PUBLIC HEALTH RESEARCH

Socio-Ecological Framework on Risk of Prolonged Dengue Outbreak in Seremban District: A Qualitative Study

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ABSTRACT

Introduction	A prolonged duration of a dengue outbreak in a locality poses a detrimental risk to the susceptible population. There have been limited studies looking into the socio-ecological factors that can be modified to break the chain of transmission. Therefore, this study aimed to explore and identify the socio-ecological attributes experienced by the health authority in the Seremban district.
Methods	A qualitative study was performed using an in-depth interview (IDI) technique based on semi-structured questionnaires. Results were thematically analysed when theoretical saturation was achieved.
Results	A total of 12 respondents participated in this study, representing various backgrounds and involved in dengue control activities. There were nine modifiable socio-ecological themes generated, namely (1) illegal dumpsite, (2) illegal gardens, (3) illegal man-made structures, (4) old unused items, (5) idle damaged vehicles, (6) construction site, (7) drainage system, (8) physical structure, and (9) lack of community engagement. A model framework was conceptualised from the analysis. The health authority identified that these issues require urgent attention and collaborative action by various stakeholders.
Conclusion	The identified socio-ecological factors have been a challenge for the health authority. Nevertheless, identifying these attributes signifies the key to tackling the prolonged duration of the dengue outbreak. Ultimately, a multi-agency approach and community participation are vital to ensure a sustainable vector control program.
Keywords	Dengue; Disease Outbreaks; Community Participation; Socio-ecological factor

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INTRODUCTION

The World Health Organisation (WHO) estimated around 390 million dengue infections occurred per year where 96 million of dengue infections manifest clinically.[1] Likewise, dengue in Southeast Asia is a major illness which caused economic burden exceeding upper respiratory infections and Japanese encephalitis.[2] Dengue is also deemed as the most transmissible disease in Malaysia surpassing HIV/AIDS and tuberculosis.[3] In Malaysia, there were 130,101 dengue cases recorded in 2019 and this accounts for 49,486 more cases (61.4%) than it was recorded in 2018.[4]

Dengue is a dynamic disease with wide range of clinical presentations, and some cases may progress unexpectedly. Symptoms typically last 2-7 days which includes high fever (up to 40°C), eye pain, severe headache, swelling, muscle and joint pain, and vomiting.[5] Till date, there is no specific treatment; however, hospital care is vital for severe dengue or dengue fever with a warning signs cases.[6] With lack of curative treatment and absence of safe vaccine, prevention remains the main strategy. Applying epidemiological triad of dengue transmission which are vector (infected female *Aedes aegypti* and *Aedes albopictus*) and environmental factors is crucial. This is because these mosquitoes thrive in human-populated area with high adaptability and resilient characteristics to ensure survival. Their eggs are able to survive in waterless container up to 9 months, however, a small amount of water is still needed to hatch,[7, 8] while transovarial transmission further worsens the risk.

Ecological factors such as temperature, humidity, and rainfall were shown to have significant impact on the risk of dengue transmission and number of dengue cases as they alter the activities of the vector such as feeding activity and shorten the life cycle.[9, 10] However, these factors are regarded as non-modifiable since it is unregulated. Some researchers also utilised Industry Revolution (IR) 4.0 technology to develop prediction model based on these ecological factors.[11, 12] Despite the technology's ability to forecast the next locality outbreak, there are some limitations due to sole reliance on non-modifiable ecological attributes.

Nevertheless, it is proven that human behaviours can disrupt the ecology which accounts for the reason of the higher number of dengue outbreak in densely populated area.[13-15] For example, scattered garbage due to inappropriate social behaviour. The unkept humanmade containers are also the potential breeding sources for dengue vector resulting in high receptivity potential of the area. Subsequently, the introduction of few dengue viruses (DENV) into the high receptivity area will inevitably cause cataclysmic chains of transmission. Besides, transovarial transmission in widespread potential breeding areas will trigger exponential dengue transmissions and thus, prolonging the duration of the outbreak. This inter-relationship between human behaviour and ecological changes are called socio-ecological factors.

It is then imperative to determine the socio-ecological factors that cause Seremban district to suffer from prolonged duration of dengue outbreaks. While many studies have examined the general epidemiology and clinical aspects of dengue, there were comparatively little focus on the socio-ecological risks within specific local contexts. This gap is important because the characteristics that sustain outbreaks often vary by locality,[16] and without understanding these contextual drivers, outbreak control strategies may remain generic and less effective. Therefore, this qualitative study aims to explore and identify the socio-ecological factors from the health authorities' viewpoints. The socio-ecological framework produced in this study can then be adopted by other localities with similar prolonged duration of dengue outbreaks.

METHODS

Study Setting

This qualitative study was conducted in Seremban Health District Office (PKDS) and Negeri Sembilan Department of Health (JKNNS) from July 2020 until August 2020. The data obtained represent the current situation in Seremban district with an estimated population close to 700,000.

Study Design and Sampling Technique

An IDI technique was conducted solely by the principal investigator, MAIAZ. Theoretical sampling was used to obtain appropriate respondents who are experts and has vast experience in the field. The criteria used to select the respondents include consented to participate, has at least minimum 2 years of dengue vector control activities experience, and able to converse in either Malay or English language. The list of respondents was identified and the invitation cards and questionnaires were sent together with the details of the study at least one week earlier to confirm the respondents' participations. The decisions of participations were updated either via direct phone calls or face to face encounter. Data collections were carried out with semi-structured interviews and audio recordings.

The questions asked were listed in Table 1. The total number of respondents interviewed were 12 despite saturation was achieved after 6 interviews. The duration of the IDI session ranges from 20 to 55 minutes. The respondents were comfortable with the interviewer to discuss in details of the actual phenomenon at the ground levels. Triangulation was done by field observation at the outbreak area as well as by reviewing the available records such as summons form or clearance notices. All respondents conversed in Malay language were transcribed verbatim. The transcripts were then translated into English by the principal investigator

who is proficient in both languages. To ensure accuracy and minimise potential bias, the translations were independently verified by another co-researcher. Although thematic saturation (in terms of recognizing major themes) appeared to have been reached by interview 6, we continued interviewing until 12 participants. This was done to ensure meaning saturation (i.e. to capture subtler variations, depth, and nuance within themes), to validate consistency across respondents, and to allow for deviant/uncommon cases and this approach is consistent with another public health qualitative research done by Hennink et al. which showed that while code saturation can occur early, additional interviews up to ~12 can help to stabilize the themes and enrich the findings.[17]

Table 1 Questions in the Semi-Structured Interviews.

No	Questions
1.	Can you describe the trend of dengue cases in Seremban district in the past 2 years?
2.	Can you describe the trend of dengue outbreak localities in Seremban district in the past 2 years?
3.	Can you explain the cause of the increasing number of dengue outbreaks in Seremban district?
4.	How can you elaborate on the socio-ecological factors that contribute to the prolonged dengue outbreak in Seremban district?
5.	How do you find social contribution to the issue of dengue outbreak control and prevention activity?
6.	Is there anything you would like to share with me regarding locality which repeatedly becomes an outbreak within the same year?

The six phases of thematic analysis based on Braun and Clarke were used to analyse the qualitative data.[18] The transcripts were initially imported into data management software called ATLAST.ti8. In phase 1, the familiarisation of the data was performed through repetitive reading through the whole set of data. In phase 2, initial coding was carried out to organise the data segments from the entire data set into meaningful codes. The codes were then sorted into potential themes in phase 3 after coding all the transcripts by identifying significant repeated patterns across the data. The principal investigator conducted these initial 3 phases.

In phase 4, all themes were independently reviewed and revised by two other researchers, MNJ and MRH. These reviewers performed a comprehensive thematic analysis and updating, involving re-examining the original data for relevant data events for each potential theme such as extending, collapsing or discarding initial themes involving generating new themes, and addressing the themes. The subsequent thematic network concepts were then applied to promote the structuring of the themes. The basic themes derived from the textual data were categorised into the organising themes that were then linked to form global themes. These were then presented as a model depicting the multiple levels of themes and its relationship.[19] In phase 5, the emerging themes and networks were defined and given a name. Finally, review of the literature was performed prior to being incorporated into the final write-up in phase 6.

Ethical Approval

This study has been approved by the Medical Research & Ethics Committee of the Ministry of Health Malaysia (MREC) - NMRR-19-3909-51875 - and approved by the Ethics Committee in National University of Malaysia - UKM.FPR.SPI 800/2-28 -. This study has registered with the National Medical Research Register (NMRR). Informed consent was obtained from the respective respondents prior to participations in this study.

RESULTS

The characteristics of respondents were presented in Table 2. The respondents were selected based on their job scopes in dengue control activities. According to recommended guideline in controlling dengue outbreak, the activity needs to incorporate multi-disciplinary actions from vector control team, enforcement team, and also the health promotion team. An additional step was also carried out by including a representative from Ministry of Health (DRBP) as well as a representative from Pahang state (DMRBS) to look for potential transferability of the findings and to ensure rigorousness of the data. Both representatives have significant amount of experience in dengue control activities at the ground levels.

Following data familiarisation, a total of 146 codes were generated from screening all data for the risk factors that contribute to the prolonged duration of dengue outbreak in Seremban district. These codes were categorised into 18 basic themes as shown in Figure 1 and were then sorted into three main domains namely (1) vector factor, (2) host factor, and (3) environmental factor by the principal investigator. Subsequently, all independent investigators reviewed the grouping and agreed on 2 clusters of organising themes, which were (1) modifiable factor (the main subsets of all domains interceptions) and (2) the residual domain factor. The organising themes were linked to form the overall framework of risk factors for prolonged dengue outbreak as depicted in Figure 1. In regard to the main objective of this study, the focus is then

given on the 9 attributes of the modifiable factors as mentioned in the abstract. Those attributes are (1) illegal dumping site, (2) illegal gardens, (3) illegal man-made structures, (4) old unused items, (5) idle damaged vehicles, (6) construction site, (7) drainage system, (8) physical structure, and (9) lack of community engagement.

Table 2 Demographic characteristics of respondents.

No	Age	Gender	Ethnicity	Working Experience
1	36	Male	Malay	5
2	32	Male	Indian	3
3	47	Male	Malay	10
4	43	Female	Malay	3
5	32	Male	Malay	3
6	57	Male	Malay	8
7	47	Female	Malay	12
8	38	Female	Malay	11
9	42	Male	Malay	15
10	36	Female	Malay	3
11	37	Male	Malay	6
12	46	Male	Malay	8

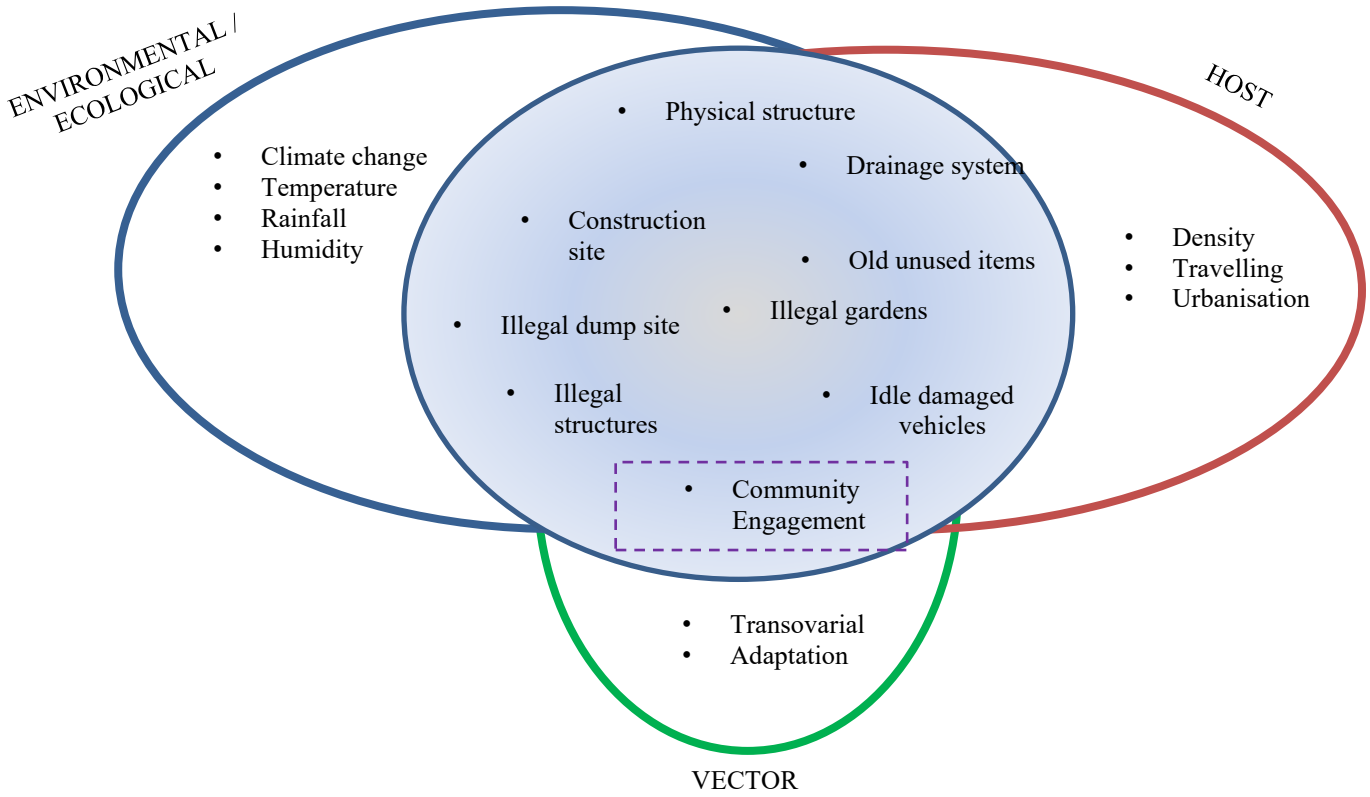

Figure 1 Framework of Socio-Ecology Risk Factor for Prolonged Dengue Outbreak

Illegal Dumping Sites

Improper waste disposal was identified as the main socio-ecological risk factor for prolonged dengue outbreaks in Seremban, with illegal dumping areas serving as breeding grounds for Aedes mosquitoes, particularly in densely populated and lower socioeconomic localities. This issue reflects poor human attitudes toward the environment, with perpetrators including both local residents and irresponsible industries. Despite varying sources, illegal dumping sites share similar characteristics; either open land or hillside areas accessible by vehicles, and the activities are often done at odd hours, making enforcement difficult.

If in housing areas, this garbage was produced by the residents. They made an illegal dumping site at the corner of the road. The common examples ... were household items such as a bed mattress of an old sofa set. ... household rubbish that was not properly disposed of ... Therefore, all these by-products and rubbish at illegal dumping sites will not be collected or removed... (DMHBMD)

... And we can assume this illegal dumping activity was perpetrated by the local residence, the shopper or the business. (DVRS)

When there is a piece of waste, it will start to accumulate. Usually, those perpetrators will dispose of the garbage at this illegal dumpsite at midnight. (PNABR)

Illegal Gardens

Illegal gardens in neighbourhoods are also potential mosquito breeding sites that contribute to dengue transmission. These lands are termed illegal as they are ungazetted and typically ownerless, a common feature across Seremban due to societal cultural practices. Often beginning as personal or community projects, many gardens were later abandoned and left unmaintained. During outbreaks, search and destroy operations in these areas frequently detected Aedes larvae, while enforcement efforts faced challenges due to ownership disputes.

The second leading cause would be the establishment of illegal gardens at the reserved area… in the beginning the place was properly maintained, but after a while the maintenance interrupted which leads to collection of water often at the flower pots, inside any plastic containers, buckets or any water containers inside these illegal gardens. (DMHBMD)

... when there is a dengue outbreak, we will check everything including the area outside the house. Even to the extend checking the illegal garden. ... found the place for mosquito breeding as a result of storing rainwater. (DLR)

..., this black water tank is usually used to store water in order to water the plant. (PABMS)

Illegal Man-Made Structures

The highly discussed attributable factor in this study is the presence of man-made structures in "no man's land" area such as car garages and illegal chicken coops, which serve as potential Aedes breeding sites. Like illegal gardens, these unmaintained structures found pose similar enforcement challenges. Built on limited budgets, they are prone to retain water after rainfall, further increasing the breeding risks.

This so-called illegal structure is among the reason for dengue transmission or causing a prolonged duration of dengue outbreak. ... this chicken coop (structure) is located at reserved area… will have containers or items to store water for feeding. (DMHBMD)

... such as hut and parking garage. ... becomes the source of breeding due to inappropriately maintained. ...the parking garage is… used to store shabby items that could hold water… (DVRS)

... take Taman KM as an example ... there are only 20 houses in the area, but the total number of cases thus far have reached 40. …one of the reasons was due to the presence of illegal structures such as illegal parking garage and chicken coop. (PNABR)

Old Unused Item

All respondents elaborated on this factor. The old unused items such as old tyres, paint container, and plastic buckets were the commonly found items during vector control activities. The hoarding attitude coupled with inappropriate housekeeping measure was described as the key to potential breeding place for the mosquitoes.

... found a breeding place behind the back alley where old unused items that have the potential to store water being kept and not disposed of well. (EMA)

The residence attitude who likes to keep shabby items such as old tyres, paint container or old furniture outside the compound could have stored water. (DMFBMY)

Not really a problem in a new housing area. I believe that old residency yes. Even some turn their house into a storage for the shabby items and sell them. (PABMS)

Idle Damaged Vehicles

Improperly managed unused vehicles, particularly those with broken windows, doors, or open compartments, can become mosquito breeding sites. In some outbreak areas, damaged cars and minivans are left around automotive shops, reflecting poor attitudes that disrupt the environment and promote vector abundance.

This idle car at the roadside usually has no windows or no back door. Thus, any water that entered can starts to accumulate on the floor or at any car part that we sometimes felt illogical to have a breeding place. (EMA)

This (idle damage car) can be an issue sometimes. The problem of an unused car is that the people left it just like that, ... when there are broken windows. ...and rainwater can enter the car and start to collect in it. (DLBR)
Sometimes, when there are broken windows, the rainwater will start to collect and nobody is going to care. So, breeding can take place even at the cushion itself. (PYBMY)

Construction Site

The construction site in this context referred to proper, well-planned, and official construction areas approved by the local authority. Although this attribute is discussed by all respondents, there were variable opinions regarding the potential risk that cause prolonged dengue outbreak in the affected locality. Nevertheless, all respondents agreed that insufficient monitoring could contribute to catastrophic events of massive breeding ground.

I am on the side that agrees about the construction site is one of the risk factors for a prolonged duration of dengue outbreak ..., whenever there is a construction project in the locality outbreak locality, we will have difficulty stopping the outbreak ... we will often find a massive breeding source. (DMHBMD)

The construction site usually has incomplete structure. There will be a loophole or many places to collect water. Thus, making it a potential place for Aedes to breed. (DMFBMY)

If we look at the situation in the whole of Malaysia, the percentage of dengue outbreak contributed from the construction area is roughly between 8-9% positive for breeding Aedes. (DRBD)

Drainage System

Obstructed or disrupted drainage flow was identified as a cause of dengue outbreaks in Seremban, with respondents highlighting rain gutters and sand traps as key issues. The disruptions were attributed to improper waste disposal and natural factors such as tree roots altering drain structures.

... an engineering defect for the obstructed drainage flow. For example, GCH and VH, that water accumulated in the drains due to rubbish obstructing the flow has led to massive breeding area. (DVRS)

... like in DP and also SV, the structural problem of the gully trap has caused water to accumulate and allowed for Aedes to breed. (DNDBMD)

The human behaviour that threw garbage into the drains will lead to obstruction. Even if the drains are not obstructed, rubbish such as polystyrene food containers can store water. (DRBD)

Physical Structure

Few respondents also claimed that physical structure of building could serve as the potential vector breeding place. This is especially seen in structure that is difficult to repair, hence allowing for potential continuous dengue transmission and, thus prolonging the outbreak.

..., they repeatedly become outbreak due to the structure of the building itself. Every year we will expect to face the same problem. ..., and once we solved it, it takes not more than six months to become an outbreak again. (DMHBMD)

... the empty house that is not maintained will have some defect, example the floor, the flushing cistern and many more. (EMHBAH)
Those abandoned house usually has damaged to the roof, windows or the door. And when the rainwater enters, it will start to accumulate. Sometimes even the floor traps water. This place contributes to breeding... (DRD)

Lack of Community Engagement

Community engagement was identified as a key socio-ecological factor, with 75% of respondents emphasizing its importance in preventing prolonged dengue outbreaks. They agreed it is the most sustainable way to monitor local areas, while lack of participation makes control difficult. In Seremban, platforms for engagement include Combination for Behavioural Impact (COMBI), which has direct link with the District Health Office, as well as *Kawasan Rukun Tetanga* (KRT) and *Majlis Pengurusan Komuniti Kampung* (MPKK), both collaborating with health authorities. Overall, community engagement was considered the most crucial factor, as it fundamentally influences the risk of prolonged outbreaks.

I can say with great confidence that those localities with COMBI platforms are actively

helping us to break the epidemiology triangle and chain of dengue transmission. (DVRS)

Usually, COMBI will be formed in the area where dengue outbreak starts to occur. ... when COMBI was established ..., the number of cases for the particular outbreak reduce or not recorded anymore. ...at some places, the COMBI itself helps from outbreak prevention. (DMFBMY)

... when the locality has COMBI established most of the time, they can subdue the outbreak faster as compared to a locality without COMBI. (PABMS)

Despite the focus on the modifiable socio-ecological risk factors, few important points were also highlighted by the respondents in regards to the residuals of the three domains, essentially considered as non-modifiable attributes. For instance, the ecology domain, the attributes were climate change, temperature, rainfall, and humidity. As for the vector domain, the themes were transovarial dengue transmission and vector adaptation. While the host domain, the risk factors revealed were population density, human travelling, and urbanisation. These were not discussed further since it is densely highlighted in the literature.

DISCUSSION

To date, most of the literature findings centred around the impact of non-modifiable socio-ecological factors toward the risk of dengue infection. This is the first study to explore the modifiable risk factors contributing to the risk of prolonged dengue outbreak. In general, the attributes are correlated with the abundance potential of dengue vector as risk of continuous dengue transmission will increase with the introduction of dengue virus in areas with high Aedes population. Nevertheless, failure to determine significant potential breeding places will certainly impair the effort to break the chain of transmission and cease the prolonged outbreak.

Illegal dumping sites eventually lead to solid waste pollution hence creating profound potential places for Aedes mosquitoes to breed.[20] A local study conducted in Johor supports this theme as the study able to predict risk of dengue transmission in residence around the illegal dumping site using spatial modelling.[21] The locations in the study have almost similar characteristics with this study population hence external generalisation is possible. While the study locations share several characteristics with the present study population; such as rapid urbanisation and inadequate waste disposal practices, there may also be contextual differences in socio-demographic factors, local governance, or environmental conditions that limit direct comparability. Thus, the potential for external generalisation exists, but it should be interpreted with caution and supported by further empirical validation in diverse settings. Furthermore, another study has also successfully demonstrated that improvement in solid waste management would inevitably reduce the risk of dengue transmission.[22] Few options could be employed and are feasible, such as increasing frequency of garbage collection schedule or enhancing the "reduce, reuse and recycle" program to the whole population. For example, these interventions largely depend on balancing resource availability, community acceptance, and long-term sustainability. Intervention such as enhancing solid waste management and more frequent garbage collection were practical, as these build on existing municipal services and require only moderate financial investment.

Construction sites are also potential sources for massive Aedes breeding place. A study by Hammond et al described that *Aedes sp* is capable to breed productively in water puddle at the construction area especially with incomplete structures. Therefore, the dengue virus transmission to new Aedes generation is quick thus, affecting wide range of susceptible residences.[23] Another study described the odds of the major cluster of dengue at construction site were between 3.3 to 17.4 compared to location without nearby construction site.[24] Therefore, it will be unwise to neglect the construction areas in preventing dengue outbreak.

Obstructed drainage system flow may cause dengue outbreak transmission. A study by Zainon et al. had described the common cause of breeding place for Aedes mosquito in the drainage system was the poor draining and piping systems with unreachable clogged rain gutter causing it impossible for maintenance.[25] Furthermore, another study also demonstrate positive correlation between vector breeding rate with denser drainage network in low rise areas.[26] Faulty or structural defect to the system will lead to water stagnation which made suitable condition for the mosquito to lay eggs. The structural defected building could also foster as a breeding place. The uneven surface of flat roof structures, insufficient gradient of floor trenches, and unwanted building elements such as metal hollow were found to encourage breeding place due to stagnant water.[25]

Other attributes such as illegal structure, illegal garden, idle damaged vehicle, and old unused items shared a similar characteristic in becoming the potential Aedes breeding place. This qualitative study revealed that this attribute served as place for water storages following rainfall and also provide shady conditions from excess sunlight and heat. Many man-made items are also prone to be the breeding ground for Aedes mosquitoes such as

plastic containers, buckets, drums, pots, bottles, and cans.[27-30]

The resources limitation faced by health authority will hinder successful prevention and control activities, thus community engagement was considered as one of the major factors for preventing prolong dengue outbreak. Furthermore, the local residents should be more accustomed to the neighbourhood, have direct access, and good relationships among the community to continuously look after the area. Strong participation from the community in vector control activities organised by the health authority is the main driving factor to tackle the socio-ecological attributes hence preventing the prolonged duration of dengue outbreak.[31] Common activities that will require community participation are *gotong-royong* and *Ops Gempur Aedes*. Tremendous cooperation is also very much needed during thermal fogging, search and destroy, and ultra-low volume (ULV) spray activities.

Residence health empowerment is important to overcome this problem. This can be achieved by good and structured platform tailored specifically to combat dengue which is COMBI. The fundamental ideas of COMBI establishment in Seremban is for social mobilisation and community empowerment in changing behaviour to prevent dengue transmission.[32, 33] All our respondents agreed that COMBI has successfully achieved its main objectives to prevent the occurrences of dengue outbreak especially in avoiding prolonged outbreak, contrary to the report from previous study.[34] This could be explained by the differences in local setting of the study and the higher community acceptance towards the program in Seremban. This intervention is also considered highly feasible as it relies on local participation and mobilisation, though its success depends on sustained motivation and leadership. Overall, empowerment initiatives like COMBI show strong acceptability and adaptability across settings, making them essential for behaviour change and long-term dengue prevention.

There are two main strengths in this study. First, the diversity of the respondents from both the implementer level (district) and state level (data ownership) has provided robust discussions and exploration on the subject. This can be seen from the earlier theoretical saturation achieved in this subject. Furthermore, good rapport between the principal investigators and respondents have allowed for comprehensive interview sessions within short arrangement duration. Secondly, nature of the IDI coupled with semi-structured questions allowed for further exploration of the given topic. Most of the examples given were directly related to the actual data that is considered classified.

The main limitation of this study is the timing of the qualitative data collection. Due to pandemic and the implementation of a movement control order in Malaysia, the normal routine activities of the Seremban population could be interrupted. The community activities such as *gotong-royong* and COMBI meetings were not conducted. Hence, the socio-ecological attributes gathered in this study may not represent the true normal circumstances. Therefore, future research should utilise the attributes in this study for accuracy testing and generalisability by using the quantitative approach.

CONCLUSION

This study has identified the socio-ecological risk factors which contribute the prolonged duration of dengue outbreak in Seremban district. These socio-ecological risk factors which describe the inter-relationship between human behaviour and ecological factors in prolonged dengue outbreak can be used by other districts that experiences similar problem. Further strategies and actions should incorporate community participation to ensure sustainability. Multi-agency collaborations are also necessary in view of legal implication bindings in each specific attributes, which is beyond the health authority jurisdictions.

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Declaration of Conflicting Interests

No potential conflicts of interest declared.

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