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An Interdisciplinary Approach in Improving Preparedness for Post-Disaster Dengue in George Town, Penang, Malaysia

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ABSTRACT

Risk communication that mosquito-borne infectious diseases such as dengue could follow water-related disasters is insufficiently seen. Dengue could pose a significant public health challenge to the disaster-stricken, already vulnerable locations. Outbreaks of infectious diseases and occurrences of natural disasters are on the rise, which are likely to cause negative impacts on tourist destinations. The UNESCO World Heritage Site of George Town, Penang, Malaysia, is no exception. Academic researchers comprising experts in engineering, disaster management, medicine, and social sciences from three universities in Malaysia and Japan adopted an interdisciplinary approach in an effort to improve preparedness by addressing a gap in risk communication in public health and disaster risk reduction. The researchers conducted field studies in George Town involving multiple stakeholders in the heritage area and interviewed the local authority to understand the structure of governance for matters pertaining to dengue prevention and control in post-disaster situations. A lack of visual data was identified and the gap in risk communication was confirmed. We then observed drainage conditions in another world heritage site in Singapore for comparison, followed by an informational exchange with the local agencies handling public communication and flood prevention. Furthermore, we consulted with the disaster management authority in Putrajaya, Malaysia, to review the current preparedness at the heritage site in George Town. This interdisciplinary collaborative study aims to explore effective strategies and best practices for dengue prevention and control in association with disaster mitigation. The importance of community engagement and participatory approaches in implementing integrated risk communication is also discussed. Recommendations for future interventions are provided to guide policymakers, researchers, and practitioners in prioritizing and investing in collaborative approaches.

Keywords: *Interdisciplinary collaboration, post-disaster risk communication, UNESCO World Heritage Site.*

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1. INTRODUCTION

In recent years, the confluence of natural disasters and infectious disease outbreaks has heightened concerns about the vulnerability of communities with compounded risks, particularly located in tourist-focused heritage areas. Among the numerous challenges arising from this intersection, the threat of post-disaster dengue outbreaks in the tropics has emerged as a significant and often underestimated concern. Currently, there is little information on dengue prevention seen in risk communication of water related disasters in Penang. Dengue fever, transmitted by *Aedes* mosquitoes, not only poses a substantial public health risk but can also exacerbate the devastation brought about by natural disasters [1]. This paper delves into the intricate dynamics between disaster susceptibility and dengue transmission, focusing on the unique vulnerability of tourist-oriented heritage sites. To illustrate this complex interaction, we examine the case of George Town, Penang, Malaysia, a UNESCO World Heritage Site renowned for its historical significance and vibrant tourism industry. The convergence of factors such as dense urban populations, inadequate drainage systems, and an influx of visitors makes heritage areas like George Town particularly susceptible to the rapid propagation of dengue

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vectors following water-related disasters. By shedding light on the nuanced challenges faced by such locales, this study aims to underscore the imperative

for holistic risk communication strategies that encompass both existing risk management and the mitigation of infectious disease outbreaks. Through a multidisciplinary lens, we endeavour to provide insights that can inform targeted interventions, enhance community resilience, and ultimately contribute to safeguarding the cultural heritage and public health in disaster-prone tourist destinations.

Addressing these challenges requires an interdisciplinary approach—one that integrates engineering, public health, social sciences, and environmental planning to formulate comprehensive solutions. Recent studies have underscored that collaboration across disciplines enhances disaster response by encompassing physical, social, and psychological dimensions [2][3]. When experts from diverse sectors collaborate, they develop strategies that are not only technically sound but also socially relevant and inclusive. These collaborative frameworks have been shown to result in more effective disease surveillance, risk communication, and community engagement during crises [4][5]. Participatory approaches that involve local stakeholders, medical professionals, urban planners, and communication experts are particularly effective in contributing to long-term resilience.

This paper presents an interdisciplinary study aimed at enhancing preparedness for post-disaster dengue outbreaks in George Town, Penang, Malaysia. By addressing the gaps in risk communication pertaining to disaster response and mitigation strategies of infectious diseases, experts from diverse fields collaborate to formulate effective approaches. The study combines insights from engineering, disaster management, medicine, and social sciences to suggest measures for mitigating impacts of dengue in disaster-stricken areas. This study is guided by three main research questions; (1) what prevents the National Disaster Management Agency (NADMA) and the Ministry of Health (MoH) to work together in the Penang State, (2) what is the situation of the epicentre (previous and expected) in George Town, Penang and (3) what is the best tool to improve dissemination of risk communication to both local and international travellers (when integrating risk communication of water-related disaster and dengue prevention and control) in George Town, Penang.

2. LITERATURE REVIEW

2.1 Compounded Risks of Dengue Outbreaks in Disaster-Affected Areas

Research attention in recent years has continued to emphasise the intricate interplay between natural disasters and the occurrence of dengue outbreaks. The compounding impact of these events on vulnerable populations underscores the urgency of comprehensive disaster management strategies that integrate public health considerations.

A study by [6] utilises spatial modelling to demonstrate that dengue transmission intensifies following natural disasters, especially in regions with high population density and suboptimal housing conditions. This work indicates the role of socioeconomic factors in amplifying post-disaster dengue risk, reiterating the significance of a holistic understanding of vulnerabilities. [7] provide insights into the complexities of dengue transmission in post-flood settings, revealing that stagnant water following floods can facilitate increased mosquito breeding. This work emphasises the dynamic nature of disease transmission in disaster-affected areas and calls for adaptable surveillance and control strategies.

[8] examines the intersection of COVID-19 and dengue outbreaks in disaster contexts, shedding light on the challenges posed by the dual health threats. The author highlights the importance of robust healthcare systems and integrated disaster preparedness measures to address multifaceted health risks during crises. Building on this trajectory, [9] and [10] present a comprehensive assessment of factors influencing dengue outbreaks in disaster-stricken areas. Their findings underscore the importance of disaster risk reduction strategies that encompass both environmental and socio-economic dimensions, reinforcing the need for interdisciplinary collaboration. In the previous study by [11] and [12], the authors explore the impact of climate change on dengue risk in the aftermath of extreme weather events. These work emphasizes the long-term implications of changing climatic patterns on disease transmission dynamics, further accentuating the need for adaptive strategies.

Collectively, these previous studies reaffirm the pressing need for comprehensive understanding and interdisciplinary approaches to address the amplified risk of dengue outbreaks in disaster-affected areas. The intricate interaction between natural disasters, disease-mediating vectors, and vulnerable populations necessitates not only enhanced disaster management strategies but also tailored interventions that integrate insights from public health, epidemiology, urban planning, and social sciences.,

2.2 Factors Contributing to Dengue Risk Escalation after Disasters

The interplay between natural disasters and the escalation of dengue risk has garnered increasing attention k. Previous literature has illuminated the factors that amplify dengue transmission following disasters, highlighting the need for comprehensive strategies to mitigate these risks. [13] utilize mathematical modelling to examine how disaster-induced population displacement can facilitate dengue transmission. The study reveals that the movement of people from affected areas can lead to the spread of dengue to new regions, stressing the need for effective surveillance and containment measures. Expanding on this theme, [14] investigate the impact of post-disaster housing conditions on dengue

transmission. Their research underscores the role of temporary shelters and inadequate housing in fostering mosquito breeding sites, emphasizing the importance of addressing housing vulnerabilities in disaster recovery plans. In a study by [15], the authors explore the relationship between disaster-induced water scarcity and increased dengue transmission. The interruption of clean water supply can force communities to store water, inadvertently creating breeding sites for mosquites. This research advocates for integrated water management strategies that account for both disaster response and disease prevention.

[16] delves into the impact of changes in human behaviour after disasters on dengue transmission dynamics. Their study illustrates increased outdoor activities or altered waste disposal practices induced by disasters can inadvertently contribute to heightened mosquito distribution and disease spread. Amidst the evolving landscape, [17] employs machine learning to analyse the complex factors driving post-disaster dengue outbreaks. Their research identifies predictors such as climate conditions, social vulnerability, and population mobility, contributing to a more nuanced understanding of the interconnected drivers of dengue risk escalation.

The displacement of populations, inadequate housing, water scarcity, changes in behaviour, and complex interactions among various factors underscore the necessity of a holistic approach to disaster response and recovery that encompasses public health and disaster management considerations.

2.3 Role of Risk Communication in Disaster Preparedness and Dengue Prevention and Control

Effective risk communication plays a pivotal role in disaster preparedness where the compounding challenges of disasters and infectious disease outbreaks necessitate tailored and targeted communication strategies. Previous studies have emphasized the critical role of risk communication in integrating disaster preparedness and dengue prevention efforts.

Focusing on the integration of risk communication in disaster preparedness, [18] underscore the importance of clear and concise messages in promoting preventive behaviours among populations at risk. Their study demonstrates how effective communication can influence the adoption of protective measures during disaster scenarios, including vector control practices.

[19] examine the role of risk communication in promoting public participation in disaster response efforts that encompass both immediate relief and dengue prevention. Their study highlights the potential of communication strategies that emphasize the interconnectedness of disaster mitigation and vector-borne disease control. [20] investigate the impact of risk communication on community engagement in dengue control programmes. Their research reveals that targeted communication campaigns enhance community understanding of dengue transmission and prevention methods, facilitating active participation in vector control initiatives.

With the emergence of digital tools, [21] and [22] explore the role of mobile health (mHealth) applications in dengue prevention and disaster preparedness communication. Their findings demonstrate that mHealth platforms offer a promising avenue for delivering timely information, promoting behavioural change, and enhancing community engagement. Furthermore, an investigation by [23] examines the integration of community-based approaches and risk communication in dengue prevention. Their study reveals that participatory communication strategies enhance the effectiveness of dengue control efforts, e.g., involvement of local communities in the co-creation of risk messages.

Collectively, these studies highlight the critical role of risk communication in aligning disaster preparedness and dengue prevention efforts. Clear and targeted communication strategies facilitate the adoption of preventive behaviours, enhance community engagement, and foster resilience in the face of disasters and dengue outbreaks.

2.4 Malaysian Public Administration and Bureaucracy

The review of public administration and bureaucracy in Malaysia highlights several key points. The system is characterized by a centralized authority within federal ministries and agencies, reflecting a hierarchical decision-making process with limited power delegation. This structure, influenced by colonial history, has led to bureaucratic inefficiency and corruption. The implementation of the New Economy Policy (NEP) increased government involvement in the economy and society, although there have been shifts towards more market-oriented policies. Governance reform efforts are motivated by various factors and social pressures, with administrative frameworks established during colonial rule serving as the foundation for national administration.

The district administration, established during British rule, continues to play a crucial role in service provision and development projects, serving as a vital link between citizens and government. The Malaysian bureaucracy has been praised for its stability and contribution to the nation's prosperity through effective implementation of development goals, but it also faces challenges.

However, [24] mentioned that the Malaysian public bureaucracy faces several contradictions and limits. The disproportionate concentration of authority at the federal level restricts decision-making and efficiency, while the convergence of politics and administration raises concerns about the impartiality and efficacy of the public service. Local

democracy is lacking due to limited autonomy and resources for local government agencies, and the absence of elected local representatives.

Despite these challenges, the Malaysian public bureaucracy has achieved some accomplishments, but it still faces significant obstacles that need to be addressed to improve governance and accountability.

2.5 Malaysia Disaster Management Structure

Malaysia is frequently thought to be less vulnerable to significant natural disasters. However, Malaysia is susceptible to hazards like flooding, mudslides, and landslides due to its tropical climate [25][26]. The National Security Council (NSC) developed Directive No. 20, a national strategy, management framework, and disaster assistance programme, in 1997. Under Directive No. 20, the NSC was tasked with serving as the lead agency and coordinating the implementation of suitable measures in the event of a disaster. But given the frequency and severity of natural disasters that Malaysia experiences now, it is clear that the country may no longer be immune to catastrophic events like earthquakes, floods, and tsunamis [27][28].

Consequently, the federal government decided to create the National Disaster Management body (NADMA) in October 2015 as a separate body tasked with disaster risk management (DRM) and related issues. Three-tier committees oversee all disaster-related matters under NADMA Directive No.1: the District Disaster Management and Relief Committee (DDMRC), chaired by the District Officer, the State Disaster Management and Relief Committee (SDMRC), chaired by the Secretary of State, and the Centre for Disaster Management and Relief Committee (CDMRC), chaired by the Deputy Prime Minister at the federal level [29][25][30][31] as shown in Figure 1 in the following page. Under the Malaysia disaster management structure, seven service themes were established including; (1) search and rescue, (2) health and medical services, (3) media, (4) support, (5) security control, (6) welfare, and (7) warnings and alerts.

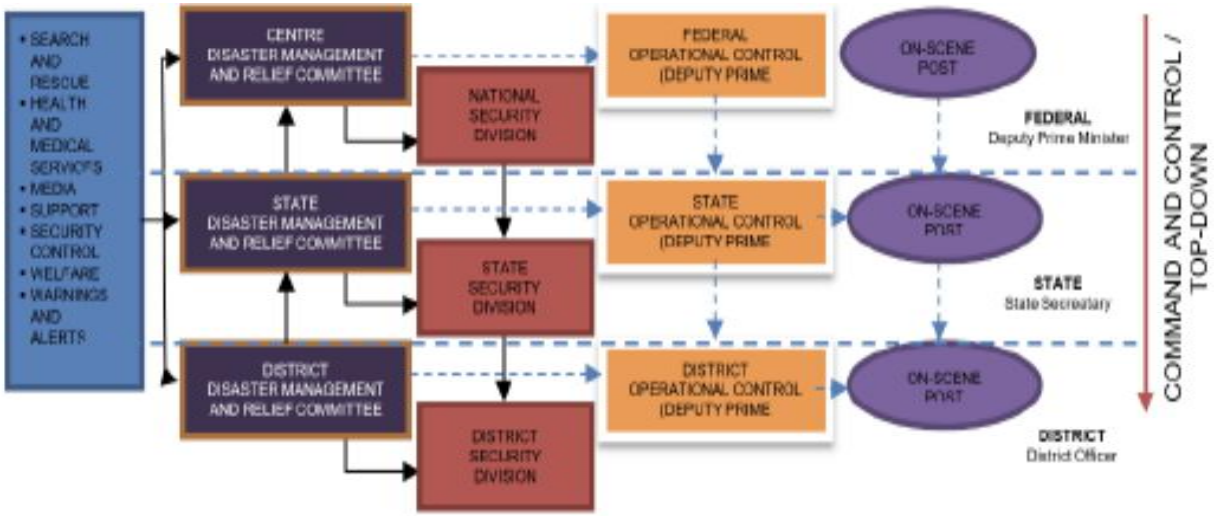

Figure 1: Malaysia Disaster Management Structure (adapted from [25])

2.6 Identification of Gaps in Risk Communication and Strategies for Disaster Preparedness and Dengue Prevention

In the context of risk communication gaps, [32] explore the challenges associated with disseminating accurate and timely information during public health emergencies. Their study emphasizes the need for transparent and consistent communication strategies that consider diverse information requirements by populations. Turning to dengue prevention, [33] identify gaps in community knowledge and awareness of dengue transmission and prevention measures in a disaster-prone region. Their research underscores the importance of tailored communication approaches that address local misconceptions and knowledge deficits. Building on this understanding, [34] examine gaps in risk communication infrastructure and capacity for disaster preparedness in vulnerable communities. Their study highlights the need for strengthening local communication networks and empowering community leaders to effectively convey disaster-related information.

[34] investigate the gaps in risk communication strategies concerning disaster preparedness and dengue prevention in urban slum areas. Their research suggests the integration of participatory approaches, such as community workshops and theatre, to enhance understanding and engagement. [35] and [36] focus on digital gaps in risk communication and disaster preparedness. Their study underscores the need for inclusive approaches that consider digital divides in

marginalized populations, ensuring equitable access to critical information during disasters. Addressing these gaps to mitigate risks and foster resilience necessitates context-specific strategies that are inclusive, participatory, and culturally sensitive, in empowering communities with essential knowledge and tools.

3. METHODOLOGY

The present study was conducted in three stages. The first stage included the review of previous literatures and structures of relevant government agencies in the context of this study. The geographical, cultural, social and other aspects of the area were then observed on site, and finally climatic factors that could affect the situation were well-known. The following subsections describe the methodology and approach in details.

3.1 Composition of the interdisciplinary research team

The research team comprises multinational researchers from three universities in various disciplines, namely civil engineering, environmental engineering, public health, medicine, business administration, and political science. Each researcher addressed the research problems making the best use of own expertise and collectively discussed the strategies to overcome the problems identified in the study.

3.2 Selection of the research site as the case study

The selection of Penang, Malaysia, as a case study in this research is highly justified due to its unique position as a UNESCO World Heritage Site and its susceptibility to both natural disasters, especially water-related disasters, and dengue outbreaks. Penang's historical significance and vibrant tourism industry make it an emblematic representative of heritage areas that face multifaceted challenges. Its dense urban population, coupled with inadequate drainage systems and a reliance on tourism, underscore the potential for increased vulnerability to post-disaster dengue outbreaks. Examination of Penang as a case study can shed light on the intricate dynamics between disaster management, public health, and heritage preservation. Moreover, the findings can offer valuable insights into the strategies necessary to enhance preparedness, mitigate risks, and safeguard the well-being of both residents and visitors in similar disaster-prone heritage locations.

3.3 Site observations and information collection through fieldwork

The fieldwork was conducted over the span of 12 months in Penang, Singapore, and Putrajaya (see Figure 2 for location on map). The aim of the fieldwork in Penang was to investigate the location of the study and observe the physical, cultural, social, and climatic factors that contribute to the vulnerability of the heritage site towards flood disasters, and consequently, mosquito-borne infectious diseases, specifically dengue. Interviews were conducted to gain an in-depth understanding of the issues and challenges faced by the residents, heritage NGOs, local authorities, city council officers and dengue researchers from a local university. Additional three days were allocated to observe and investigate the possible Aedes breeding sites at the tourist hotspot within the George Town World Heritage Site.

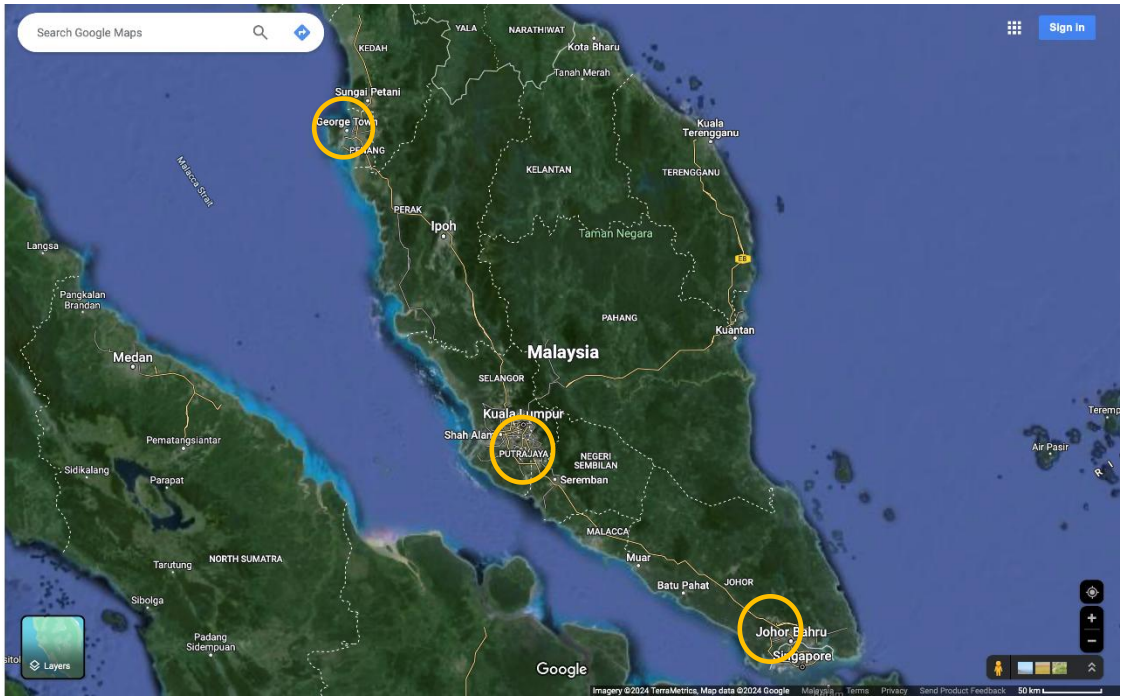

Figure 2: Fieldwork locations: George Town, Putrajaya and Singapore (source: Google Map)

The neighbouring country and another tropical tourist destination the secondary location for our fieldwork. Information was collected by observation and interviews. We comparatively explored the current practices, especially the norms that have been adopted by the residents and public authorities in alleviating the risks of dengue as well as drainage systems to overcome the torrential rainfall. Observation was focused on the Singapore Botanic Gardens, a UNESCO World Heritage Site as well as the Marina Barrage, a place characterised by three functions: a water supply, flood control, and lifestyle attraction. Interviews and discussions were conducted at the National Environment Agency, Singapore, and the Public Utilities Board. The researchers were also able to study the risk communication measures and the community awareness programme undertaken by the authorities in inculcating best practices among the residents to improve their preparedness and resilience towards dengue fever and flood disasters.

In Putrajaya, Malaysia's administrative centre, we conducted semi-structured interviews with government agencies and experts from local universities. We obtained information regarding the policies and measures taken by the Malaysian authorities to improve disaster preparedness and risk communication strategies for the general public.

4. FINDINGS FROM THE FIELDWORK

George Town

Characteristics found in the core and buffer zone

George Town, located on the northwestern coast of Penang Island in Malaysia, stands as a beacon of cultural heritage and historical significance. Recognized as a UNESCO World Heritage Site since 2008, George Town epitomizes the rich tapestry of diverse cultures, architectural marvels, and vibrant urban life that characterize this enchanting city. This overview provides insights into the geographical features, heritage boundary, and climatic conditions that shape the unique identity of George Town [37].

Situated within the state of Penang, George Town occupies a strategic location along the Malacca Strait, a vital maritime artery linking the Indian Ocean to the South China Sea [37]. The city's geographical coordinates are approximately 5.4164° N latitude and 100.3327° E longitude. Bordered by the sea to the east, George Town boasts a picturesque coastline adorned with sandy beaches and bustling waterfront promenades, offering residents and visitors alike a serene escape and stunning views of the azure waters.

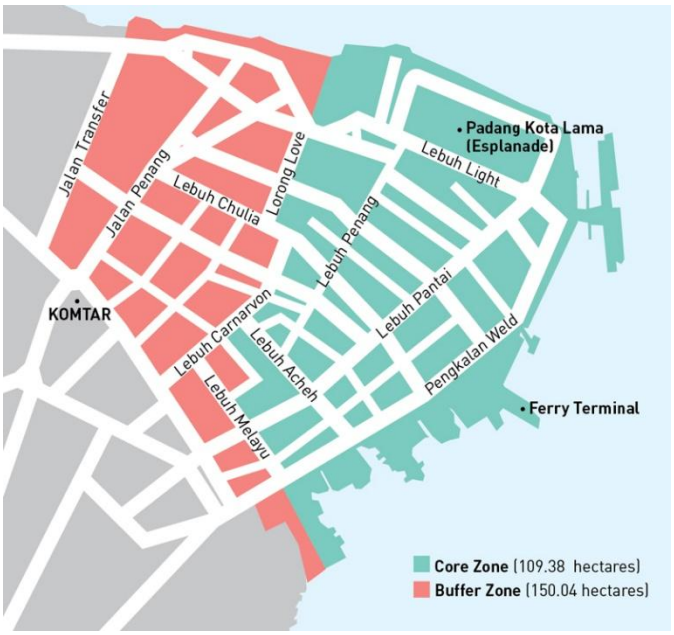

Figure 3: The boundary of core and buffer zone of George Town World Heritage Site

Refer to Figure 3 shown above, the UNESCO World Heritage Site designation encompasses both the core zone (109.38 hectares) and buffer zone (150.04 hectares) of George Town, delineating the boundaries within which the city's architectural and cultural treasures are preserved and celebrated [37]. The core zone encompasses the historic heart of George Town, including its iconic colonial-era buildings, ancient temples, and vibrant street life. Surrounding this core area is the buffer zone, extending the protective umbrella of heritage conservation to the broader urban fabric and safeguarding the city's unique character from encroaching modern development.

George Town experiences a tropical climate characterized by warm temperatures, high humidity, and abundant rainfall throughout the year. The city's proximity to the equator ensures relatively consistent weather patterns, with temperatures ranging from 25°C to 32°C (77°F to 90°F) on average. The rainy season typically occurs from April to October, with peak precipitation in September and October, while the drier months span from November to March. Annual rainfall averages around 2,500 to 3,000 millimeters, nourishing the lush vegetation that adorns the city's streets and parks and contributing to its verdant charm [38][39].

Field study at the Penang Heritage Trust, the George Town World Heritage Incorporated, the City Council of Penang Island, and the Vector Control Research Unit, USM.

The researchers explored the unique characteristics of George Town which boasts a harmonious blend of diverse ethnicities, including Malays, Chinese, Indians, Peranakans (Baba and Nyonya), and Sikhs, coexisting and celebrating their cultural richness together. The city's tangible heritage, influenced by its British colonial past, is evident in its architectural landmarks and religious sites, while intangible cultural elements manifest in its fusion cuisine, language, local dialects, and fashion. Notably, the heritage site stands out for its vibrant urban life, where generations-old family trades continue to thrive, albeit historically segregated along ethnic lines, a legacy partly attributed to British colonial policies.

The field study that was conducted through the streets of George Town revealed both the cultural vibrancy and pressing challenges facing the heritage area. The threat of mosquito-borne diseases, exemplified by a Chikungunya outbreak in 2020, looms over the city, exacerbated by inadequate drainage systems and litter-clogged roadside drains, impeding access for cleaning efforts. While it is a concern for safety to have drain covers in place in the heritage area (for pedestrians & tourists visiting the area), it is also important to keep the drains clean and well-maintained to ensure that it does not become a mosquito breeding place. Furthermore, rising sea levels pose a significant risk of flooding, exacerbated during high tide seasons, prompting infrastructure adaptations like the newly elevated Esplanade walkway. Issues such as improper surface drainage in areas like Little India underscore the urgent need for comprehensive flood mitigation strategies to safeguard the heritage site against environmental threats exacerbated by climate change.

Vector Control Research Unit (VCRU) at Universiti Sains Malaysia (USM) plays a pivotal role as a WHO collaboration center responsible for disseminating WHO-standard sampling and testing instruments for use in areas afflicted with dengue and malaria in Penang. The unit provides annual reports on the status of insecticide resistance and virus detection, with a particular focus on managing and investigating insecticide resistance, as emphasized by the WHO. Notably, mosquito surveillance efforts have predominantly targeted Aedes albopictus in residential areas characterized by lush vegetation, while Ae. aegypti species are prevalent in urban locales with high-rise structures, necessitating more time-intensive sampling methods. Despite the active presence of Ae. albopictus, mosquito surveillance has yet to be conducted at the heritage site in George Town.

Furthermore, insights gleaned from the discussion underscored the strategic initiatives undertaken by Malaysian health authorities, particularly the Ministry of Health and State Health Department, in combating dengue outbreaks. Efforts include the targeted release of female Wolbachia-infected mosquitoes to suppress Ae. aegypti populations, although the endeavor is labor-intensive. Future Wolbachia projects are slated to commence in Kelantan and Johor Baru. However, the absence of virus surveillance research, both for human hosts and vector populations, in the heritage site raises concerns about the adequacy of disease monitoring efforts. The expert in VCRU also highlighted the dearth of informative materials delineating mosquito breeding risks in various building types across Penang, advocating for the production of such materials to enhance public and private stakeholders' awareness and proactive mitigation efforts against dengue outbreaks.

George Town World Heritage Incorporated (GTWHI), established by the Penang State Government in 2010, is entrusted with the mission of preserving and promoting the Outstanding Universal Value (OUV) of the George Town UNESCO World Heritage Site. Comprised of a diverse team of professionals, GTWHI oversees the management, conservation, and sustainable development of the heritage site, which includes over 5,000 buildings. Their efforts extend beyond the physical structures to encompass the safeguarding of living heritage and cultural promotion, with a focus on engaging the local community and fostering youth participation.

To fulfill its mandate, GTWHI collaborates with various stakeholders and partners to organize workshops, exhibitions, and heritage celebrations aimed at enhancing cultural education and capacity building. With sponsorship from the Penang State Government and in collaboration with UNESCO, GTWHI implements around 50 programs annually, addressing diverse aspects of heritage conservation and disaster risk management. Additionally, the organization provides consultations and resources to heritage building owners, architects, and builders, ensuring the appropriate restoration and maintenance of heritage properties while conducting inventory, documentation, and research projects to deepen understanding of George Town's heritage.

In addressing contemporary challenges such as water disasters and fire hazards, GTWHI actively engages with the community through communication channels like WhatsApp and Facebook, facilitating timely information dissemination

and feedback collection. Moreover, the organization collaborates with urban planning authorities to develop guidelines for property development within the heritage area, ensuring adherence to heritage conservation standards and fire disaster mitigation measures. Through its multifaceted approach, GTWHI remains committed to safeguarding the rich cultural heritage of George Town while fostering sustainable development and resilience within the community.

The Environmental Health Section of the City Council of Penang Island collaborates closely with the State Health Department to address public health concerns within the region. Their core activities encompass various initiatives aimed at public health education and promotion, particularly in schools. This includes lectures and roadshows on topics such as personal hygiene, food safety, and contagious diseases, targeting both primary and pre-school students. Additionally, mandatory talks for food handlers and entrepreneurs on food hygiene issues are conducted to ensure compliance with licensing requirements, along with typhoid vaccinations for these individuals.

Vector and pest control efforts, particularly targeting mosquitoes, crows, and rodents, are intensified within the city area to mitigate the risk of disease transmission. This includes thorough inspections for mosquito breeding sites, clearing of rubbish from open lands and drains, and application of insecticides in public drains. In response to Dengue outbreaks, the section promptly conducts search and destroy operations, accompanied by fogging within a designated radius of confirmed cases. Challenges such as residents' lack of cooperation, especially in accessing premises for inspections, and tampering with surveillance devices pose obstacles to effective vector control measures. Additionally, recent water supply disruptions due to floods in neighboring regions heighten the risk of mosquito breeding if water containers are left open, emphasizing the importance of community participation in disease prevention efforts to avoid fines.

Overall situation of dengue and the vector in Malaysia

The interview with the Chairperson of the Centre for Toxicology & Health Risk Studies (CORE), UKM who is also an expert in Dengue studies, provided invaluable insights into dengue awareness and prevention strategies in Malaysia. It was noted that the predominant approach to combating dengue focuses on knowledge dissemination among schoolchildren, rather than targeting older generations. This preference is influenced by prevailing perceptions, attitudes, and political beliefs, underscoring the need for nuanced and targeted educational campaigns to effectively engage diverse demographic groups. Additionally, discussions centered on the deployment of Aedes aegypti mosquitoes carrying Wolbachia in certain regions of Malaysia as a novel approach to vector control. While the efficacy of this intervention is still under scrutiny, it represents a promising avenue for further investigation in the ongoing battle against dengue transmission.

Furthermore, the findings from the interview highlighted the multifaceted nature of dengue prevention efforts, emphasizing the importance of biological control measures such as the introduction of betta fish to curb mosquito breeding in drain sumps. However, challenges persist in waste and food container disposal post-flood disasters, contributing to the proliferation of mosquito breeding sites and escalating the risk of dengue and leptospirosis outbreaks. Collaborative action among communities, local authorities, and researchers emerged as a cornerstone of effective dengue prevention, with each stakeholder group playing distinct yet complementary roles in promoting public health and mitigating the burden of dengue within Malaysian communities.

Singapore

Observation from in and near the Botanic Gardens and the Marina Barrage

The researchers visited the Singapore Botanic Gardens and observed how the trees and roads were maintained (such as condition of plants and drainage). There was neither flood warning displays nor anti-dengue message in the garden. The roadside drain in the garden were well kept, and there were no stagnant water in the drains as shown in Figure 4 below. Several locations near the Ginger Garden, Wetland and Ethnobotany Garden were also inspected to assess the risk of aedes breeding spot.

Figure 4: Observation by the research team in Singapore Botanical Gardens

At the Marina Barrage, the researchers were given a briefing on the measures and strategies taken by the Singaporean government for stormwater management and the ABC water management system as shown in Figure 5 below. The all-year tropical climate means Singapore has high quantity of rainfall throughout the year and if not mitigated properly, the surface rain-off and stormwater collection will lead to catastrophic flash flood in the city and business districts. The essence of Singaporean stormwater management strategies lies in 3 integral stages: **Source, Pathway** and **Receptor.**

Figure 5: Briefing by the Public Utilities Board, Singapore and educational exhibition at the Marina Barrage

It is crucial to provide adequate drainage, to have all developments comply to the minimum platform level and to retrofit older structures/infrastructures for this purpose. The stormwater management strategy includes collection point in each of the stages. Every single drop of water is collected and channeled to detention tanks, retention ponds, or reservoir under key infrastructures, and excess water would be channeled to the sea. The efforts made and measures taken by Singaporean authorities were well documented and showcased into an educational exhibition gallery for creating awareness and knowledge sharing at the Marina Barrage which is free to be accessed by the public and tourists.

New developments were planned and designed to abide by these strategies, and older infrastructures were retrofitted to improve their functions. The result of a well implemented stormwater strategy is adequate drainage reserves, flood prevention, flood risk alleviation and recharge the groundwater. In an urban landscape such as Singapore, the high percentage of impervious surfaces often results in a greater volume of surface runoff. Flood risks are higher due to an intense storm that generates a higher volume of surface runoff that exceeds the drainage design capacity.

A sustainable approach taken in Singapore's stormwater management, is practicing the active, beautiful, clean waters design features (ABC). It is a strategy that distributes collected water in a well-planned and designed natural drainage system, whereby water collected is filtered naturally due to ABC design. As the ABC water management systems prioritise natural design, the well-executed system not only alleviates flood risk, but also is beneficial in recharging the groundwater aquifer and increase the overall real estate value of open spaces and residential areas in Singapore. The PUB is also involved in educating the public. The main attraction of ABC design and its sustainable aspect are more acceptable to the public, as PUB kept sharing success stories on all media available to promote the design concept throughout Singapore. Singapore is also able to secure and reserve the land surrounding the canal, or important drainage structure – by getting the authorities and legislative bodies involved.

Further exploration in the city reveals that Singapore has many plants in public areas and the lush vegetation around the city, possess a certain risk of dengue to the tourists as well as the locals. Therefore, the efforts made by the government should be closely coordinated among different agencies to ensure that timely actions can be taken to benefit the public.

Insights gained for outreaching to the general public, health education, and risk communication from NEA

According to the National Environment Agency (NEA), it is important to have a standard risk level/index that can easily be comprehended by the public. Singapore is promoting dengue risk preparedness and prevention at the individual level. The agency shared success stories of dengue risk preparedness and empowered school teachers by providing sufficient materials and information so that they could teach the students in school. The NEA has developed a teaching package on dengue risk, available on the NEA website for use by schools and the public. There is also funding available for organizations, schools, and communities to apply for efforts in greater environmental sustainability.

Furthermore, there are levels of communication, and the amount of information differs from one level to another. Knowing the audience is key, and efforts to educate the public should begin with understanding the public itself. It is crucial to document the possible risk of dengue around buildings/dwellings, as previously catalogued by the NEA for the Singapore public. Such a document has not been produced in Malaysia (confirmed by the Penang fieldwork findings), and therefore, it would be a good contribution by the research.

Another initiative done by the NEA is “Citizen Science” where the government empowers the people with scientific knowledge so they can assist in creating awareness and educating the public. This group will also provide feedbacks to the policy makers. It is also crucial that we make sense of the data, make the information accessible to all so that it can be appreciated and understood by everyone involved.

Putrajaya

Information given by the National Disaster Management Agency

The interview between researchers and the Director of Operation, Coordination Section, NADMA Malaysia has shed light on critical aspects of disaster management in the region. The roles and activities of the National Disaster Management Agency (NADMA) throughout the disaster management stages, including pre-disaster, during a disaster, and post-disaster, were thoroughly examined. Notably, it was observed that while leaflets and public information efforts primarily focus on monsoon floods and water head incidents, there is a glaring absence of materials addressing the risks associated with dengue in water-related disasters. This gap underscores the necessity for tailored risk communication strategies to effectively mitigate the impact of such health threats.

Moreover, insights gleaned from the interview highlighted the potential health risks posed by evacuation centers in the aftermath of disasters. The increased waste generated by evacuees poses a significant challenge, as these centers may inadvertently become breeding grounds for mosquitoes and other vector-borne diseases, exacerbating public health concerns. Furthermore, the meeting underscored the urgent need for comprehensive risk communication aimed at international travelers, particularly to destinations like Penang. Collaboration between inter-ministerial entities emerged as a pivotal factor in enhancing public education efforts, emphasizing the importance of coordinated initiatives in bolstering disaster preparedness and response strategies within the region.

5. DISCUSSION

5.1 Integrating Heritage-Sensitive Governance in Urban Risk Management

Managing post-disaster dengue in heritage cities like George Town requires the integration of urban risk governance with public health and heritage conservation. The city’s status as a UNESCO World Heritage Site imposes constraints on infrastructure development, land use, and drainage upgrades. While its compact design, cultural vibrancy, and historical architecture contribute to its Outstanding Universal Value (OUV), these same features increase vulnerability to flood-related hazards and mosquito-borne diseases.

Malaysia’s disaster management system, though guided by NADMA Directive No. 1 [31], remains heavily centralized and segmented between federal entities such as NADMA and the Ministry of Health. Local implementation responsibilities further complicate coordination. In George Town, multiple institutions—including the Penang Heritage Trust (PHT), George Town World Heritage Incorporated (GTWHI), Vector Control Research Unit (VCRU), and the City Council are operating independently under different mandates, resulting in limited cross-sectoral collaboration and inefficiencies in managing shared risks.

The absence of formal mechanisms to coordinate efforts among these agencies has hindered effective action. For example, GTWHI handles heritage preservation and public engagement, while the City Council focuses on environmental health and dengue control. Although VCRU has the expertise for mosquito surveillance, no consistent monitoring is conducted within the most vulnerable heritage core. In contrast, Singapore’s National Environment Agency (NEA) showcases a well-integrated model that blends environmental health, education, and communication under a

unified system. Initiatives such as “Citizen Science” and transparent outbreak reporting enable stronger public participation and situational awareness.

To strengthen George Town’s resilience, a heritage-sensitive governance approach should rest on four key pillars: institutional integration, localised heritage planning, community engagement, and transparent communication. Establishing a coordinated working group that includes NADMA, state health authorities, GTWHI, and academic partners would foster better alignment of disaster preparedness and public health within the constraints of heritage preservation. By adapting best practices from Singapore and leveraging digital platforms, George Town can protect both its cultural identity and public safety amid escalating environmental threats.

5.2 Mitigation

Findings from this research indicate that mitigation measures are imperative in minimizing the vulnerability of residents and visitors in impending flood disasters and dengue outbreaks. Comparing the findings obtained in Penang and Singapore, where both are frequented by tourists and characterized by densely populated urban areas, we can deduce that there are different approaches taken by the authorities in each place. Singapore takes a more proactive stand in preparing for disasters by managing factors of climate change within the city-state. All new developments, refurbishments and retrofitting of old infrastructures in the urban are done in meticulous consideration of the environment while embracing sustainable methods and green technology. By managing these factors, flood disaster risk can be mitigated. The city of George Town, Penang has also begun to impose protocols in their new developments, refurbishments, and retrofitting. However, modifications or structural mitigations against flood disasters are rather difficult if not prohibited. This is because a part of the city of George Town needs to observe heritage structures specifications and regulations as a UNESCO World Heritage Site.

The findings have revealed that the governance of mitigation efforts by the federal agency and ministry may not overlap with those made by the state or municipal authorities. For disaster-related matters, the state and municipal agencies precede the federal agencies regarding mitigation and response efforts, as stated in the NADMA Directive No 1 [31]. In some situations, this may cause miscommunication between the state and federal agencies, even causing delays due to bureaucracy and procedures in these two parties. Furthermore, NADMA is under the governance of the Prime Minister's Department and is a separate entity from the Ministry of Health. Inter-ministry collaboration requires extensive planning and coordination to ensure timely action can be taken.

Malaysia and Singapore belong to the Western Pacific Region of the World Health Organisation and share many challenges in common, including dengue endemicity. Public health measures conducted by both authorities in Penang and Singapore in response include: fogging of insecticides in affected areas with outbreaks, source reduction (removal of stagnant water to reduce mosquito breeding sites) and the use of penalties for owners of premises for breeding mosquitoes. The residents in both locations are relatively familiar with the dengue disease and anti-dengue actions recommended by the local authorities [40].

The relationship between awareness programs and mitigation is instrumental in enhancing preparedness for post-disaster dengue. Awareness programs play a vital role in educating the public about the importance of preventive measures, early symptom recognition, and community-based interventions. This knowledge empowers individuals to actively participate in mitigation efforts and take responsibility for their own health and well-being [41][42]. In the case of Penang, disaster mitigation and preparedness for the community is reinforced by community drills by the Malaysian Civil Defense Force and is supported by the Penang State Government, while the Penang City Council and the Penang State Health Office are supporting awareness and education on dengue prevention.

Furthermore, awareness programs contribute to fostering a culture of preparedness within the community. By disseminating information about dengue and its transmission, individuals are more likely to adopt preventive practices and seek timely medical attention, thereby reducing the severity and spread of the disease in the event of a disaster [43][44][45]. In addition, the effectiveness of mitigation strategies is amplified by targeted awareness programs. When communities are well-informed, they are more likely to comply with vector control measures, environmental sanitation practices, and proper waste management, which are essential components of dengue mitigation. This, in turn, leads to improved efficacy of mitigation efforts and a reduction in the potential for large-scale dengue outbreaks post-disaster [46][41][47].

Although the two locations are only 575km apart by air, differences in strategies were observed. In Singapore, source reduction is more heavily emphasized than fogging operations, and periodical on-site inspections were conducted by the authority in residential areas and construction sites [48]. Furthermore, the number of dengue cases and the locations of infections are made available online via NEA’s website, and we confirmed that banners and posters were put up at places such as construction sites and train stations to alert dengue risks.

The two world-famous tourist destinations, George Town and Singapore, are likely to face an increasing demand to transfer local knowledge to tourists as a mitigation strategy. The vulnerability of tourists is apparent, especially among

those who are not familiar with tropical climates and the potential risk of flood and susceptible visitors from non-endemic regions. Such an effort is essential, particularly during the monsoon season and when reported dengue cases show an upward trend locally.

5.3 Risk Communication

Timely and comprehensive information dissemination to targeted community is crucial in ensuring the safety and preparedness in the event of disaster as post-disaster risk communication. Effective risk communication on the possible occurrence of disasters will increase the probability of human safety and reduction of human exposure to hazard for the locals and tourists alike. Disaster risk communication in the city of George Town is nation-centric, whereby information is being dispersed through the official social media of the National Disaster Management Agency and local news. While the information is easily accessible by the locals, the same cannot be said for tourists, especially non-Malay speakers. The common way of relaying risk communication to tourists is through their accommodation facilities and tourist information centre in the city. The current situation suggests a serious challenge in providing post-disaster risk communication, especially to foreign tourists.

In the case of George Town, the local agency and NGO who are the custodians of the preservation and promotion of the heritage areas had periodically shared information on disaster risk reduction through their official website, distributing fliers and print materials as well as sharing information through community WhatsApp group in the heritage areas. It should be highlighted that materials evidencing potential risks are lacking in George Town.

Being compact in size, Singapore has an advantage in organising risk communication nationwide in much more efficient and faster way. Mainstream and social media are utilized effectively in addition to the official websites of the governmental agencies in providing warning and periodical updates of both dengue outbreaks and flood occurrences. Although risk communication is implemented nationwide by the authorities in all four official languages (Malay, English, Chinese and Tamil), key messages may not reach a foreign segment of local population and visitors with little or no command in these four languages [49].

Information on dengue outbreaks (the number of reported cases and locations of infections) is an integral component in effective risk communication. Official data is crucial in motivating the general public to take preventive measures. If the local authorities choose not to make the information available, the risk of a prolonged dengue outbreak can be imminent. The members of the general public will be unlikely to raise their guard against dengue transmission and, therefore, remain at risk without taking preventive measures. We noted contrasting strategies taken by the two locations we investigated. People in Penang may not know about the occurrences of dengue outbreaks unless they notice the authorities conduct fogging and/or inspect for mosquito presence in particular areas.

On the other hand, the authorities in Singapore adopted a more inclusive stance in preventing dengue outbreaks by disclosing information to the general public and encouraging the community to take proactive and precautionary measures against dengue outbreaks. Strong political endorsement and involvement were observed in nationwide campaigns.

It is encouraging, however, that authorities in both locations organise awareness campaigns and knowledge-sharing sessions to empower the younger generations with good knowledge and practices in preventing dengue. As trans-sectoral initiatives started gaining momentum while shortage of manpower and material constraints exist, academic experts as well as industry partners have essential roles to play in providing effective skill training and instructive materials for educational programmes in collaboration with the government agencies [49]. Based on the findings from the Singapore fieldwork, the researchers recommend that the federal and Penang state agencies in collaboration with the universities to prepare educational materials to empower the educational sector in transferring knowledge of dengue prevention for the children and youth. Making use of current technologies, such as artificial intelligence AI in mobile apps with location sharing for tourist, that gives notifications of potential risks of dengue and disaster will enable vital information to be transmitted directly to tourist that visited Penang

6. CONCLUSION AND WAY FORWARD

This paper discussed the challenges in dealing with mosquito-borne diseases that might follow natural disasters and the need to improve disaster preparedness in vulnerable areas, particularly in tropical tourist destinations. The UNESCO World Heritage Site of George Town, Penang, Malaysia, was focused in the present case study. The compound risk was confirmed in George Town where risks of water-related disasters are heightened especially with the rising sea-level and climate change; and dengue outbreaks pose a unique public health challenge with movements of people in the tropical location.

As natural disasters and infectious disease outbreaks are expected to intensify with more frequency, it is important to address the gap between disaster management and public health management immediately. To fill this gap, experts from diverse academic fields can provide a holistic approach to risk communication strategies by integrating perspectives

ranging from the natural sciences to the social sciences. Formation of strategies that encourage proactive measures among the targeted communities in mitigation of flood disaster risk and prevention of dengue outbreaks require consideration of multi-facet needs arising from ethnic, cultural and geographical elements. In this respect, our interdisciplinary research team from diverse cultural and geographical backgrounds endeavoured to identify organisational constraints observed in the context of Malaysian national versus provincial structure in risk communication.

These measures taken by the general public can complement the actions taken by government agencies, practitioners, and other stakeholders to increase preparedness and protect the health and well-being of locals and tourists alike. Future research will focus on refining post-disaster risk communication strategies to increase awareness and knowledge among residents and younger generations about disaster preparedness and dengue prevention and control in George Town, a UNESCO World Heritage Site.

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REFERENCES

[1] Basaria, A. A., Ahsan, A., Nadeem, A., Tariq, R., & Raufi, N. (2023). Infectious diseases following hydrometeorological disasters: current scenario, prevention, and control measures. Annals of Medicine and Surgery, 85(8), 3778.

[2] Gabrielová, J., & Veleminsky, M., Sr (2014). Interdisciplinary collaboration between medical and non-medical professions in health and social care. Neuro endocrinology letters, 35 Suppl 1, 59–66.

[3] Faber, M. H., Giuliani, L., Revez, A., Jayasena, H., Sparf, J., & Mendez, J. (2014). Interdisciplinary approach to Disaster Resilience Education and research. Procedia. Economics and Finance, 18, 601–609. https://doi.org/10.1016/s2212-5671(14)00981-2

[4] Rocklöv, J., & Tozan, Y. (2019). Climate change and the rising infectiousness of dengue. Emerging Topics in Life Sciences, 3(2), 133-142. https://doi.org/10.1042/ETLS20180123

[5] Lahiri, S., Snowden, B., Gu, J., Krishnan, N., Yellin, H., & Ndiaye, K. (2021). Multidisciplinary team processes parallel natural disaster preparedness and response: A qualitative case study. International Journal of Disaster Risk Reduction, 61, 102369. https://doi.org/10.1016/j.ijdrr.2021.102369

[6] Reiner Jr., R. C., Stoddard, S. T., Forshey, B. M., King, A. A., Ellis, A. M., Lloyd, A. L., ... & Perkins, T. A. (2018). Time-varying, serotype-specific force of infection of dengue virus. Proceedings of the National Academy of Sciences, 115(4), E755-E762.

[7] Liu, S., Chien, T., Yang, T., Yeh, Y., Chou, W., & Chow, J. C. (2021). A Bibliometric Analysis on Dengue Outbreaks in Tropical and Sub-Tropical Climates Worldwide Since 1950. International Journal of Environmental Research and Public Health, 18(6), 3197. https://doi.org/10.3390/ijerph18063197

[8] Vikas. (2020). The Southwest Monsoon During COVID-19 Pandemic: A Potential Concern. Asia-Pacific Journal of Public Health, 32(6–7), 374–375. https://doi.org/10.1177/1010539520944729

[9] Rahman, M. S., Ekalaksananan, T., Zafar, S., Poolphol, P., Shipin, O., Haque, U., Paul, R., Rocklöv, J., Pientong, C., & Overgaard, H. J. (2021). Ecological, Social, and Other Environmental Determinants of Dengue Vector Abundance in Urban and Rural Areas of Northeastern Thailand. International Journal of Environmental Research and Public Health, 18(11), 5971. https://doi.org/10.3390/ijerph18115971

[10] Baharom, M., Ahmad, N., Hod, R., Arsad, F. S., & Tangang, F. (2021). The Impact of Meteorological Factors on Communicable Disease Incidence and Its Projection: A Systematic Review. International Journal of Environmental Research and Public Health, 18(21), 11117. https://doi.org/10.3390/ijerph182111117

[11] Wang, Y., Zhao, S., Wei, Y., Li, K., Jiang, X., Li, C., Ren, C., Yin, S., Ho, J., Ran, J., Han, L., Zee, B. C. Y., & Chong, K. C. (2023). Impact of climate change on dengue fever epidemics in South and Southeast Asian settings: A modelling study. Infectious Disease Modelling, 8(3), 645-655. https://doi.org/10.1016/j.idm.2023.05.008

[12] Bhatia, S., Bansal, D., Patil, S., Pandya, S., Ilyas, Q. M., & Imran, S. (2022). A Retrospective Study of Climate Change Affecting Dengue: Evidences, Challenges and Future Directions. Frontiers in Public Health, 10, 884645. https://doi.org/10.3389/fpubh.2022.884645

[13] Guad, R. M., Wu, Y. S., Aung, Y. N., Sekaran, S. D., Wilke, A. B., Low, W. Y., Sim, M. S., Carandang, R. R., Jeffree, M. S., Taherdoost, H., Sunggip, C., Lin, C. L., Murugaiah, C., Subramaniyan, V., & Azizan, N. (2021). Different Domains of Dengue Research in Malaysia: A Systematic Review and Meta-Analysis of

Questionnaire-Based Studies. International Journal of Environmental Research and Public Health, 18(9), 4474. https://doi.org/10.3390/ijerph18094474

[14] Alves, L. D., Lana, R. M., & Coelho, F. C. (2021). A Framework for Weather-Driven Dengue Virus Transmission Dynamics in Different Brazilian Regions. International Journal of Environmental Research and Public Health, 18(18), 9493. https://doi.org/10.3390/ijerph18189493

[15] Jafari, N., Shahsanai, A., Memarzadeh, M., & Loghmani, A. (2011). Prevention of communicable diseases after disaster: A review. Journal of Research in Medical Sciences : The Official Journal of Isfahan University of Medical Sciences, 16(7), 956-962. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3263111/

[16] Reina Ortiz, M., Le, N. K., Sharma, V., Hoare, I., Quizhpe, E., Teran, E., Naik, E., Salihu, H. M., & Izurieta, R. (2017). Post-earthquake Zika virus surge: Disaster and public health threat amid climatic conduciveness. Scientific Reports, 7(1), 1-10. https://doi.org/10.1038/s41598-017-15706-w

[17] Yin, S., Ren, C., Shi, Y., Hua, J., Yuan, Y., & Tian, W. (2022). A Systematic Review on Modeling Methods and Influential Factors for Mapping Dengue-Related Risk in Urban Settings. International Journal of Environmental Research and Public Health, 19(22). https://doi.org/10.3390/ijerph192215265

[18] Bradley, D. T., McFarland, M., & Clarke, M. (2014). The Effectiveness of Disaster Risk Communication: A Systematic Review of Intervention Studies. PLoS Currents, 6. https://doi.org/10.1371/currents.dis.349062e0db1048bb9fc3a3fa67d8a4f8

[19] Nkombi, Z., & Wentink, G. J. (2022). The role of public participation in disaster risk reduction initiatives: The case of Katlehong township. Jàmbá : Journal of Disaster Risk Studies, 14(1). https://doi.org/10.4102/jamba.v14i1.1203

[20] Rajapaksha, R. M., Abeysena, C., & Balasuriya, A. (2023). Health seeking behaviours, dengue prevention behaviours and community capacity for sustainable dengue prevention in a highly dengue endemic area, Sri Lanka. BMC Public Health, 23(1), 1-9. https://doi.org/10.1186/s12889-023-15404-5

[21] Bhattarai, A.H., Sanjaya, G.Y., Khadka, A. et al. The addition of mobile SMS effectively improves dengue prevention practices in community: an implementation study in Nepal. BMC Health Serv Res 19, 699 (2019). https://doi.org/10.1186/s12913-019-4541-z

[22] Dammert, A. C., Galdo, J. C., & Galdo, V. (2014). Preventing dengue through mobile phones: Evidence from a field experiment in Peru. Journal of Health Economics, 35, 147-161. https://doi.org/10.1016/j.jhealeco.2014.02.002

[23] Mulderij-Jansen, V., Elsinga, J., Gerstenbluth, I., Duits, A., Tami, A., & Bailey, A. (2020). Understanding risk communication for prevention and control of vector-borne diseases: A mixed-method study in Curaçao. PLoS Neglected Tropical Diseases, 14(4). https://doi.org/10.1371/journal.pntd.0008136

[24] Siddiquee, N. (2013). Public Management and Governance in Malaysia: Trends and Transformations. Routledge, Taylor & Francis. https://doi.org/10.4324/9780203074275

[25] Center for Excellence in Disaster Management and Humanitarian Assistance [CEDMHA] (2016). Malaysia: Disaster Management Reference Handbook 2016.

[26] Shaluf, I. M., & Ahmadun, F. -R. (2006). Disaster types in Malaysia: An overview. Disaster Prevention and Management, 15(2), 286-298.

[27] Khailani, D. K., & Perera, R. (2013). Mainstreaming disaster resilience attributes in local development plans for the adaptation to climate change induced flooding: A study based on the local plan of Shah Alam City, Malaysia. Land Use Policy, 30(1), 615-627.

[28] Zahari, R. K., Ariffin, R. N. R., Asmawi, M.Z., & Ibrahim, A. N. (2013). Impacts of the 2004 tsunami: Preparedness of the Malaysian coastal communities. Procedia - Social and Behavioral Sciences, 105, 569-576

[29] Chan, N.W. (2012). Impacts of disasters and disasters risk management in Malaysia: The case of floods. In Y. Sawada & S. Oum (Eds.), Economic and welfare impacts of disasters in East Asia and policy responses (pp.503-551). Tokyo: ERIA.

[30] National Security Council [NSC] (1997). Directive No.20. Malaysia: National Security Council, Prime Minister Department.

[31] National Disaster Management Agency [NADMA] (2024), Arahan NADMA No. 1, Dasar dan Mekanisme Pengurusan Bencana Negara. Malaysia: National Disaster Management Agency, Prime Minister Department.

[32] Kruk, M. E., Myers, M., Varpilah, S. T., & Dahn, B. T. (2015). What is a resilient health system? Lessons from Ebola. The Lancet, 385(9980), 1910-1912. https://doi.org/10.1016/S0140-6736(15)60755-3

[33] Zaki, R., Roffeei, S. N., Hii, Y. L., Yahya, A., Appannan, M., Said, M. A., Wan, N. C., Aghamohammadi, N., Hairi, N. N., Bulgiba, A., Quam, M., & Rocklov, J. (2019). Public perception and attitude towards dengue prevention activity and response to dengue early warning in Malaysia. PLOS ONE, 14(2), e0212497. https://doi.org/10.1371/journal.pone.0212497

[34] Albris, K., Lauta, K. C., & Raju, E. (2020). Disaster Knowledge Gaps: Exploring the Interface Between Science and Policy for Disaster Risk Reduction in Europe. International Journal of Disaster Risk Science, 11(1), 1–12. https://doi.org/10.1007/s13753-020-00250-5

[35] Jiang, L., Huang, Y., Cheng, H., Zhang, T., & Huang, L. (2021). Emergency Response and Risk Communication Effects of Local Media during COVID-19 Pandemic in China: A Study Based on a Social Media Network. International Journal of Environmental Research and Public Health, 18(20), 10942. https://doi.org/10.3390/ijerph182010942

[36] Kondo, S., Hirose, Y., & Shiroshita, H. (2018). Risk communication and disaster information. In Trust. https://doi.org/10.1007/978-981-13-2775-9_12

[37] Plan Malaysia. (2022). George Town UNESCO World Heritage Site Special Area Plan. State Government of Penang, PLANMalaysia@Pulau Pinang, City Council of Penang Island and George Town World Heritage Incorporated. https://jpbd.penang.gov.my/images/faris/pdf/2022/Content%20RKK%20Tapak%20Warisan%20Dunia%20Unesco%20Georgetown-Penggantian/Laporan%20Draf%20Akhir-BI/VOLUME%20II%20-%20DEVELOPMENT%20CONTROL.pdf

[38] MMD. (2021). Annual Report. Retrieved May 12, 2023, from Malaysian Meteorological Department website: https://www.met.gov.my/en/penerbitan/laporan-tahunan/

[39] MMD. (2022). Annual Rainfall Anomaly. Retrieved August 12, 2022, from Malaysian Meteorological Department website: https://www.met.gov.my/en/pendidikan/iklim-malaysia/

[40] Liew, C., Soh, L. T., Chen, I., & Ng, L. C. (2021). Public sentiments towards the use of Wolbachia-Aedes technology in Singapore. BMC Public Health, 21(1), 1-12. https://bmcpublichealth.biomedcentral.com/counter/pdf/10.1186/s12889-021-11380-w.pdf

[41] Mudin, R N. (2015, June 1). Dengue Incidence and the Prevention and Control Program in Malaysia. https://doi.org/10.31436/imjm.v14i1.447

[42] Rizvi, D. (2022, January 1). Health education and global health: Practices, applications, and future research. Journal of education and health promotion, 11(1), 262-262. https://doi.org/10.4103/jehp.jehp_218_22

[43] Selvarajoo, S., Liew, J W K., Tan, W., Lim, X Y., Refai, W F., Zaki, R A., Sethi, N., Sulaiman, W Y W., Lim, Y A L., Vadivelu, J., & Vythilingam, I. (2020, June 12). Knowledge, attitude and practice on dengue prevention and dengue seroprevalence in a dengue hotspot in Malaysia: A cross-sectional study. https://doi.org/10.1038/s41598-020-66212-5

[44] Ahbirami, R., & Zuharah, W F. (2020, March 27). School-based health education for dengue control in Kelantan, Malaysia: Impact on knowledge, attitude and practice. https://doi.org/10.1371/journal.pntd.0008075

[45] Runge-Ranzinger, S., Kroeger, A., Olliaro, P., McCall, P J., Tejeda, G S., Lloyd, L S., Hakim, L S., Bowman, L., Horstick, O., & Coelho, G E. (2016, September 21). Dengue Contingency Planning: From Research to Policy and Practice. PLoS neglected tropical diseases, 10(9), e0004916-e0004916. https://doi.org/10.1371/journal.pntd.0004916

[46] Sim, S., Ng, L C., Lindsay, S W., & Wilson, A L. (2020, August 27). A greener vision for vector control: The example of the Singapore dengue control programme. PLoS neglected tropical diseases, 14(8), e0008428-e0008428. https://doi.org/10.1371/journal.pntd.0008428

[47] Ong, S O. (2016, May 1). Dengue Vector Control in Malaysia: A Review for Current and Alternative Strategies

[48] Yoshikawa, M. J. (2013). Vector control and surveillance operations in the republic of Singapore. Tropical medicine and health, 41(2), 61-66. https://www.jstage.jst.go.jp/article/tmh/41/2/41_2011-04/_pdf

[49] Yoshikawa, M. J., Hamada, A., & Liew, C. (2023). Addressing Needs of Foreign Schoolchildren to Combat a Global Epidemic of Dengue Virus Infection: Transnational and Trans-Sectoral Initiatives. In Integrated Science of Global Epidemics (pp. 563-585). Cham: Springer International Publishing. https://link.springer.com/chapter/10.1007/978-3-031-17778-1_27