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TOWS MATRIX OF ENVIRONMENTAL HEALTH MANAGEMENT FOR FLOOD DISASTER IN MALAYSIA

Zaza Hulwanee M. Z.[1,2], Farah Fatin F.[1,2], Mohd Anwar S. A.[1,2], Saliluddin S. M.[3*]

[1]DrPH Candidates, Department of Community Health, Faculty of Medicine & Health Sciences, Universiti Putra Malaysia.
[2]Training Management Division, Ministry of Health Malaysia
[3]Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia

**Corresponding author: Suhainizam Muhamad Saliluddin; email:suhainizam@upm.edu.my*

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ABSTRACT

Background: Compared to its neighbouring countries, Malaysia is relatively free from severe natural disasters. In Malaysia, flood is the most commonly occurring natural disaster and has become an issue as it threatens lives and properties, as well as severely disrupts social and economic activities. In addition to causing the population to be exposed to adverse environmental conditions, a flood also disrupts environmental health services. Effective management of environmental health following a flood disaster is of primary importance. The aim of this article is to discuss the strengths, weaknesses, opportunities, and threats in the provision of clean water, sewage disposal, and disaster waste management for the flood disaster in Malaysia as well as to recommend viable improvements in the planning of environmental health management for the disaster.

Materials and Methods: Articles and reports were accessed from PubMed, Medline, Google, Google Scholar, and by manual searches. This review was guided by the following research question: 'What are the strengths, weaknesses, opportunities, and threats to the current flood disaster management in Malaysia, specifically in the provision of clean water, sewage disposal, and disaster waste management?' The search terms include 'flood disaster', 'environmental health', 'clean water', 'sewage', 'disaster waste', 'evaluation', and 'Malaysia'.

Result: 91 potentially relevant articles were identified, and 30 were assessed and reviewed in the final stage. The relevant points are clustered into the TOWS matrix to develop the strategies and recommendations for improvement. The strategies include strengths-opportunities, weaknesses-opportunities, strengths-threats, and weaknesses-threats.

Conclusion: Four main elements that require improvement in the provision of clean water, sewage system, and disaster waste disposal during flood in Malaysia include areas of legislation, regulations, and guidelines, flood disaster management plan, public attitude and community resilience, as well as collaboration, cooperation, and partnership between local and international stakeholders. More empirical evidence and evaluation studies of the current environmental health management are required to provide critical information on the current local scenario and to guide the appropriate actions for improvement.

Keywords: Disaster, flooding, clean water, sewage, disaster waste

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1.0 Introduction

Malaysia is a country in the Southeast Asian region, comprising of Peninsular Malaysia to the west and East Malaysia to the east. It is located near the equator, just outside the Pacific Ring of Fire. Therefore, Malaysia is relatively free from severe natural disasters such as volcanic eruptions, earthquakes, and volcanic eruptions, which are common occurrences in the neighbouring countries. Nevertheless, Malaysia is still subjected to natural disasters such as monsoon floods, landslides, forest fires, tsunami, and severe haze, as well as man-made disasters as a result of technological disasters due to plant and factory failures, transportation accidents, public place failures, and production failures (Mohamed Shaluf & Ahmadun, 2006).

In Malaysia, flood is the most commonly occurring natural disaster due to the geographical characteristics of the country that brings an abundance of rain during the monsoon season and also due to convectional rain during the hot but humid periods (Department of Drainage Malaysia [DID], 2009). Despite being a common occurrence, flood becomes an issue when it threatens lives and properties, as well as severely disrupts social and economic activities. At times, a flood event is classified as a disaster when it occurs unexpectedly, covers large areas, affects a large population and many properties, and exceeds the ability of the community or society to cope using its own resources (Noji, 2000). From 2012 until 2017, 12 occurrences of flood were reported (National Disaster Management Agency [NADMA], 2017), which had affected mostly the states in the East Coast of Malaysia.

The most common environmental impacts of flood disaster are grouped by the availability of clean water and sanitation, wastewater and solid waste disposal, safe, clean and sufficient food, vector control, and health of the affected community (Kintziger et al., 2017; Wisner & Adams, 2002). The groups that are most vulnerable to the impacts of flood are women, children, the elderly, the rural poor, the displaced, and people with disabilities (Global Network of Civil Society Organisations for Disaster Reduction [GNDR], 2013; Shimi, Parvin, Biswas & Shaw, 2010). According to the World Health Organization (WHO), the major risk factor for communicable disease outbreaks associated with impacts of flooding is the contamination of drinking water facilities secondary to water treatment plants shutdown and disrupted piped water supply due to site flooding. As water supply and sanitation are severely affected, the risk of the spreading of waterborne and fatal diseases subsequently increases during the flood period (Mahmood, 2004). Full recovery of the water supply system is expected only after two weeks post-disaster, thus the need for alternative sources of clean water such as portable water tankers and bottled drinking water.

Heavy rainfall also adversely affects the available septic tanks and small private sewage treatment systems. Flooding and saturated soil conditions contribute to the malfunction of private sewage systems. Another aspect of concern is the management of sewage from temporary settlements and relief centres. Issues that may arise from these conditions include contamination of private drinking water supplies, disruption of sewage network system, and contamination of buildings as well as belongings with effluent contaminated water. In these situations, the potential of communicable disease outbreaks is high and this puts the public at a higher risk of contracting infectious diseases. Hence, it is vital to look into the sewage management system and be prepared for potential flood disasters.

Besides clean water and sewage management issues, disaster waste is also a concern. Floods can result in large quantities of solid and liquid waste that would jeopardize public health,

hinder reconstruction, and pose negative impacts to the environment, if not managed properly. Disaster waste is generated during the actual disaster and later, during the response and recovery phase. The waste may contain valuable materials such as concrete, steel (Kourmpanis et al., 2008), timber, as well as organic materials which are suitable for composting (Environmental Protection Agency [EPA], 2008; Baycan, 2004). Some valuable materials can be recycled as reconstruction materials to reduce the burden on natural resources that might otherwise be harvested for reconstruction or sold off as a source of income for the affected communities. Therefore, safe handling, removal, and management of disaster waste are important aspects particularly during the disaster response and recovery phase.

As flood causes the population to be exposed to adverse environmental conditions and disrupts the available systems and services, effective management of environmental health following a flood disaster is of primary importance. Pressing issues that require consideration after a flood disaster include: the provision of appropriate shelter for individuals or groups of people left homeless (Alderman, Turner & Tong, 2012); the distribution of safe and accessible water, first in sufficient quantities for drinking purposes and then for other domestic uses (Cann, Thomas, Salmon, Wyn-Jones & Kay, 2013; Baqir et al., 2012); and the protection and distribution of safe food products (World Health Organization [WHO], 2018). Other issues that must be addressed in order to control environmental hazards are sanitary evacuation for excreta, liquid wastes, and refuse (WHO/UNICEF Joint Water Supply & Sanitation Monitoring Programme, 2014; Cann et al., 2013), protecting populations from common vectors of disease in stricken areas (WHO, 2018), and promoting healthy living particularly in terms of personal hygiene and sanitary housing (United Nations International Children's Emergency Fund [UNICEF], 2012; Alderman et al., 2012).

In Malaysia, the management of environmental health before, during, and after a flood disaster involves various agencies. Agencies such as the Department of Irrigation and Drainage (DID), Public Works Department, Malaysian Meteorological Department, local agencies, Department of Environment (DOE), and Department of Town and Country Planning are typically involved in the flood mitigation process (Center for Excellence in Disaster Management & Humanitarian Assistance [CFE-DM], 2016; Shafiai & Khalid, 2016; DID, 2009). During and after a flood disaster, agencies that provide assistance in environmental health management include the Ministry of Health Malaysia (MOH), local authorities, and National Solid Waste Management Department (CFE-DM, 2016; Shafiai & Khalid, 2016; National Security Council [NSC], 1997). The roles of the agencies involved are explained briefly in Table 1.

For effective management of environmental health during and after a flood disaster, it is crucial to have a preparedness plan in effect even before the disaster actually occurred. During a disaster, success in environmental health management largely depends on exercising good and rapid judgement, coupled with appropriate response measures. Decisions are best made by taking into account the initial rapid ground assessment on the severity of the disaster and the specific effects of the disaster on the local community. High-level decision makers should also be trained in implementing sound response measures to maintain decent environmental health after a disaster.

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Table 1. *Roles of agencies in environmental health management of flood disaster in Malaysia*

Agency	Roles
Department of Irrigation and Drainage (DID)	To monitor river flow, rain, and floods. To oversee flood mitigation plans such as improving river channel sections, building of flood bunds, levees, ring bunds, and bypass flood ways, use of mining pools for flood attenuation, and construction of flood retention dams to regulate flood flows and minimise flood occurrence (CFE-DM, 2016).
Public Works Department	To monitor risks of landslides (CFE-DM, 2016).
Malaysian Meteorological Department	To provide information and warning on weather, sea conditions, seismicity, and tsunamis. Special emphasis is given to heavy rainfall, strong wind and high waves, intense haze episodes, and drought (CFE-DM, 2016).
Department of Environment (DOE)	To plan and implement management strategies for substance or hazardous waste To regulate waste treatment and disposal license. To coordinate enforcement activities for illegal disposal of wastes. To plan and implement contaminated land management (CFE-DM, 2016).

The aim of this article is to discuss the strengths, weaknesses, opportunities, and threats in the provision of clean water, sewage disposal, and disaster waste management for flood disaster in Malaysia as well as to recommend viable improvements in the planning of environmental health management specific to flood disaster. For the purpose of this article, disaster waste does not include human corpses and animal carcasses.

2.0 Materials and methods

Literature review was conducted using scoping review method, following the framework outlined by Arksey and O'Malley (2005). This review was guided by the following research question: 'What are the strengths, weaknesses, opportunities, and threats to the current flood disaster management in Malaysia, specifically in the provision of clean water, sewage disposal, and disaster waste management?' The search terms used include 'flood disaster', 'environmental health', 'clean water', 'sewage', 'disaster waste', 'evaluation', and 'Malaysia'.

Sources of literature include electronic databases, namely PubMed and Medline; public domain databases, namely Google and Google Scholar; and articles and reports accessed through manual searches, which were identified by combing through the references from relevant literature. The *a priori* decision was made to only screen the first 100 hits after sorting them based on relevance. Information used in this article was obtained from guidelines, reports, articles, journals, and various publications related to environmental health management in disasters published by numerous sources such as the MOH, academic institutions, and international organisations frequently involved in disaster management. All published and unpublished articles and reviews were included. Materials published in other languages apart from English and Malay were excluded.

Figure 1 shows a flow diagram depicting the study selection process in accordance with the PRISMA statement (Moher, Liberati, Tetzlaff, Altman & The PRISMA Group, 2009). The search yielded 91 potentially relevant articles. 30 articles were assessed and reviewed to determine the strengths, weaknesses, opportunities, and threats in the aspect of providing clean water, sewage disposal, and disaster waste management in a flood disaster. Strengths are defined as internal attributes and resources that support a successful outcome. Weaknesses are internal attributes that work against a successful outcome. Opportunities are external factors

that can be capitalised to support a successful outcome. Threats are external factors that can work against a successful outcome.

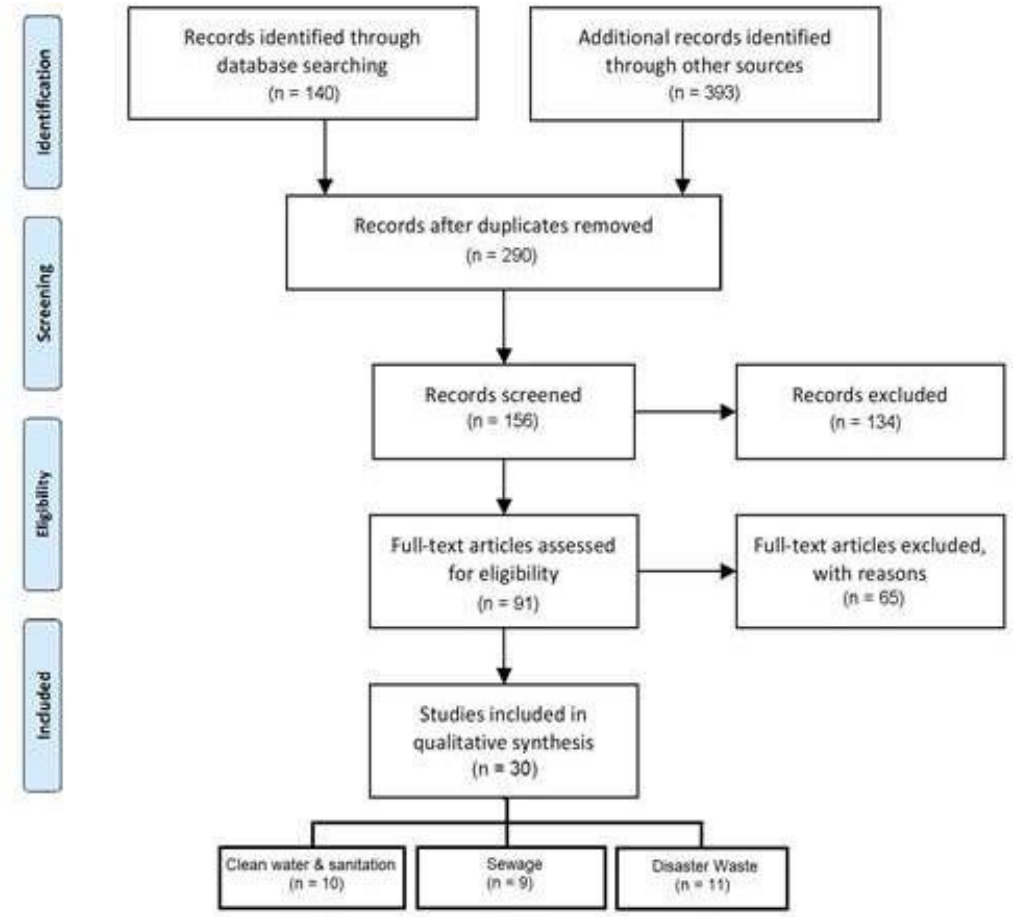

Figure 1: PRISMA flow diagram for environmental health management in a flood disaster

The identified key internal and external factors are subsequently clustered into the TOWS matrix (Weihrich, 1982), as shown in Table 2. TOWS matrix is a tool for situational analysis, which serves as a conceptual framework for a systematic and comprehensive analysis that facilitates the matching of external threats and opportunities with internal weaknesses and strengths to develop potential strategies and actions for the improvement of environmental health management related to a flood disaster (Weihrich, 1982).

Table 2: *TOWS Matrix*

	STRENGTHS	**WEAKNESSES**
OPPORTUNITIES	**STRENGTH-OPPORTUNITY (S-O) STRATEGIES** Use strengths to take advantage of opportunities	**WEAKNESS-OPPORTUNITY (W-O) STRATEGIES** Overcome weaknesses by taking advantage of opportunities
THREATS	**STRENGTH-THREAT (S-T) STRATEGIES** Use strengths to avoid threats	**WEAKNESS-THREAT (W-T) STRATEGIES** Minimise weaknesses and avoid threats

3.0 Results and discussion

Most flood disaster studies in Malaysia discuss flood disaster management from the aspects of pre-disaster, during the disaster, and post-disaster (Islam, Kamaruddin, Ahmad, Jan & Anuar, 2016; Shafiai & Khalid, 2016; Said, Abdul Gapor, Samian & Abd Aziz, 2013; Zaiton, Mohd Bahrin & Zaharah, 2013; Musa et al., 2013; Chan, 2012; Chan, 1995). Only a few studies actually discuss the aspects of clean water provision, sewage disposal, and disaster waste management related to a flood disaster (Zawawi, Yusof, Ismail & Bakar, 2017; Yahaya, Lim, Taha & Pereira, 2016; Yusof, Zawawi & Ismail, 2016; Saat et al., 2016; Pertubuhan Arkitek Malaysia [PAM], 2015; Saat et al., 2015).

Findings from the literature review were analysed using the TOWS matrix to recommend potential strategies for the improvement of three aspects in environmental health management, namely clean water provision, sewage disposal, and disaster waste management. The summaries of the strengths, weaknesses, opportunities, and threats in the provision of clean water, sewage disposal, and disaster waste management in a flood disaster are listed in Tables 3 and 4 below.

3.1 Strengths, weaknesses, opportunities, and threats to the environmental health management

Environmental health management is defined as the intentional modification of the natural and built environment in order to reduce undesirable risks to human health and to provide opportunities to improve health (Wisner & Adams, 2002). Management of environmental health in a flood disaster involves three big areas, which include the provision of clean water, a well-planned sewage disposal, and disaster waste management.

3.1.1 Provision of clean water in flood disaster management

In terms of sources of clean water after flood, one of the strengths and opportunities is the availability of alternative water sources such as rainwater (Centers for Disease Control and Prevention [CDC], 2017). This is considered a fortunate situation since in most situations during a flood disaster, water supply from centralised plants to households will need to be disconnected to avoid contamination of the treated water (Wisner & Adams, 2002). Rainwater, which is relatively clean and abundant during the rainy season, can be harvested for daily use (Che-Ani et al., 2009; Ho et al., 2007). There are also temporary communal tube wells that can be used by the affected villagers, often dug by non-governmental organisations as part of the disaster response (Pan American Health Organization [PAHO], 2000), but they are also susceptible to contamination (Sirajul Islam et al., 2007). A noticeable weakness in the provision of clean water is the absence of affordable and reliable technological innovation to re-establish clean water supply according to WHO standards in a timely manner post flood (WHO, 2002). Meanwhile, threats in the provision of clean water after flood include high water consumption per person and the disruption of clean water supply during the disaster (CFE-DM, 2016).

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Table 3: *Strengths and weaknesses in the provision of clean water, sewage disposal, and disaster waste management in a flood disaster*

Strengths (S)	Weaknesses (W)
(wS1) Villagers are used to two sources of water supply from centralised plants and local wells (PAM, 2015). **(wS2)** Non-governmental organisations (NGOs) have managed to dig tube wells at locations recommended by the villagers for temporary communal use (PAHO, 2000). **(wS3)** Water supply is chlorinated before consumption and the source is disinfected and protected (WHO, 2002). **(wS4)** Availability of national guidelines on drinking water quality (MOH, 2010). **(sS1)** Initiation of government agencies pertaining to sanitation and hygiene (community kitchen, temporary shelter, toilets, water supplies, and solid-waste disposal (Lokman Hakim, 2015). **(sS2)** DID's Flood Mitigation Policy and Strategy and development of flood forecasting models (Department of Irrigation and Drainage [DID], 2017). **(sS3)** Sewage treatment plants are located at higher grounds - categorisation by Indah Water Konsortium (Bernama, 2017). **(dS1)** Awareness promotion and public education in relation to disaster waste management by distributing educational material (Saat et al., 2015). **(dS2)** Availability of laws and regulations in managing waste – Local Government Act (2007), Environmental Quality Act (1974), Solid Waste and Public Cleansing Management Act (2007).	**(wW1)** Water supplies from centralised plants have to be disconnected during disaster (Wisner & Adams, 2002). **(wW2)** Wells would be contaminated during flood (Sirajul Islam et al., 2007). **(wW3)** Lack of formal means of declaring that the re-established water supplies are safe as per WHO standards (WHO, 2002). **(sW1)** Ad-hoc construction of sanitary and sewage systems without consideration of possible contamination risks, especially as density increases (PAM, 2015). **(sW2)** Limited enforcement for a sudden increase in the number of pollution sources (Integrated Water Resources Management [IWRM], 2017). **(sW3)** Absence of a government agency that is directly responsible for regulating the pour flush latrine system in the rural areas (PAM, 2015). **(sW4)** Lack of interaction and cooperation amongst government agencies in managing sewage disposal after floods (Lokman Hakim, 2015). **(sW5)** Policy on desludging has not been gazetted (Chan, 2012). **(sW6)** Existing sewage and drainage systems are not capable of handling a sudden surge of rainwater, causing flood during rainy season (Chan, 1998). **(sW7)** Obstruction of sewage treatment capacity during flood (Bernama, 2017). **(dW1)** Solid Waste and Public Cleansing Management Act (2007) does not specify disaster waste and does not comprehensively address the scope of waste management (Yusof et al., 2016). **(dW2)** No proper disaster waste management system or standard operating protocol (PAM, 2015; Saat et al., 2015). **(dW3)** Prolonged disaster waste collection process (Lokman Hakim, 2015). **(dW4)** Disaster waste management is arranged and handled by several government agencies (Yusof et al., 2016). **(dW5)** No special committee in charge of managing disaster waste (Zawawi et al., 2017). **(dW6)** No specific tasks for each agency in managing disaster waste (Zawawi et al., 2017). **(dW7)** No enforcement in handling disaster waste (Zawawi, Yusof & Ismail, 2016). **(dW8)** Destruction of local waste disposal system after flood (Lokman Hakim, 2015). **(dW9)** Unengineered waste disposal sites (Rahim, Yusoff, Samsudin, Yaacob & Rafek, 2010). **(dW10)** Lack of facilities such as collection bins and trucks (Saat et al., 2016) and insufficient landfill sites for waste disposal (Manaf, Samah & Zukki, 2009). **(dW11)** Insufficient funds and financial allocation to manage disaster waste (Saat et al., 2016).

(wS) – Strength in the provision of clean water
(wW) – Weakness in the provision of clean water
(sS) – Strength in sewage disposal
(sW) – Weakness in sewage disposal
(dS) – Strength in disaster waste management
(dW) – Weakness in disaster waste management

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Table 4: *Opportunities and threats in the provision of clean water, sewage disposal, and disaster waste management in a flood disaster*

Opportunities (O)	Threats (T)
(wO1) Harvesting rainwater as an alternative source of water supply may reduce the abundant amount of rainwater that goes to the drainage and avoid flood (Che-Ani, Shaari, Sairi, Zain & Tahir, 2009).	**(wT1)** High water usage per person and high maintenance of the infrastructure for water supply (CFE-DM, 2016).
(wO2) Rainwater is relatively clean, independent, and able to provide sufficient alternative water supply (Ho et al., 2007).	**(sT1)** Unseen risks from existing sewage system and water supply (e.g. contamination of surrounding areas and water due to leaching and overflow of wastewater and chemicals during flood) (PAM, 2015).
(SO1) Educating locals on the toxicity of sewage and safe sanitary provision (Lokman Hakim, 2015).	**(sT2)** Spreading of faecal-oral disease (Hamzah, 2015).
(sO2) Possibility of connecting sewage system with agricultural system (e.g. fertiliser and conversion to energy) (PAM, 2015).	**(dT1)** Presence of illegal dumping sites (Norafiza, 2013).
(sO3) Undamaged sanitary and sewage system after floods (PAM, 2015).	**(dT2)** Inappropriate residents' behaviour such as throwing waste in stages, dumping waste at undesignated sites (e.g. along roadsides), and recollecting waste from waste management agencies (Saat et al., 2016).
(sO4) Individual septic tanks at most houses (PAM, 2015).	**(dT3)** Open burning of disaster waste (PAM, 2015; Saat et al., 2015).
(dO1) Assistance in waste education and communal work by the NGOs (Saat et al., 2015).	**(dT4)** Unexpected magnitude of flood (Saat et al., 2016).
(dO2) Cooperation between all parties within the waste sector in public awareness (Yusof et al., 2016).	**(dT5)** Lack of recycling market for disaster waste (Oh, Pang & Chua, 2010).
(dO3) Communal work to clean up the disaster waste (Saat et al., 2015).	

(wO) – Opportunity in the provision of clean water
(wT) – Threat in the provision of clean water
(sO) – Opportunity in sewage disposal
(sT) – Threat in sewage disposal
(dO) – Opportunity in disaster waste management
(dT) – Threat in disaster waste management

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3.1.2 Sewage disposal in flood disaster management

One of the strengths identified in sewage disposal following floods is the current ability and preparedness of the government and other responsible agencies in managing sewage at all phases of the disaster. Currently, there are several regulations regulating sewage disposal in Malaysia, such as the Environmental Quality (Sewage) Regulations (2009) under the Environmental Quality Act (1974). However, there are no specific provisions on the management of sewage disposal following disasters. Government agencies involved in the flood disaster preparedness plan have outlined different strategies to manage environmental health based on their capabilities and job scopes. For instance, MOH plays a vital role in ensuring good sanitation and hygiene in order to control the spread of infectious diseases following a flood. Other related agencies such as the Indah Water Konsortium (IWK) has developed its preparedness plan based on individual sewage treatment plants which are categorised according to the risk of flooding. With regard to weaknesses, limited manpower and financial resources has been cited as one of the main causes for improper sewage management during disaster. At present, no specific policy or guideline has been proposed to encounter sewage problems during disaster. Furthermore, no specific agency has been directly assigned to manage sewage problems following a flood, resulting in poor coordination, collaboration, and cooperation between agencies involved in sewage management (PAM, 2015). Other identified weaknesses include a poorly planned and an unsystematic construction of sewage network, leading to the obstruction and incapability of the sewage system to handle a sudden surge of rainwater which causes flood during the rainy season (IWRM, 2017; PAM, 2015; Chan, 1998).

Possible opportunities in sewage management include the involvement of NGOs and communities, and engineering advancement. Most of the population in flood-prone areas are aware of the impact of poorly managed sewage, such as its toxicity and the risks of contracting infectious diseases (Lokman Hakim, 2015). As a result of awareness and educational activities, the affected population are mindful of safety precautions that should be taken during a flood. In most areas, especially urban areas, due to engineering advancement, most houses have individual septic tanks which can remain intact even after a flood (PAM, 2015). In addition, there are also threats in the sewage management after a flood. Identified threats include the inability to assess the magnitude of the flood, the extent of sewage contamination due to an overflow of wastewater and chemicals during flood (PAM, 2015), as well as the risks of faecal-oral diseases spreading from the existing sewage system (Hamzah, 2015).

3.1.3 Disaster waste management in flood disaster management

At a broader level, the availability of a legal framework to provide for and regulate the management of solid waste as well as the effort to educate the population regarding disaster waste (Saat et al., 2015) are the strengths in disaster waste management. Meanwhile, the identified weaknesses in the current disaster waste management practice are the lack of vision, framework, plans and benchmarks (PAM, 2015; Sat et al., 2015), uncoordinated and unspecified roles for the agencies (Yusof et al., 2016; Zawawi et al., 2017; Zawawi et al., 2016), as well as insufficient funds (Saat et al., 2016) and lack of solid waste management facilities such as landfills (Rahim et al., 2010; Manaf et al., 2009), collection bins, and garbage trucks (Saat et al., 2016). Often, the response to managing disaster waste are either no action is taken, in which the waste is left to accumulate and decompose, or improper action, in which the waste is removed and dumped in an uncontrolled manner (Rahim et al., 2010). The National Solid

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Waste Management Department has been established to propose policies, plans, and strategies in respect of solid waste; however, disaster waste management is not mentioned in either the Solid Waste and Public Cleansing Management Act (2007) and its regulations or the National Solid Waste Management Policy (Yusof et al., 2016).

Available opportunities in disaster waste management after a flood include a strong network of agencies within the waste sector and NGOs dedicated to educate the public regarding proper waste management as well as community involvement (Yusof et al., 2016; Saat et al., 2015). On the other hand, threats to the current disaster waste management include inappropriate community attitude (Saat et al., 2016; PAM, 2015; Saat et al., 2015), unexpected magnitude of flood (Saat et al., 2016), and lack of recycling market for disaster waste (Oh et al., 2010).

3.2 Strategies for improvement

Potential strategies and actions for improvement in environmental health management during a flood disaster, specifically in the aspects of the provision of clean water, sewage disposal, and disaster waste management are presented in Table 5.

3.2.1 Strength-Opportunity (S-O) Strategies

The strength-opportunity (S-O) strategies draw on the strengths to take advantage of the opportunities. One of the strategies is to empower the community with regard to the idea of using other sources of clean water following a flood disaster, such as the portable atmospheric water generator (Dash & Mohapatra, 2015) and mobile water purification system (Werber et al., 2016; Savage & Diallo, 2005). These water sources are viable options as flooding in Malaysia is mostly due to heavy rainfall. Communities in flood-prone areas in the East Coast of Malaysia are already able to adapt to different sources of water, mainly from centralised water-treatment plants as well as local wells. However, making these new technologies affordable and accessible to individuals and households is a challenge. It requires and relies on the cooperation of new partners, especially from within the private sector (UNICEF, 2016). This strategy is aligned with the two targets in the Sustainable Development Goal (SDG) 6 (clean water and sanitation), which are to achieve universal and equitable access to safe and affordable drinking water for all as well as to achieve adequate and equitable access to sanitation, as the destructive impacts of flood are an increasing threat to clean water and sanitation system (United Nations Development Programme [UNDP], 2015). UNICEF Strategy for Water, Sanitation, and Hygiene (WASH) 2016-2030 also advocates developing strategies which are built on lessons from existing programmes and experiences to ensure that children, in particular, have access to clean water and adequate sanitation, even in extreme events such as floods (UNICEF, 2016). Lessons learned over the previous UNICEF WASH Strategy 2006-2015 include the substantial value in technological innovation, good and sustainable programme models and management practices, and the importance of building community resilience (UNICEF, 2016).

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Table 5: *TOWS Strategies in the provision of clean water, sewage disposal, and disaster waste management in flood disaster*

S-O Strategies	W-O Strategies	S-T Strategies	W-T Strategies
(S-O1) To empower the community with regard to the idea of alternative sources of clean water such as rainwater (Che-Ani et al., 2009; Ho et al., 2007; Centers for Disease Control and Prevention [CDC], 2017), portable atmospheric water generator (Dash & Mohapatra, 2015), and mobile water purification system (Werber, Osuji & Elimelech, 2016; Savage & Diallo, 2005). **[wO1, wO2, wS1]** **(S-O2)** To establish cooperation especially from within the private sector to develop and provide affordable and accessible alternative sources of clean water to individuals and households (UNICEF, 2016). **[wO1, wS2]** **(S-O3)** To issue regulation, policy, and guidelines specific to the management of disaster waste (National Institute for Environmental Studies [NIES], 2015; Joint UNEP/OCHA Environment Unit, 2013; Asari et al., 2013; EPA, 2008). **[dS2, dO1, dO2]** **(S-O4)** To educate the public on the "3R" concept (Agamuthu & Victor, 2011), toxicity of waste and its impact to human and environment (PAM, 2015), the importance of reducing disaster debris generation by building and strengthening their homes to resist floods (EPA, 2008), and the reuse and recycling of disaster debris (World Bank, 2008). **[dO1, dS1, dS2]** **(S-O5)** To establish cooperation between agencies within the waste sector in educating the public on disaster waste management (Zawawi, Yusof, Kamaruzzaman & Ismail, 2015). **[dO1, dO2, dS1]** **(S-O6)** To establish continuous engagement with the community to empower them and to build resilience (Zawawi et al., 2015). **[dO1, dO3, dS1]**	**(W-O1)** To promote proper harvesting and usage of rainwater (Ho et al., 2007). **[wO1, wO2, wW1, wW2]** **(W-O2)** To design and establish flood-resistant sewage network with possible alternative connections (PAM, 2015). **[sO2, sO3, sW1, sW6, sW7]** **(W-O3)** To enhance health promotion and education on the toxicity of sewage and benefits of safe sanitary (Lokman Hakim, 2015). **[sO1, sW1]** **(W-O4)** To engage all parties within the waste sector in the development of a comprehensive framework in managing disaster waste after flood (Zawawi et al., 2017; Yusof et al., 2016). **[dO2, dW2, dW3, dW4, dW5, dW6, dW7, dW9]** **(W-O5)** To engage the public in disaster waste management (Saat et al., 2015). **[dO3, dW8]**	**(S-T1)** To educate the public and implement psychological intervention to reduce water usage per person (de Miranda Coelho, Gouveia, de Souza, Milfont & Barros, 2016). **[wT1, wS1, wS2]** **(S-T2)** To enforce waste legislation. **[dT1, dT2, dT3, dS2]** **(S-T3)** To promote awareness and provide education on disaster waste to encourage a change of attitude and behaviour among the public (Rahmaddin, Hidayat & Yanuwiadi, 2015**). [dT1, dT2, dT3, dS1]**	**(W-T1)** To organise a disaster drill exercise in order to anticipate and manage threats and weaknesses during a real event occurrence (Nazli, Sipon & Radzi, 2014). **[wT1, sT1, dT4, wW1, wW2, sW1, sW2, sW3, sW4, sW6, dW2, dW5, dW6]** **(W-T2)** To set up contingency funds for emergency response along with local vendor agreements to ensure stock supplies during floods (Phalkey, Dash, Mukhopadhyay, Runge-Ranzinger & Marx, 2012). **[sT4, dT4, sW2, sW3, sW6, dW10, dW11]**

S-O	Strength-Opportunity	W-O	Weakness-Opportunity		
S-T	Strength-Threat	W-T	Weakness-Threat		
wS	Strength in the provision of clean water	sS	Strength in sewage disposal	dS	Strength in disaster waste management
wW	Weakness in the provision of clean water	sW	Weakness in sewage disposal	dW	Weakness in disaster waste management
wO	Opportunity in the provision of clean water	sO	Opportunity in sewage disposal	dO	Opportunity in disaster waste management
wT	Threat in the provision of clean water	sT	Threat in sewage disposal	dT	Threat in disaster waste management

In a disaster of larger scale, temporary settlements and relief camps with sanitation and water treatment facilities may be established. Regular water quality monitoring and disease surveillance activities may be conducted as well. On top of that, rigorous hygiene promotion is also conducted in the temporary settlements and relief camps using different approaches that should be suitable for different age groups. These activities are usually carried out by the first responders in the affected areas, mainly the government health workers and community workers from various NGOs. It is important that the affected communities be made aware of the activities conducted pertaining to the provision of clean water and sanitation. In order to efficiently and effectively cater the needs of the affected communities, decisions must be tailored based on the situation on the ground (Krishnan, Twigg & Johnson, 2013).

With regard to solid waste management (SWM), the Solid Waste and Public Cleansing Management Act (2007) provides a comprehensive and coherent approach to SWM, including institutional arrangements (Yahaya & Larsen, 2008). The provisions in this act covers any type of waste except for scheduled waste, sewage, and radioactive waste. This act also provides the fundamental authority and resources for the implementation of 3R (reduce, reuse, and recycle) policies and waste minimisation (Agamuthu & Victor, 2011). However, there is no specific provision for disaster waste. Amendments may be made to the Solid Waste and Public Cleansing Management Act (2007) to include disaster waste so that the National Solid Waste Management Department may issue regulations, policies, and guidelines (National Institute for Environmental Studies [NIES], 2015; Joint UNEP/OCHA Environment Unit, 2013; Asari et al., 2013; EPA, 2008) specific to the management of disaster waste. The 3R concept can be included as part of the disaster waste management system. Members of the public can be made aware of the importance of building homes and public buildings that can resist floods as to reduce the generation of disaster debris post flood (EPA, 2008). Other means of controlling disaster waste generation is through the reuse and recycling of disaster debris, as had been done by countries like Indonesia, which was severely devastated by the tsunami (World Bank, 2008). Environmentally sound management of chemicals and wastes throughout their lifecycle is advocated in the SDG 12, which is responsible consumption and production (UNDP, 2015). In order to motivate the public to adopt the 3R concept, communities in flood-prone areas can be educated on the subject of toxicity of waste and its impact on human and the environment (PAM, 2015). Success in educating the public relies on the cooperation between agencies within the waste sector and continuous engagement with the community members for the purpose of empowering them and building resilience (Yusof et al., 2010).

3.2.2 Weakness-Opportunity (W-O) Strategies

The weakness-opportunity (W-O) strategies entail taking advantage of external opportunities to minimise or overcome weaknesses. In the environmental health management of flood disaster, the weaknesses in the provision of clean water after flood can be overcome by proper harvesting of rainwater for consumption. New technologies in rainwater harvesting will make a difference in resolving the shortage of clean water supply during a disaster (Ho et al., 2007). Concerning the aspect of sewage management, proper designing of sewage network with possible alternative connections especially in areas with a high risk of flooding will reduce the possibility of groundwater and surface water contamination (PAM, 2015). This is in line with one of the targets specified in the SDG 11 (sustainable cities and communities), which is “to increase the number of human settlements that adopt and implement integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change,

resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030" (UNDP, 2015).

Another target in the SDG 11 is to reduce the number of people affected by water-related disasters (UNDP, 2015). In order to reduce the transmission and incidence of infectious diseases during floods, health promotion and sanitary hygiene education for the affected community should be enhanced, even more so if there is widespread malfunction of the sewage system (Lokman Hakim, 2015). A W-O strategy that can be implemented in disaster waste management is promoting strong collaboration and networking among agencies within the waste sector from both government and private sides in the planning stage of the national and local disaster preparedness plan (Zawawi et al., 2017; Yusof et al., 2016). With limited resources in managing disaster waste, proper coordination and specification of roles for all related agencies, NGOs, and involvement of the public will make disaster waste management more effective and sustainable (Saat et al., 2015). This is in line with the multi-stakeholder partnerships target in the SDG 17 (partnership for the goals) which is "to encourage and promote effective public, public-private, and civil society partnerships, building on the experience and resourcing strategies of partnerships" (UNDP, 2015).

3.2.3 Strength-Threat (S-T) Strategies

For strength-threat (S-T) strategies, internal strengths are utilised to avoid the occurrence of external threats. Internal strengths are crucial to overcome the threats posed by a disaster. In the environmental health management of clean water provision and disaster waste disposal, the threats can be overcome through collaborative efforts by the local government and NGOs to promote awareness and to provide education by distributing promotional and educational materials. Psychological intervention may also be implemented to encourage the public to practice water conservation methods and to execute proper disaster waste disposal (Saat et al., 2015). There are available laws and regulations pertaining to the management of waste, for example the Local Government Act (2007), Environmental Quality Act (1974), and Solid Waste and Public Cleansing Management Act (2007). One of the strategies is strict enforcement of these acts by relevant authorities as a way to deter the public from throwing their waste at undesignated dumping sites after the flood subsides.

Meanwhile, an S-T strategy to minimise the risks of faecal-oral diseases as a result of sewage contamination after flood is to have a well-planned DID's Flood Mitigation Policy and Strategy (Department of Irrigation and Drainage [DID], 2017). Currently, one commendable effort by the DID is the development of flood forecasting models to guide the department in predicting the time, location, and scale of a flood. In areas predicted to be severely affected by flood, sewage treatment plants can be built at high-rise areas to lessen the risk of wastewater and chemicals overflowing during a flood and to reduce water contamination, which can subsequently reduce the spread of waterborne diseases. The next strategy is to protect and disinfect available water sources and to chlorinate the water before consumption (WHO, 2002). The quality of drinking water must conform to the National Drinking Water Quality Standard (Ministry of Health [MOH], 2010). This can be achieved by having affordable, reliable, and portable water quality testing equipment that can measure multiple related parameters. Multiple agencies can contribute towards the innovation of this equipment, including the academic partners. Another strategy is to initiate a combined and concerted effort between agencies within this sector to promote sanitary and hygiene activities in community kitchens, temporary relief centres, and shelters before, during, and after flood (Lokman Hakim, 2015). This strategy

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can lead to a more efficient management during and post-disaster, be it financially or in terms of other resources.

3.2.4 Weakness-Threat (W-T) Strategies

The final strategy is essentially the most defensive position in the TOWS strategies. The weakness-threat (W-T) strategies are most often implemented when an event is expected or has already reached a bad state. When many known weaknesses are anticipated and there are threats to the event, stakeholders will need to implement two-pronged strategies to minimise those weaknesses and avoid the threats. This is because the impact of weaknesses on the environmental health management will be more pronounced if threats are also present. For example, the burden of managing disaster waste by the local authorities will be worse if the community demonstrates a poor attitude towards reducing, reusing, and recycling their wastes. One of the strategies that can be implemented is to organise a flood disaster drill focusing on the issues of clean water, together with sewage and disaster wastes. The drill should involve the relevant authorities, NGOs, as well as the local communities in order to anticipate and manage weaknesses and threats during the real event occurrence (Nazli et al., 2014). It is also a good strategy to develop community resilience towards disasters, in line with the SDG 11 (sustainable cities and communities) and SDG 13 (climate action) (UNDP, 2015).

Another possible strategy to reduce weaknesses and avoid threats is to set up contingency funds as part of the disaster preparedness plan to allow a timely emergency response. Local vendors that can provide basic necessity supplies such as clean drinking water, water storage containers, ration packs, and hygiene kits should be identified and agreements should be made beforehand to ensure sufficient stock supplies during flood (Phalkey et al., 2012). This is also part of the strategies to achieve one of the targets in the SDG 2 (zero hunger), which is "to end hunger and ensure access by all people, in particular the people in vulnerable situations, to safe, nutritious, and sufficient food" (UNDP, 2015).

4.0 Conclusion and recommendation

Flood disasters are usually followed by the spread of water-related diseases, depending on the environmental conditions and human behaviour that determine control and prevention of diseases (Connolly et al., 2004). Therefore, from a public health perspective, provision of clean water supply, hygiene interventions, and waste management are very significant in disaster response efforts.

Generally, environmental health management issues related to flood disasters in Malaysia have not been seriously addressed. We have identified the following four main elements that can be improved in order to have a better environmental health management in Malaysia: legislations, regulations, and guidelines; flood disaster management plan at the district, state, and central level in the area of risk assessment, risk management, preparedness and response plan, training and response exercise, and evaluation; public attitude and community resilience; and the collaboration, cooperation, and partnership between local and international stakeholders. Developing management strategies for environmental health, particularly concerning a disaster, is a fundamental task. Strategies to address weaknesses and threats of the current system must be realistic, taking into account both limits and resources; that is, the strategies must be guided

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by the local situation and needs. Thus, more empirical evidence and evaluative studies of the current environmental health management system, specifically on the provision of clean water, sewage disposal, and disaster waste management are required to provide critical information on the current local scenario and steer the actions that should be taken for improvement.

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Declaration

The authors declare no conflict of interest.

Authors' contributions

Author 1: Information gathering, preparation, and editing of manuscript
Author 2: Information gathering, preparation, and editing of manuscript
Author 3: Information gathering, preparation, and editing of manuscript
Author 4: Review of manuscript and editing

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