ORIGINAL ARTICLE

Profiling of Aedes Mosquito Breeding Sites at Residential Construction Sites in Malaysia

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ABSTRACT

Introduction: Poor waste management led to mosquito breeding grounds. Previous research found that construction sites are the mosquito breeding area thus it's important to understand how construction sites affect mosquito breeding. **Methods:** This study utilized a prospective study to determine the characteristic of breeding preference in residential construction sites. On-field breeding preference survey was conduct in the selected project site in 12 weeks (1st October 2021 until 31st December 2021). Wet container inspection was carried out according to types of the residential construction building and progress of the site. All possible wet materials and containers was inspected and record accordingly in the form during the surveillance. **Results:** Result shows that the most preferred containers found was building floor (41.68%), others such as planter box that use for landscape purpose, drainage system, building mould and lift wells. The results of the research indicate that prospective containers with water and breeding sites at high rise construction sites were found to be more than those at low rise construction sites. **Conclusion:** Overall, substantially fewer water containers were discovered in low rise projects compared to high rise projects. Construction management need encourage all the workers to do best management practice such as proper waste disposal and removal of the water and possible wet container and conduct awareness among the workers.
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INTRODUCTION

Dengue fever is one of the major public health problems in Malaysia. Dengue virus regularly affects about 50 million people and causes more than 20,000 deaths (1). According to Couret (2) and Jong (3), dengue virus is transmitted by the bite of an adult female Aedes aegypti or Aedes albopictus mosquito. In a 2010 study, female mosquitoes were found to breed indoors and in households because of the female mosquito's ability to collect blood meals for reproduction (1). The mosquito life cycle occurs primarily in water, especially during the juvenile stage in a container (4-8). There are two types of containers commonly used for mosquito breeding: artificial and natural. Female adult mosquitoes primarily lay their eggs in water containers. A large number of potential breeding containers, whether man-made or natural, is one of the main risk factors for pupal emergence. Human actions to store water in the midst of a water supply crisis, as well as inadequate waste disposal, result in a large number of potential breeding containers (9-10). Researchers also discovered large numbers of mosquito pupae in containers that were no longer in use. According to the studies, most natural breeding sites are coconuts and tree cavities. The most suitable artificial breeding containers, such as tires and plastic containers, are located near residential areas and are recycled (9-14). In Africa, discarded car tires are reused as fencing, to weigh down tin roofs, and to reduce soil erosion.

The selection of containers for infestation can be influenced by factors such as location, opening area, amount of water, and organic material that serves as a food source for juvenile mosquitoes. Vegetation is one of the most important food sources for mosquito larvae. Previous research shows that the presence of organic material influences larval survival (12,15-17). Containers used for gardening, such as containers with rooted plants and flower pot holders, contain a significant amount of organic material, usually from soil, plants, and insects, providing food for bacterial growth and larval development (12).

In addition, coconut shells provide nutrients for juvenile growth by leaching minerals from the endodermis (18). In a study conducted in 2020, it was found that the number of juveniles increased when the water level in the breeding tanks increased. A breeding tank with a small entrance area would have made it difficult for female mosquitoes to find a suitable place to lay eggs. On the other hand, a container with a large opening area could attract female mosquitoes to lay eggs because it is easier to identify, contains a larger volume of water, and provides a stable environment for juvenile mosquito growth. A bucket used for gardening and household chores has a high potential for attracting juvenile mosquitoes because the container can hold large amounts of water and has a large surface area, while Banerjee (2013) found that an earthen container has a larger surface area than other containers. Another study conducted in India found that the number of mosquitoes was not related to the surface area of the container (12-13).

The construction sector is a component of urbanization (19). Construction is one of the most important factors in Malaysia's economic development (20). With reference to Malaysia's gross domestic product (GDP) in April 2021, the construction sector increased from RM 8,916 million in the second quarter of 2020 to RM 14,861 million in the third quarter of 2020. However, an increase in construction activity without effective management would have serious environmental impacts, including waste generation, ecological imbalance, and alteration of the living environment (21). Construction waste is generated by operations such as site clearance, material use, and human error (22). Improper handling of construction waste has contributed to mosquito breeding sites. According to one study, construction sites are among the preferred breeding sites and habitats of mosquitoes (23). Therefore, the main objective of this research is to study and understand the impact of construction sites on mosquito breeding, especially in the context of Malaysia. Since the existing literature on this topic is insufficient, this study aims to shed light on the potential impacts of construction activities on mosquito populations, thus providing valuable insights for public health and environmental management efforts.

MATERIALS AND METHODS

Study site

The state of Selangor is located on the west coast of Peninsular Malaysia and is bounded by Perak to the north, Pahang to the east, Negeri Sembilan to the south, and the Strait of Malacca to the west. Four project sites were selected for monitoring in Selangor and Wilayah Persekutuan Kuala Lumpur. Three projects were located in the state of Selangor: project site A was located in Klang district, while projects C and D were located in the Sepang area. Wilayah Persekutuan Kuala Lumpur was the location of another project (B). This research site was chosen due to the high number of dengue cases recorded by the Ministry of Health in Selangor and Kuala Lumpur federal area in 2019 (Figure 1). Epidemic weeks are periods of time when there is an increased incidence of a particular disease or condition. By selecting 12 epidemic weeks, the study ensures a sufficient amount of data to analyze and draw meaningful conclusions. A longer time frame allows for the detection of fluctuations in mosquito breeding patterns and potential outbreaks that may not be detectable in a shorter time frame.

Figure 1: Selected project site location and current progress, (A)-Project A located in Klang, (B)-Project B located in Wilayah Persekutuan Kuala Lumpur, (C)- Project C located in Sepang, and (D)-Project D located in Sepang

Three project sites are designated as suburban residential, one as urban. Two of the projects are service apartments (Projects A and B), and the other two are two-story townhomes (Projects C and D). Project A consists of five large apartment blocks. Blocks A, B, and C each have 32 stories, while blocks D, E, and F each have seven stories. There are five different floor plans for the apartments in this project: Type A has two bedrooms and two bathrooms, Type B has three bedrooms and two bathrooms, Type C has one bedroom and one bathroom, and Type D and E have five bedrooms and three bathrooms. The project is located near a residential neighborhood, two private schools, retail space and the Klang River. The current status of work is shell construction with a temporary drainage system and storage space. Project B will be followed by a one-block, 20-story apartment building. This project site is located near stores, residential areas and private schools. The public drainage system was structurally and architecturally upgraded. For Project C, a two-story townhouse was designed with twelve blocks and 256 apartments. Each block consists of units with different floor plans: Work currently underway included structural and architectural upgrades, as well as a temporary drainage system and storage. Finally, Project D, a two-story row house. It consists of 12 blocks with a total of 130 apartments. Each apartment has four bedrooms and four bathrooms. The project site is located near another construction area and Lake Cyberjaya. Work currently underway included structural and architectural measures, as well as a temporary drainage system and storage facility. Table I summarizes the geographic, physical, and environmental descriptions of each site.

Study design

In this study, a prospective investigation was conducted to examine the characteristic of breeding preference in residential buildings. A larval survey study was conducted over 12 weeks at the four project sites (October 1, 2021 to December 31, 2021). The information collected will then be tabulated and analyzed using descriptive and statistical values. In the first phase, four project sites were selected, three in the state of Selangor and one in Wilayah Persekutuan Kuala Lumpur. Data from the selected project sites, including project specifics and progress, were collected. In phase two, larval surveys and wet container data collection were conducted at the selected project site. Field data were collected over a 12-week period from October 2021 through December 2021. A weekly survey (once per week) was conducted at each project site with project staff present from 0800 to 1000 hours.

Table I: Geographical, physical and ecological description of each locality

Study sites (geographical description)	Physical description	Ecological description
Project A (Located at Kapar, Klang)	• Progress project is 52.52% until level 7 • Main construction work activities include beam, column, slab preparation and concreting. • Serviced apartment. Consist of 6 blocks. • Block A, B and C consist of 32 floors • Block D, E and F consist of 7 floors	• Under construction • Vegetation around the project site • Temporary drainage and storage area
Project B (Located at Kuala Lumpur)	• Progress project is 55.2% that focus on level B1. B2, G, L1 and L20. • Main construction work activities include hacking, demolition and concreting. • Serviced apartment. Consist of 1 block and 20 floors.	• Under construction • Structural and architectural work activities • Vegetation around the project site • Public drainage
Project C (Located at Sepang)	• Progress project is 39.8% in 12 block. • Main construction work activities was structural, ground slab and roof beam slab. • Double storey terrace house. Consist of 21 block and 256 unit. • Each block consists of house with different layout plan	• Under construction • Vegetation around the project site • Temporary drainage and storage area
Project D (Located at Sepang)	• Progress project is 41% in 12 block. • Main construction work activities include structural and roof work. • Double storey terrace house. Consist of 16 block and 130 unit	• Under construction • Structural and architectural work activities • Vegetation around the project site • Temporary drainage and storage area

Data Collection and Management

On-site larval surveillance and species identification were conducted from October 1, 2021 to December 31, 2021 at five selected project sites in Selangor and Wilayah Persekutuan Kuala Lumpur. Three of the project sites were high-rise residential buildings, while the other two were low-rise residential buildings. Each project site had its own specific processes based on site activities, design, and permitting. The general construction process included site mobilization, shell work, roof construction, architectural work, mechanical and electrical work, exterior work, cleaning work, infrastructure work, and TNB substation installation.

During larval monitoring, all potentially wet materials and containers were systematically inspected and recorded using a standardized form. Containers or materials positive for mosquito larvae were identified, and details such as container type, physical analysis of water, and environmental information were documented. Larvae were collected following standard larval collection procedures (30). Containers were thoroughly examined with a flashlight, and juvenile mosquitoes were collected using a standard spoon suitable for the size of the breeding habitat. The collected juveniles were transferred to glass containers using pipettes (11,18). The collected juveniles were placed in universal bottles and labeled with the date and time of collection, the zone and gridlines of the collection area, and the code of the container. They were then transferred to standard larval rearing trays. Larvae and pupae were counted and identified to species under a compound microscope. The number of juveniles was recorded (22). All identified containers were given an identification code based on the guidelines in "Garis Pengawalan Nyamuk Aedes di Tapak-Tapak Pembinaan" (DOSH, 2015) were identified, as shown in Table II.

Data Analysis

Data collected during monitoring are recorded accordingly. In this study, the collected data were registered in a database developed using Microsoft Excel 2013 for descriptive data analysis to determine the preferred reproduction in residential construction sites.

Table II: Container identification code based on based on the Malaysian Ministry of Health's 2015 guidelines for detecting Aedes in construction sites.

Code	Description
C1	Basement
C2	Lift wells/hole
C3	Building floor
C4	Balcony
C5	Pile hole
C6	Water channel
C7	Drainage
C8	Soil/ground hole
C9	Building material mold
C10	Tank
C11	Canvas cover
C12	Cement mixer
C13	Wheelbarrow
C14	Crane
C15	Brick block
C16	Drum container
C17	Food container
C18	Cans
C19	Paint container
C20	Bottle
C21	Unused iron material
C22	Others

The found containers were classified into 22 categories and separated by project site and compared to project site types, i.e., high-rise and low-rise. The data were then summarized in a tabular analysis showing the distribution of breeding preferences based on project types. Entomological indicators (BPRs) were also adapted and used in this study.

The breeding preference ratio (BPR) and index of available containers (IAC) and index of contribution to breeding sites (ICBS) for each project site are used to calculate dengue mosquito density and receptacle attractiveness category in the study area. All positive and wet containers are recorded accordingly. Each empty container is also noted. The data collected were used to calculate IAC, ICBS, and BPR, which were modified based on the data collected in the field and following Flaibani and friends (2020). Finally, the ratio is determined using the values of IAC and ICBS (BPR). The ratio with a value less than one is considered final because female mosquitoes do not find this category attractive. In contrast, more than one category was used for which a ratio value was recognised.

RESULTS

Table III summarises the results of the surveillance. After 12 weeks of surveillance, a total of 3714 containers of water were sampled at four selected project sites, and 126 (3.4%) of the containers contained immature mosquitoes. Figure 2 shows the epidemiological indices by container category based on the project site and the preferred containers of water detected at the selected project site. For Project A, a total of 960 containers of water and 20 (2.08%) of brood were detected. Building floor (n=624; 65%), building material mould (n=124; 13%), live wells or holes (n=90; 9%), wheelbarrow (n=33; 4%), water channel (n=27; 3%), crane (n=27; 3%), bottle (n=21, 2%), and others such as contractor's storage yard (n=9, 1%). However, in Project B, only 92 (5.6%) of the 1640 water tanks were affected by hatcheries, as shown by the monitoring results. Category C22, which includes vases used in the landscape, had the most containers of water (n=498; 30%), but the preferred container for propagation was drainage (n=35; 29%). The most water containers (n=703; 96%) and breeding sites (0.96%) were discovered on the floor of the building at the low-rise project C. Finally, for Project D, the total number of containers with water evaluated was only 383, and breeding and building material moulds were detected in six of these containers. The majority of containers with water (n=220, 57%) were those with mould.

The total number of water-filled containers studied for high-rise and low-rise projects was 2,600 and 1,114, respectively. The number of containers with breeding was 112 for the high-rise project and 14 for the low-rise project. It has been clearly shown that high-rise projects are more favourable than low-rise projects for raising young animals. The 845 and 703 container floor categories have the greatest potential in low-rise and high-rise buildings, respectively. The BPR revealed non-significant patterns for each project site type. Flaibani's research indicates that values below one indicate that female mosquitoes did not find this category attractive, while values above one indicate that this category was used. According to the BPR values in Table IV, all values were less than one, indicating that all categories detected in elevated and low-rise structures were unattractive to female mosquitoes. To ensure that the construction site is free of mosquito breeding, management must encourage all workers to use best management practises, such as proper waste disposal, removal of standing water and potentially wet containers, and worker training.

Different development types and construction phases affect the types of containers placed at the selected project site, as evidenced by the monitoring activities conducted as part of the current research (24-25). Project B had the most containers, with a total of 1640 detected. A 2018 study found that mosquitoes, particularly Aedes and Culex species, have evolved to nest in artificial containers that are easily accessible at construction sites (24). However, species identification was limited throughout the surveillance effort. All containers that contained juveniles were identified and recorded on the monitoring sheet without species

Table III: Epidemiologic indexes by categories of containers based on project site

Code	Categories	Total number of water containers found (*n*)						Total number of water containers found with breeding					
		A	B	C	D	Total	%	A	B	C	D	Total	%
C1	Basement	0	0	0	0	0	0.00	0	0	0	0	0	0.00
C2	Lift wells/hole	90	251	0	0	341	9.18	3	0	0	0	3	2.38
C3	Building floor	624	221	703	0	1548	41.68	12	22	7	0	41	32.54
C4	Balcony	0	0	0	0	0	0.00	0	0	0	0	0	0.00
C5	Pile hole	0	0	0	0	0	0.00	0	0	0	0	0	0.00
C6	Water channel	27	0	0	0	27	0.73	0	0	0	0	0	0.00
C7	Drainage	0	483	0	0	483	13.00	0	35	0	0	35	27.78
C8	Soil/ground hole	0	0	0	0	0	0.00	0	0	0	0	0	0.00
C9	Building material	124	0	0	220	344	9.26	0	0	0	0	0	0.00
C10	Tank	0	0	0	0	0	0.00	0	0	0	0	0	0.00
C11	Canvas cover	2	0	0	1	3	0.08	1	0	0	1	2	1.59
C12	Cement mixer	0	11	0	11	22	0.59	0	0	0	0	0	0.00
C13	Wheelbarrow	33	33	2	18	86	2.32	0	0	0	0	0	0.00
C14	Crane	27	0	0	0	27	0.73	0	0	0	0	0	0.00
C15	Brick block	0	0	0	0	0	0.00	0	0	0	0	0	0.00
C16	Drum container	0	12	12	97	121	3.26	0	1	1	2	4	3.17
C17	Food container	3	37	11	19	70	1.88	0	0	0	2	2	1.59
C18	Cans	0	0	0	0	0	0.00	0	0	0	0	0	0.00
C19	Paint container	0	0	0	0	0	0.00	0	0	0	0	0	0.00
C20	Bottle	21	94	3	15	133	3.58	0	0	0	0	0	0.00
C21	Unused iron material	0	0	0	0	0	0.00	0	0	0	0	0	0.00
C22	Others	9	498	0	2	509	13.70	4	34	0	1	39	30.95
	TOTAL				**3714**						**126**		

*Note: A = Project site A, B = Project site B, C = Project site C, D = Project site D.

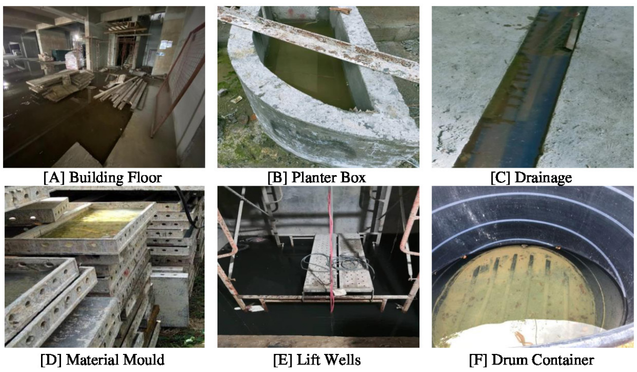

Figure 2: The images of most preferred containers with water that found in selected project site

identification. Wilke and colleagues discovered in 2018 that juveniles occurred in elevator shafts with standing water, stairwells, jersey plastic barriers, and soil puddles. A study conducted at construction sites in Kuala Lumpur found that the most productive breeding sites for immatures were flooded floors, drains, plastic containers, elevator shafts, water barrels, and buckets, while the most productive breeding sites for adults were plastic containers, water barrels, and buckets (26). These results are corroborated by Rahim and Hassan, who found that the most desirable water containers at all project sites were located indoors, in the shade, and under low solar radiation (26-27). Containers discovered included building floors, planters, drainage systems, building material moulds, and elevator shafts. In addition, unevenly constructed concrete floors had created waterlogging that held water for extended periods of time, providing a favourable location for egg laying (28-29).

DISCUSSION

The proliferation of mosquitoes at construction sites is of great concern for several reasons, including potential public health and environmental consequences. The presence of standing water and favorable breeding conditions at these construction sites creates an ideal habitat for several mosquito species, including those known to transmit dangerous diseases such as dengue fever, Zika virus, and chikungunya (30). It is important to understand and address this problem to prevent disease outbreaks and minimize the negative impact on communities. One of the main consequences of mosquito breeding on construction sites is the increased risk of disease transmission. Mosquitoes are vectors of numerous pathogens, and their proliferation in these areas can facilitate the spread of disease to nearby populations (5,10). Construction workers and residents living near these sites are particularly vulnerable to mosquito-borne infections. The consequences can be severe, ranging from mild flu-like symptoms to more severe cases requiring hospitalization, and in some cases, death. Controlling mosquito breeding on

Table IV: Epidemiologic indexes by categories of containers based on types of project site

Code	Categories	Types of Project Sites									
		High Rise					Low Rise				
		X	Y	IAC	ICBS	BPR	X	Y	IAC	ICBS	BPR
C1	Basement	0	0	0.00	0.00	0.00	0	0	0.00	0.00	0.00
C2	Lift wells/hole	341	3	0.13	0.03	0.00	0	0	0.00	0.00	0.00
C3	Building floor	845	34	0.33	0.30	0.03	703	7	0.63	0.50	0.02
C4	Balcony	0	0	0.00	0.00	0.00	0	0	0.00	0.00	0.00
C5	Pile hole	0	0	0.00	0.00	0.00	0	0	0.00	0.00	0.00
C6	Water channel	27	0	0.01	0.00	0.00	0	0	0.00	0.00	0.00
C7	Drainage	483	35	0.19	0.01	0.05	0	0	0.00	0.00	0.00
C8	Soil/ground hole	0	0	0.00	0.00	0.00	0	0	0.00	0.00	0.00
C9	Building material mold	124	0	0.05	0.00	0.00	220	0	0.20	0.00	0.00
C10	Tank	0	0	0.00	0.00	0.00	0	0	0.00	0.00	0.00
C11	Canvas cover	2	1	0.00	0.00	0.00	1	1	0.00	0.07	0.00
C12	Cement mixer	11	0	0.00	0.00	0.00	11	0	0.01	0.00	0.00
C13	Wheelbarrow	66	0	0.03	0.00	0.00	20	0	0.02	0.00	0.00
C14	Crane	27	0	0.01	0.00	0.00	0	0	0.00	0.00	0.00
C15	Brick block	0	0	0.00	0.00	0.00	0	0	0.00	0.00	0.00
C16	Drum container	12	1	0.00	0.01	0.00	109	3	0.10	0.21	0.00
C17	Food container	40	0	0.02	0.00	0.00	30	2	0.03	0.14	0.00
C18	Cans	0	0	0.00	0.00	0.05	0	0	0.00	0.00	0.00

*Note: X = total number of container found; Y= total number of container found with breeding; IAC= index of available container; ICBS= index of contribution to breeding sites; BPR= breeding preference ratio

construction sites is therefore essential to reduce the incidence of these diseases and protect public health.

In addition, the environmental consequences of mosquito breeding on construction sites should not be ignored. Mosquitoes play a role in the ecosystem as pollinators and as a food source for other organisms (11). However, their excessive presence and reproduction can disrupt the delicate balance of ecosystems. In addition, some mosquito control measures, such as the use of chemical insecticides, can have adverse effects on non-target organisms and further harm the environment. Therefore, it is important to explore sustainable and environmentally friendly approaches to control mosquito breeding at construction sites. A multidisciplinary approach is needed to address the problem of mosquito breeding at construction sites. Integrating entomology, GIS technology, and public health expertise can provide valuable insights into understanding mosquito population dynamics and associated diseases in these environments. By using GIS mapping techniques, we can identify high-risk areas for mosquito breeding and prioritize targeted control measures. In addition, education and awareness campaigns can be conducted to inform construction workers and the local community about the importance of eliminating breeding sites and taking preventative measures. In summary, the presence of breeding mosquitoes on construction sites is a significant problem that has potential public health and environmental consequences. To minimize disease transmission and maintain ecological balance, it is essential to prevent mosquito breeding in these areas. Future research should focus on developing innovative and sustainable strategies for effective mosquito control, taking into account the unique challenges posed by construction sites and surrounding communities.

To effectively address the problem of mosquito breeding at construction sites in Malaysia, waste management and construction site management practices need to be improved. This includes developing comprehensive waste management guidelines to ensure proper disposal and segregation of solid waste, promoting the use of covered waste containers to prevent water accumulation, and regular waste collection and disposal. Site management should focus on effective water management, regular inspections to identify breeding sites, and the use of larvicide-treated water for construction activities. Source reduction measures include regular inspections to remove potential breeding sites, removal of debris and vegetation, and modification or removal of water collection structures. Larvicide treatments can be used in areas where source reduction is difficult and target known breeding sites. An integrated pest management approach combines multiple strategies, including larvicidal treatments and biological control agents. Collaboration with stakeholders such as local governments and construction companies is critical, as are public awareness and education campaigns to encourage community participation in mosquito control efforts.

CONCLUSION

The results of the survey indicate that more potential water containers and breeding sites were found on high-rise construction sites than on low-rise construction sites. Overall, far fewer water tanks were discovered on low-rise construction projects than on high-rise construction projects.

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