

# IDENTIFICATION OF *Aedes aegypti* (L) AND *Aedes albopictus* (SKUSE) BREEDING HABITATS IN DENGUE ENDEMIC SITES IN KUALA LUMPUR FEDERAL TERRITORY AND SELANGOR STATE, MALAYSIA

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**Abstract.** In 2015, fifteen surveillances for larvae of dengue vectors, *Aedes aegypti* (L.) and *Ae. albopictus* (Skuse), were conducted in localities, which had dengue outbreaks in 2014 and 2015. The surveillances covered both indoor and outdoor of premises and the surroundings of the locality. All artificial and natural containers holding stagnant water were inspected for the presence of immature larvae. House index (HI) in all 4 localities exceeded the threshold value to implementation of dengue vector control. Taman Sungai Jelok (TSJ), Selangor, had the highest HI, container index and the highest larval density per surveillance and per hectare. The larval productivity was higher in outdoor containers, irrespective of outdoor of premises or in the general surrounding of the localities. *Ae. aegypti* was found equally breeding in indoor and outdoor artificial containers. However, *Ae. albopictus* was the dominant breeder in the outdoor artificial containers, 2.34-fold higher than *Ae. aegypti*. There is an insignificant *Ae. albopictus* population in the indoors. Plastic containers, flower pots, vases and tires were key receptacles. A very significant finding was that both vectors were found in a concrete drain holding stagnated clear water in TSJ. As for natural containers, yam, bromeliad plants and a *Terminalia catappa* tree hole (containing both vectors) were key receptacles. These findings will be useful in promoting awareness in the Malaysian Ministry of Health vector control personnel and residents on dengue vectors breeding habitats and the need for their eradication.

**Keywords:** *Aedes aegypti*, *Aedes albopictus*, breeding sites, natural and artificial containers

## INTRODUCTION

Dengue fever is a vector-borne viral disease, transmitted by the primary vector *Aedes aegypti* (L.), followed by *Ae. albopictus*

(Skuse) (Gubler, 1998). Several other vector species, such as *Ae. polynesiensis* and *Ae. scutellaris* are also dengue vectors and each has its respective ecology, behavior and geographical distribution (WHO, 2017a).

*Ae. aegypti* and *Ae. albopictus* are the important dengue vectors in Malaysia (Lee and Hishamudin, 1990). Both vector species are widespread ranging from

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coastal to inland areas. *Ae. aegypti* usually breeds indoors, while *Ae. albopictus*, previously known as a forest species, now has adapted to a wide range of environmental conditions and exploits a variety of different larval habitats (Hawley, 1988). The ability of these mosquitoes to breed in artificial containers close to human habitats and their eggs to withstand dry conditions for many months result in their effectiveness in dengue transmission (WHO, 2017a).

The number of dengue cases has increased dramatically around the world with an estimation of 3.90 billion people in 128 countries being at risk of dengue infection (WHO, 2017b). In late 2015 and early 2016, the first dengue vaccine produced by Sanofi Pasteur, Dengvaxia (CYD-TDV) was registered in several countries for use in individuals 9-45 years of age, living in endemic areas (WHO, 2017c). Other tetravalent and vaccine candidates are under development in phase 3 clinical trials, and there are also other vaccine candidates based on subunit, DNA and purified inactivated virus platforms, all of which are still at early stages of clinical development (WHO, 2017c). As there is no available highly effective vaccine and specific treatment for dengue infection, WHO (2017c) recommends dengue prevention and control to be focused on vector control methods.

In Malaysia, the number of reported dengue cases in 2014 was 108,698 with 215 deaths, and in 2015 the number increased to 120,836 with 336 deaths but was reduced in 2016 to 101,357 cases and 237 deaths (idengue Malaysia, 2017). The national dengue control program coordinated by Ministry of Health (MOH) has implemented an aggressive vector control program focusing on 'fogging' and destruction of breeding habitats.

This includes searching and destroying any potential breeding places within a 200-m radius from the reported case house, larvae destruction and educating the residents. It is mandatory to conduct fogging within 24 hours of a reported case and a 100 % destruction of breeding habitats within 3 days (MOH, 2009). In addition, within the local settings control initiatives including application of larvicides, temephos and *Bacillus thuringiensis israelensis* (Bti) (MOH, 2009) and outdoor residual spraying with pyrethroids are recommended (Lee *et al*, 2015).

MOH has outlined preventive dengue control guidelines based on the density of *Aedes* larvae and pupae (MOH, 2014). The threshold values for achieving vector control are house index (HI) <1%, Breteau index (BI) <5 and container index (CI) <10%. In the presence of a pupa, an intensive locality cleaning is required (MOH, 2014). The intensive field surveillance within a radius of 200-400 m of the reported case requires a thorough search for the breeding habitats. Vector control personnel need to know the type of preferred habitats to conduct a productive search to treat/destroy in an outbreak site.

The larvae surveillances conducted in Malaysia over five decades have shown a changing trend in the types of larvae habitat. Initial studies on the distribution and dispersal of *Ae. aegypti* in Malaya were conducted by Macdonald in the 1950's, with particular reference to the risk of yellow fever introduction and its pertinent control programs (Cheong, 1967). Extensive surveys were then conducted from time to time summarizing breeding data from a number of urban areas in Malaysia (Cheong, 1967). The summaries showed that indoor containers, such as ant trap, earthenware jars and storage drums, were the most preferred larvae habitats. From

1984 to 1986, a nationwide larval surveillance in Peninsular Malaysia covering 6,669 houses and more than 12,000 artificial containers found that the preferred indoor habitat is concrete tank for both *Ae. aegypti* and *Ae. albopictus* (Lee, 1990). The preferred outdoor habitats are pail, bucket, pan, bowl, earthenware jar and car tire for both *Aedes* species. The study also found that both species prefer clear water over colored or polluted water for oviposition. Similar findings were observed in another larval surveillance conducted in 1985 in Jinjang, Kepong, a suburb of Kuala Lumpur (Lee and Cheong, 1987). Both *Aedes* species were found indoors and outdoors in water storage containers, such as concrete tank, drum and earthenware jars. The density of *Ae. aegypti* population is affected by water supply and rainfall. A nationwide surveillance repeated in 1988-1989 in 11 states and in the Federal Territory covering 171 towns found *Ae. aegypti* and *Ae. albopictus* nationwide, but *Ae. albopictus* is not detected in the Federal Territory (Lee and Hishamudin, 1990). A reduction of infestation was observed compared to the previous nationwide larvae survey, due to consistent suppressive pressures from the widespread anti-*Aedes* measures.

In 1990, four suburban communities near Kuala Lumpur were investigated (Lee, 1992). Monthly larvae survey indicated low *Aedes* HI and BI; however, weekly ovitrap surveys indicated high *Aedes* population. Low larvae indices are due to temephos treatment of domestic water storage containers. The high ovitrap index could have been contributed by *Aedes* breeding in cryptic containers that are not under temephos treatment.

A survey from 2008 to 2009 in dengue outbreak areas in Malaysia found that the major breeding sites for *Aedes* are plastic

containers (Rohani *et al*, 2014). The most recent *Aedes* surveillance and ovitrapping was conducted in 2014 in outbreak localities in three states in Peninsular Malaysia (Rozilawati *et al*, 2015). The surveillance covered Selangor, Federal Territory of Kuala Lumpur and Penang Island. *Ae. albopictus* is predominant in most of the localities and breeds mostly outdoors. The most common containers are plastic ware. This study suggested that the vector control program should also target *Ae. albopictus* together with the dengue primary vector *Ae. aegypti* due to the abundance of these two species in dengue outbreak areas.

In Singapore, during the 2005 dengue outbreak, a thorough investigation revealed larval habitats are equally found indoors and outdoors, and the common habitats were domestic and ornamental containers with discarded receptacles (Benjamin *et al*, 2008).

In 2014, during the dengue outbreak in Selangor, namely Ridzuan Condominium (RC) and Taman Sungai Jelok (TSJ), Kajang, ovitrap surveillance indicated the presence of both *Ae. aegypti* and *Ae. albopictus* (IMR, unpublished data). In RC the average ovitrap index (OI) from weeks 7-52 is 52% and 9% for *Ae. aegypti* and *Ae. albopictus* respectively, and in TSJ the average OI from weeks 6-52 is 45% for *Aedes*. Thus, we decided to investigate the whereabouts of the breeding habitats in a high-rise multi-story housing and in residential terrace homes. In 2015, several larvae surveillance were conducted in 4 sites, consisting of three ongoing dengue hotspots. The gathered data will be used to create public awareness and to educate vector control personnel on the types of breeding habitat that are required to be treated or destroyed.

## MATERIALS AND METHODS

### Study areas

A total of 4 localities were selected for this study, two from Kuala Lumpur Federal Territory (FT) and two from Selangor, Malaysia. Two of the localities, RC and TSJ, were chosen based on the number of dengue cases reported by the MOH in 2014 and ovitrap surveillance data during the outbreak period, which clearly indicated the presence of both *Ae. aegypti* and *Ae. albopictus* (IMR, unpublished data). Taman Sri Gombak (TSG) was chosen based on the current number of cases in 2015 (MOH, 2015), and the fourth locality, Jalan Sarikei, Kuala Lumpur based on the type of building with a high presence of potential dengue vector larvae habitat. In each locality, the type of buildings, extent of vegetation and other environmental conditions were noted.

### Larvae and pupae surveillance

The inspection was conducted by three survey teams consisting of two persons per team. Each locality was visited 2-5 times depending on the size of the study area. During the surveillance, any artificial and natural containers containing stagnant water was inspected by pouring the water into a white steel tray and observing under a torch light the presence of larvae or pupae. Long handle dippers were used for low unreachable places such as drains. For tall plants with water collecting axils or high unreachable containers, a long pipette attached to a silicone tube and suction bulb was used to collect the water samples. Individual disposable pipette was used for each water sample to transfer mosquito larvae or pupae together with the water sample into labeled specimen bottles, which were transported to the laboratory on the same day of collection and transferred into plas-

tic containers for identification. Specimens were kept for 5 days to allow eggs to hatch and larvae to mature for easier identification, which was conducted at the species level according to the Taxonomy Key of the Institute for Medical Research (IMR) (Cheong *et al*, personal communication).

The surveillance covered indoors and outdoors, including front and back yards. The types of habitat of any larva or pupa found were recorded and categorized into artificial or natural containers and in-use or unused containers. In each locality, a total of approximately 100 randomly selected houses were surveyed with consent from the owners. The general surroundings around the homes were also surveyed.

Results were recorded and analyzed as follows. HI and container index (CI) were determined using the equations:

$$HI (\%) = \frac{\text{Number of positive houses}}{\text{Total number of houses surveyed}} \times 100$$

$$CI (\%) = \frac{\text{Number of positive containers}}{\text{Total number of containers inspected}} \times 100$$

## RESULTS

The location of the study localities from a focal point, IMR, Kuala Lumpur is indicated in Fig 1. The closest distance is 1.5 km, with the furthest distance 31.9 km.

A total of 15 surveillances were completed in the four localities: four each in RC and TSG, two in Jalan Sarikei and 5 in TSJ (Table 1). The buildings ranged from high-rise condominiums to single or double story houses. There were sparse to dense vegetation in these areas. The total land area surveyed in each locality was 16.4-66.6%.

RC consisted with 3 residential blocks, namely, A, B and C. Each block had 26 floors with a total of 250 residential units. The surveillance team carefully



Fig 1—Locations of the four surveillance sites with reference to Institute for Medical Research (IMR), Jalan Pahang, Kuala Lumpur. Map not drawn to scale.

searched the surrounding perimeter of the blocks, which included the outdoor parking areas, resident's outdoor resting sites and playgrounds. As for indoors, the surveillance was conducted from the highest to lowest floor, covering indoor corridors, utility rooms and emergency exits, covering 48 residential units, with consent from the residents.

In Jalan Sarikei, the surveillances were carried out in a commercial site with shop houses. Public pathways along the shop lots, including a large public parking area were inspected. Surveillance also was conducted at temporary food stalls and car parks that were adjacent to the shop houses. The shop houses consisted of three levels with flat rooftops. On each

rooftop there was at least one black water tank, which can hold  $\geq 3,000$  liters of water. Five shop lots were inspected from roof top to the ground level.

In TSJ, the surveillances covered vacant lands, back alleys, and 61 premises, which included 39 indoor and 33 outdoor areas. Beyond the premises, 44 outdoor potential larval habitats were inspected.

In TSG, the surveillances were carried out in phase 1 of the residential site. Here the surveillance focused on outdoors as most residents did not allow indoor inspection. Sixty-nine premises were surveyed with 33 indoor and 49 outdoor areas in-

cluding abandoned houses and houses under renovation. Beyond the 69 premises, another 39 potential larval habitats were inspected.

A total of 232 premises were surveyed. HI in the 4 localities exceeded the MOH's threshold value required to implement dengue vector control (Table 2). TSJ had the highest HI and CI values. Most of the positive containers were found outdoors and there also were in-use containers (Fig 2). The very common in-use positive containers were plastic containers and flower pots/vases. In TSJ, an area of 1.25 hectares that was surveyed contained a total of 105 indoor containers (84 containers/hectare) and 146 outdoor containers (117 containers/hectare). The other contributing posi-

Table 1  
Locality and period of larval surveillance conducted in each locality.

Locality	Surveillance time frame (n = total number of surveillance)	GPS coordinates	Total area size (ha)	Larval surveillance area (ha) (% of total area)	Environment and type of building
Ridzuan Condo (RC), Petaling Jaya, Selangor.	9 Jan - 3 June 2015 (n = 4)	3°4.740'N10 1°36.363'E	3.3	2.1 (63)	High-rise condominium with good ventilations. Ground floor with paved pathways and playground. Moderate vegetation.
Jalan Sarikei (JS), Kuala Lumpur.	19 Jan - 2 April 2015 (n = 2)	3°10.593'N10 1°41.962'E	7.5	2.5 (33)	Shop houses with sparse vegetation.
Taman Sungai Jelok (TSJ), Kajang, Selangor.	15 Jan - 2 Oct 2015 (n = 5)	2°59.562'N10 1°48.119'E	7.6	1.25 (16)	Single and double-story terrace houses, with dense vegetation.
Taman Sri Gombak (TSG), Kuala Lumpur.	10 Dec 2015 -14 Jan 2016 (n = 4)	3°14.422'N10 1°41.908'E	20.7	13.8 (67)	Single and double-story terrace houses, and shop houses. Dense vegetation.

Ha, hectare

Table 2

Summary of premise surveillance for *Aedes* larvae in Ridzuan Condominium (RC), Jalan Sarikei (JS), Taman Sungai Jelok (TSJ) and Taman Sri Gombak (TSG), Malaysia.

Locality	Total number of premises	Number of positive premises (% house index)	Number of containers inspected (% positive containers)			% Container index	Ratio of positive number of premises to positive number of containers	
			Artificial containers		Natural containers			
			Indoor	Outdoor				
RC	97	11 (11)	134 (7)	33 (3)	7 (14)	4 (25)	7 (including natural containers)	1:1
JS	5	1 (20)	1 (100)	10 (0)	1 (0)	0	8	1:1
TSJ	61	29 (47)	105 (10)	68 (56)	13 (38)	0	29	1:1.9
TSG	69	12 (17)	72 (5)	77 (17)	7 (43)	0	11	1:1.5

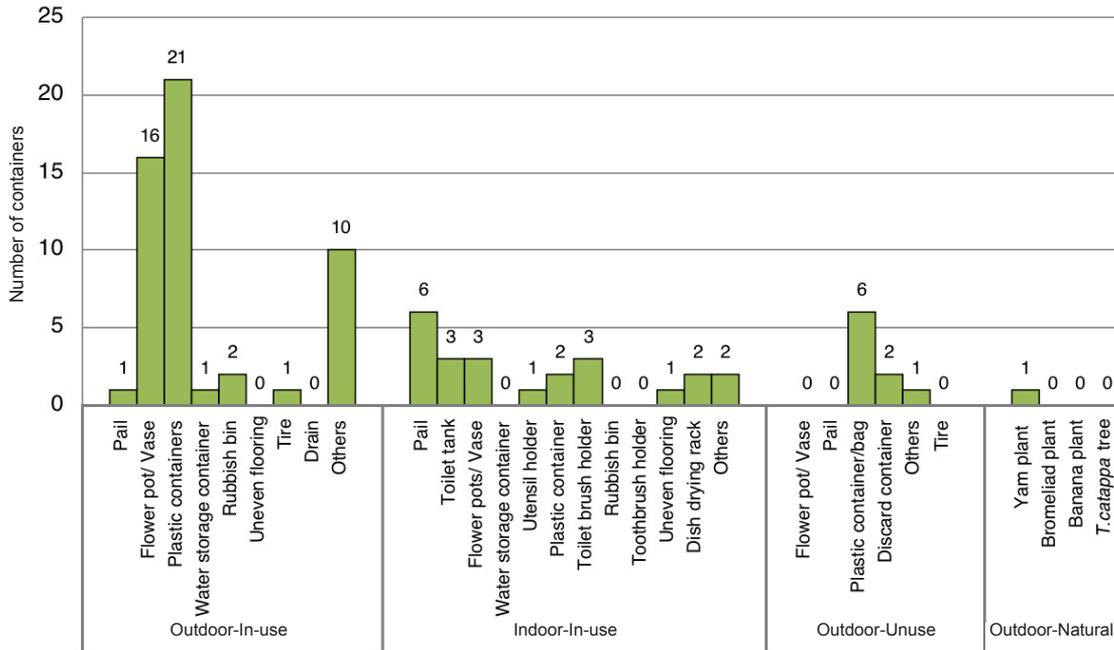


Fig 2—Types of mosquito larva/pupa-positive containers found indoors and outdoors of premises surveyed in Ridzuan Condominium and Taman Sungai Jelok, Selangor and in Taman Sri Gombak and Jalan Sarikei, Kuala Lumpur, Malaysia.

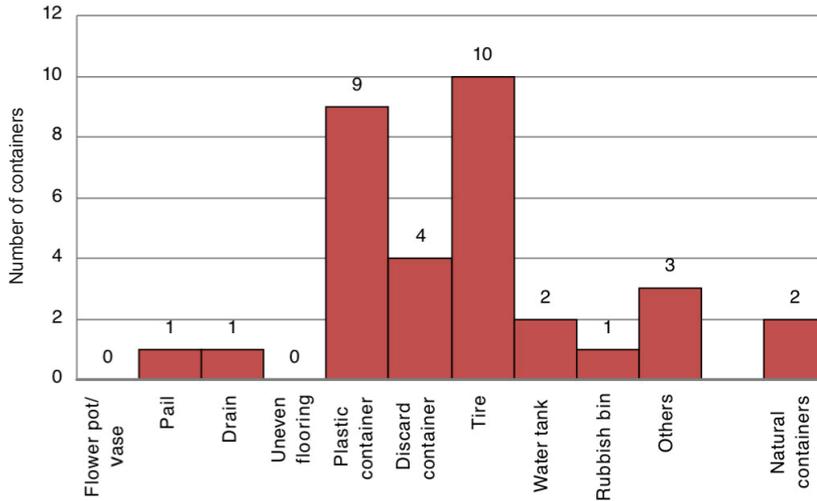


Fig 3—Types of larva/pupa-positive containers found in the surroundings of localities in Ridzuan Condominium and Taman Sungai Jelok, Selangor and in Taman Sri Gombak and Jalan Sarikei, Kuala Lumpur, Malaysia.

positive in-use containers were rails of grill gates and cooking utensils. The only positive natural container was found in the outdoor garden of RC, in the leaf axils of

the yam plant with *Ae. albopictus*. Beyond the premises, a total of 136 potential larval habitats were surveyed in the surroundings. Thirty-one artificial containers were positive together with two positive natural containers (Fig 3). All car tires were positive for a mixed *Ae. aegypti* and *Ae. albopictus*, at a ratio of 1:4.8. The next most common positive artificial container was plastic containers. Several concrete water ways (drains) were inspected and one drain in TSJ was found positive for both *Ae. aegypti* and *Ae. albopictus* lar-

Table 3  
Location and type of containers infested by *Ae. aegypti* and *Ae. albopictus*.

Category	General description of positive containers	Number of <i>Aedes aegypti</i> isolated	Number of <i>Aedes albopictus</i> isolated
Indoor, in-use	Flower pot/ vase, toilet tank, toilet brush holder, sink pvc pipe, plastic storage container, utensil holder, pails, rubbish bin, dish drying rack.	440	16
Outdoor, in-use	Flower pot/ vase, pail, drain, plastic container/ bag, water tank, plastic pipe/ pvc, tires, uneven flooring, rubbish bin.	281	531
Outdoor, unused	Flower pot/ vase, plastic container/ bag, plastic pipe or hose, discarded container, tire.	270	759
Natural	Yam plant, banana plant, <i>Terminalia catappa</i> tree hole.	5	20

vae. The *Ae. albopictus* larvae were 6-folds higher in numbers compared to *Ae. aegypti*. This drain had an uneven floor holding stagnated clear water. There was another drain in TSJ with no water, but a discard plastic container in the drain was holding *Ae. aegypti* larvae. Among the 3 natural containers that were examined, two were positive, namely, a *Terminalia catappa* tree hole (containing both *Aedes* vectors) in JS and a bromeliad plant (containing *Ae. albopictus* larvae) in TSJ.

In general, the larval productivity was much higher in outdoor containers, irrespective whether outdoor of premises or in the general surroundings of the localities (Table 3). In this entire study involving 15 surveillances, a total of 2,322 *Aedes* larvae and 158 *Culex* larvae of all 4 instars were isolated. Among the 4 localities, TSJ had the highest average number of *Ae. aegypti* and *Ae. albopictus* larvae per surveillance, with *Ae. albopictus* as the dominant population (Fig 4). This was no surprise as TSJ had the highest HI, CI and the ratio of the number of positive premises to number of positive containers among the 4 localities (Table 2). In addition, TSG had higher *Ae. albopictus* population than *Ae. aegypti*, and vice versa for RC. The latter was the only locality with *Ae. aegypti* as the dominant population and this was primarily contributed by indoor artificial containers, such as pails, cutlery holders, toilet brush holders and uneven flooring (Fig 2).

## DISCUSSION

The dengue vector surveillance was conducted in four localities, three of which had persistent dengue outbreaks in 2014 and in 2015 (MOH, 2017). In the 2014 outbreak, RC recorded 68 cases over a period of 146 days. This site recorded 26

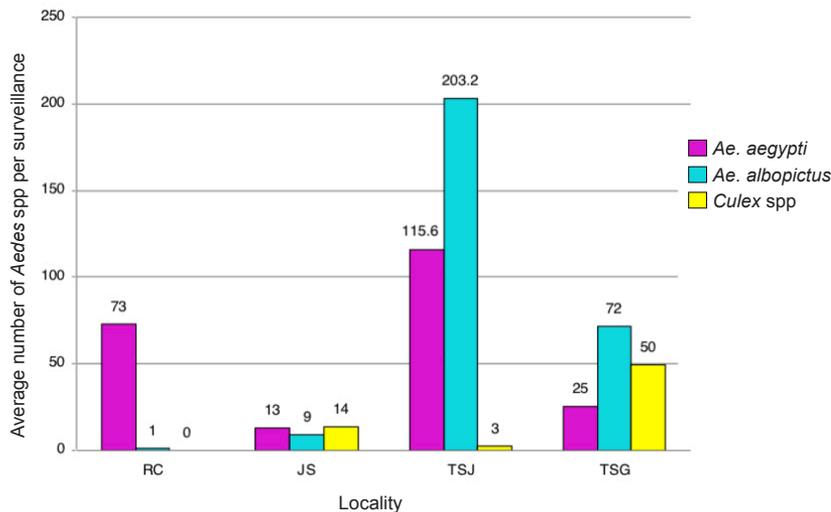


Fig 4—Average number of *Ae. aegypti* and *Ae. albopictus* larvae collected per surveillance from each locality in Ridzuan Condominium (RC) and Taman Sungai Jelok (TSJ), Selangor and in Taman Sri Gombak (TSG) and Jalan Sarikei (JS), Kuala Lumpur, Malaysia.

cases over a period of 92 days in the 2015 outbreak. In 2014 outbreak, TSJ had 30 cases over 81 days (MOH, 2014), and in 2015 outbreak, TSJ had 14 cases over 48 days and by week 36 there were 17 cases over a period of 76 days. In TSG, there were 10 cases over 37 days by week 34 of the 2015 outbreak, which increased to 23 cases by week 36 (MOH, 2017). Ovitrap surveillance conducted during the outbreaks recorded 45-52% of *Ae. aegypti* and 9% of *Ae. albopictus* (IMR, unpublished data). The ovitrap data indicated the presence of gravid female *Ae. aegypti* and *Ae. albopictus* population in the outbreak sites. Thus, the current study was initiated to detect the habitats that supported successful colonization of these mosquitoes.

HI values in all four localities exceeded the MOH's threshold value for implement dengue vector control. Artificial and natural containers positive for larvae of the two mosquito species of interest were found in both indoor and outdoor

premises and also in the surrounding area of the premises. The containers were either in-use or unused. The CI values exceeded the MOH threshold value in 2 localities, namely, TSJ and TSG. Among the 4 localities, TSJ had the least surveillance area of 1.25 hectares, but had the highest HI, CI, and the highest number of positive containers per household. TSJ also had the presence of the most number of indoor

and outdoor containers per hectare, and this was the highest ratio of containers per hectare among the 4 localities. Thus, it was not unexpected to find persistent numbers of dengue cases in TSJ over the two years.

The presence of high numbers of containers, either in-use or unused, but exposed to collect water made them suitable harborage for the colonization of dengue vectors. Similar situations were found in Trenton, New Jersey, USA, where disposable containers, such as discarded car tires, cups, boxes, and food containers and in-use containers, such as trash cans, bird baths, stored tires, and tarpaulin covers were described as potential containers for *Ae. albopictus* (Sun *et al*, 2014). In Florida Keys, USA, *Ae. aegypti* is the predominant mosquito breeding in a wide variety of containers including tires, buckets, discarded plastic containers, flower pots, plant trivets, garbage cans, and bromeliads, most of which containing water in both wet and dry seasons (Prusynski

*et al*, 2017). In northern Queensland, Australia, similar receptacles, such as tires, buckets, birdbaths, and pot plant bases provide larval habitats for *Ae. aegypti* (Jacups *et al*, 2013).

In all localities inspected in the current study the most common infested containers were plastics holding less than 1 liter of water. In Malaysia, the types of positive container have changed over the decades, from large volume earthenware jars in the 1950's to concrete tanks in the later years (Cheong, 1967; Lee, 1990). The improved economic status with piped water supply to nearly all homes has made the general population in Malaysia less dependent on stored water. However, people in this millennium are subjected to a fast moving pace of life, seeking for convenience in every daily matter. Most household items, especially food, are sold in plastic containers or plastic bags. People are very prone to use these containers only once and keep them after cleaning. Most of these containers are not dried well after cleaning, and are also not covered. This study revealed that even if the containers were covered, water was found in the container covers. Consumers have to be more conscientious in storing these used plastic receptacles in dry places, and not store them under a sink. They can also place these plastic containers and plastic bags in trash bins for recycling or for proper disposal.

The second most common positive outdoor containers were flower pots, flower pot plates and vases. In TSG, presence of *Ae. aegypti* and *Ae. albopictus* larvae and pupae from loamy soil holding about 50 ml of water on the soil surface from two potted plants were detected. An 11-fold higher population of *Ae. albopictus* relative to *Ae. aegypti* was observed. The next most productive habitat was car tires.

Every tire investigated was positive with an abundance of *Ae. albopictus*. The tires were used by residents as markers for parking spaces. This habitat could have been prevented if the residents had filled the tires with sand or cement to prevent collection of water.

In all previous *Aedes* surveillance in Malaysia since 1950s until the most recent report in 2014, there were no reports of concrete waterways (drains) being positive with *Aedes* larvae/pupae (Cheong, 1967; Lee and Cheong, 1987; Lee, 1990; Lee and Hishamuddin, 1990; Lee, 1992; Rohani *et al*, 2014; Rozilawati *et al*, 2015). However, in the current surveillances *Ae. aegypti* and *Ae. albopictus* were found in one of the drains in TSJ. The drain had stagnant storm water and contained 6 folds more *Ae. albopictus* than *Ae. aegypti* larvae. Drain water has been confirmed to provide a suitable medium for the colonization of dengue vectors (Chen *et al*, 2007). Oviposition preference in drain water was 6-fold higher compared to tap water, with 50% successful emergence. In Singapore, one of the major outdoor breeding habitats is broken/choked drain (Benjamin *et al*, 2008).

In TSJ and TSG, the dominant vector was *Ae. albopictus*, where both localities have dense vegetation. *Ae. albopictus* was primarily a forest species, which has now adapted well to an urban environment (WHO, 2017a). This study revealed *Ae. albopictus* has adapted to breed in artificial outdoor containers, showed their supremacy over *Ae. aegypti*, in outdoor in-use and outdoor unused containers. A survey from 2008 to 2009 in dengue outbreak areas in Malaysia also found *Ae. albopictus* as the dominant larvae and abundant in plastic containers (Rohani *et al*, 2014). In 2014, *Ae. albopictus* was the dominant dengue vector isolated in Selangor State and Kuala

Lumpur, but Penang Island has more *Ae. aegypti* than *Ae. albopictus* (Rozilawati *et al*, 2015).

In this study, *Ae. albopictus* was also the principal breeder in the three positive natural containers, except in the tree hole where both *Ae. aegypti* and *Ae. albopictus* were found. Natural containers are known to be the key breeding habitat for *Ae. albopictus* (Hawley, 1988). In 2009, in a survey conducted in University of Malaya, Kuala Lumpur, 50% of the surveyed natural containers (tree holes, coconut shells, fruit peels, and plant axils) are positive for *Ae. albopictus* and *Ae. niveus* larvae, without the presence of *Ae. aegypti* (Chen *et al*, 2009). The larvae of *Ae. aegypti* is known to develop in artificial containers, but insecticide pressure may have caused *Ae. aegypti* to undergo behavioral changes to grow in both artificial and natural containers (Chadee *et al*, 1998). In 1956, *Ae. aegypti* larvae were isolated from tree holes, tree stumps and bamboo stumps in Malaya close to human habitation (MacDonald, 1956).

This study confirms that the trend of positive larval habitats has changed over the decades following the social economic status and habits of people; however, the fact remains the same in that *Ae. aegypti* is the dominant indoor breeder and *Ae. albopictus* the dominant outdoor breeder. The highest number of positive containers were found outdoors, irrespective of outdoor premises or outdoor surroundings. Outdoor containers were 3.5 folds more productive than indoor containers.

Data from this study can be used by the relevant authorities to educate the general public and also by vector control personnel in their search to treat and destroy mosquito habitats during dengue outbreaks. The most common habitats

were flower pots, plastic receptacles and pails. A large percentage of the containers were generated by the residents, either knowingly with an apathy attitude or unknowingly. The residents have ownership over these habitats and should be made responsible for keeping these containers free of standing water. The MOH, together with other relevant ministries, should provide educational material and advertisements in social media to consistently remind the public not to create dengue vector habitats. The volume of plastic receptacles can also be reduced by encouraging the public to use containers and bags made from biodegradable materials.

Many home owners store unused receptacles for future use, mainly in places where they are exposed to water. It would be advisable to inform the public to dry all utensils and keep them in an enclosed location when not in use and dispose unwanted receptacles (for recycling whenever possible).

Solid waste management contractors in every residential area should be made accountable for removing discarded receptacles of all sizes, including tires. These discarded items should be disposed either through recycling, incineration or in a landfill. Currently, solid waste management contractors routinely remove trash, which has only been disposed in the home garbage bins; however, this study found discarded containers and larger items, such as damaged telephone booth and abandoned advertisement banners, strewn in public areas (of TSJ and TSG). The local authorities should implement a more stringent policy on waste management to include the removal of all types of garbage.

During a dengue outbreak and/or when an ovitrap index is above the thresh-

old value of 10% (Lee, 1992), a wide area larvicide treatment of outdoor containers is highly recommended to produce an immediate and productive outcome (Sun *et al*, 2014). Because the most productive containers are found outdoors and these containers are both ubiquitous and cryptic, the MOH vector control personnel need to conduct a fine spray larvicide application, which is able to penetrate into artificial and natural containers. Numerous publications from Australia, Malaysia, Singapore, and USA showed the effectiveness of a wettable granule Bti formulation (VectoBac® WG) application from backpack mist blowers, vehicle mounted ULV generators and aerial sprays to eliminate *Aedes* larvae population (Jacups *et al*, 2013; Sun *et al*, 2014), reduce adult density (Lee *et al*, 2008; Lam *et al*, 2010) and interrupt dengue transmission (Tan *et al*, 2012; Prusynski *et al*, 2017). Wide area spray applications with temephos (Abate®500 EC) at 200 g/hectare using vehicle-mounted ULV generator and thermal foggers also significantly impact *Aedes* larval and adult mortality and interrupt dengue transmission (Lee *et al*, 2015).

In conclusion, cycles of persistent dengue outbreak in Malaysia can be terminated if the public is civic-minded not to create obvious artificial habitats for dengue vectors; and if the MOH vector control authority treat the ever present outdoor cryptic artificial and natural containers using a wide-area larvicide treatment.

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