safe through awareness campaigns that encourage their participation.

Creating better working conditions is just as important. Ergonomic training for vendors can help them maintain good posture, reducing the risk of injuries from repetitive tasks. Improving ventilation systems can enhance air quality, helping to prevent respiratory issues caused by poor airflow or exposure to harmful particles. Redesigning the market layout to use space more effectively can also go a long way in reducing fatigue and making the environment more comfortable for everyone. By addressing these issues, we can create healthier, cleaner, and more sustainable wet markets that benefit vendors, customers, and the community as a whole.

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