Vertical Infestation of the Dengue Vectors *Aedes aegypti* and *Aedes albopictus* In Apartments In Kuala Lumpur, Malaysia

Author(s): Muhammad Aidil Roslan, Aziz Shafie, Romano Ngui, Yvonne Ai Lian Lim, and Wan Yusoff Wan Sulaiman


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ABSTRACT. Dengue is a serious public health problem in Malaysia. The aim of this study was to compare the vertical infestation of *Aedes* population in 2 apartments in Kuala Lumpur with different status of dengue incidence (i.e., high-dengue-incidence area and area with no reported dengue cases). The study was also conducted to assess the relationship between environmental factors such as rainfall, temperature, and humidity and *Aedes* population that may influence *Aedes* infestation. Surveillance with a mosquito larvae trapping device was conducted for 28 continuous weeks (January to July 2012) in Vista Angkasa (VA) and Inderaloka (IL) apartments located in Kuala Lumpur, Malaysia. The results indicated that both *Aedes* spp. could be found from ground to higher floor levels of the apartments, with *Aedes aegypti* being more predominant than *Ae. albopictus*. Data based on mixed and single breeding of *Aedes* spp. on different floors did not show any significant difference. Both rainfall (R); i.e., the amount of rainfall collected during the previous 3 wk before the surveillance period began) and RH data showed significant relationship with the number of *Aedes* larvae collected in VA and IL. No significant difference was found between the numbers of *Aedes* larvae in both study areas as well as maximum and minimum temperatures. Results also indicated adaptations of *Ae. aegypti* to the ecosystem at each elevation of high-rise buildings, with *Ae. albopictus* staying inside of apartment units.

KEY WORDS  *Aedes aegypti*, *Aedes albopictus*, Vista Angkasa, Inderaloka, dengue

INTRODUCTION

Dengue is one of the most important vector-borne viral diseases in urban and suburban areas of tropical and subtropical regions throughout the world (Gibson and Vaughan 2002). Pathologically, dengue is a flavivirus infection that may be caused by 4 distinct serotypes of viruses, which include DENV-1, DENV-2, DENV-3, and DENV-4 (Gubler 1998). These pathogens are transmitted by *Aedes aegypti* (L.) and *Aedes albopictus* (Skuse) (Rudnick et al. 1965). The clinical manifestation and symptoms of the infected individual include severe fever along with intense headache, loss of appetite, as well as serious pain in various parts of the body, and in some cases require hospitalization (Vazquez-Prokopec et al. 2010).

Worldwide, approximately 50 million cases of dengue fever and dengue hemorrhagic fever have been reported with >20,000 deaths annually, particularly in the endemic regions (Gibson and Vaughan 2002). In Malaysia, the 1st dengue fever and dengue hemorrhagic fever cases were recorded in 1902, followed by the 2nd case in 1962 in Penang (Rudnick et al. 1965). According to available records, the 1st major dengue outbreak was reported in 1970 (Rudnick et al. 1965). In 2009, there were up to 33,684 infected dengue patients reported and the figure continues to swell to 40,152 in 2010 with 118 deaths (MOH 2010). Subsequently, an increase of almost 13% over the previous year was seen in 2011, with a total of 46,171 dengue cases and 134 deaths (Maimusa et al. 2012). The recent 2012 figure indicated that the overall dengue cases in Malaysia for the 1st half of the year (January to May 2012) were 9,607 with 20 deaths as compared to the same period in 2011, when a total of 7,963 dengue cases with 12 deaths were reported (Ministry of Health Malaysia, unpublished data). Indeed, statistics are rising at an alarming rate.

Currently, there is no commercialized vaccine available for dengue. Thus, the implementation of efficient vector control surveillance is essentially paramount to prevent and reduce the number of dengue outbreaks especially in both endemic and epidemic areas (PAHO 1994). The partnership and involvement from both public health sectors and nongovernmental organizations are very much needed to initiate preventive measures particularly when the abundance of *Aedes* mosquitoes is assumed to be high enough to facilitate dengue outbreaks especially in dengue hotspot areas (PAHO 1994). Many techniques have been performed for monitoring the dispersal and abundance of dengue vectors. Several entomological indices have been developed and employed to assess the infestation of immature *Aedes* mosquito, particularly larval and pupal stages, including the Breteau Index, House Index, Container Index, pupal or demographic surveys,
and oviposition traps (Focks 2003). As for adult *Aedes*, their abundance and infestation are usually monitored using appropriate combating activities, for instance the mechanical devices such as suction aspirators (Clark et al. 1994), suction traps (Krockel et al. 2006), or sticky ovitraps (Ordonez-Gonzalez et al. 2001, Ritchie et al. 2003).

To date, many studies have been conducted to determine and monitor the *Aedes* mosquito population in Malaysia, particularly through the use of ovitraps (Cheng et al. 1982, Wan-Norafikah et al. 2010, Lau et al. 2013). With the exception of Wan-Norafikah et al. (2010) and Lau et al. (2013), there is limited information on the infestations of *Aedes* mosquitoes at high-rise buildings. Wan-Norafikah et al. (2010) conducted a study on the vertical dispersal of *Aedes* population in 4 blocks of high-rise apartments in Putrajaya, indicating that *Aedes* mosquitoes can be found at every level regardless of its height, with higher infestation at lower levels compared to higher levels. Recently, findings by Lau et al. (2013) also showed that the vertical distribution of *Aedes* mosquitoes can be found at any level in 4 multi-story buildings in Kuala Lumpur and Selangor State. Interestingly, the result also indicated that *Ae. aegypti* could be found at the highest level of these buildings (i.e., 16th floor). However, both studies did not take into consideration the environmental factors that may influence the distribution of the *Aedes* population in the latter studies. In addition, there was no mention in the previous 2 studies whether the locations studied were in high-dengue-incidence areas or areas with no reported cases of dengue. Information gathered from high- and low-density dengue areas will provide crucial data for comparison and also for a better understanding of the behavior of dengue vectors.

The present study was conducted to compare the vertical infestation of *Aedes* populations in 2 apartments in Kuala Lumpur with different status of dengue incidence (high-dengue-incidence area and area with no reported cases of dengue). In addition, the study also attempted to assess the relationship between environmental factors such as rainfall, temperature, and humidity and *Aedes* population that may influence infestation of *Aedes* mosquitoes.

**MATERIALS AND METHODS**

**Study design and study areas**

Kuala Lumpur (lat 3°08′51″N, long 101°41′35″E), the federal capital of Malaysia, constitutes an area of 243 km², inhabited by approximately 1.6 million people (Department of Statistic Malaysia 2010). The study was conducted in 2 apartments, namely Vista Angkasa Apartment (VA) (lat 3°06′46″N, long 101°39′40″E) and Inderaloka Apartment (IL) (lat 3°06′26″N, long 101°39′97″E). Vista Angkasa Apartment was selected in the study because the area has been identified as one of the apartments with high dengue incidences (i.e., dengue outbreak and cases) in the Kuala Lumpur area. In contrast, no reported dengue cases or outbreaks have been reported in IL. The selection of both apartments has been recommended and suggested by local health authorities (Kuala Lumpur City Hall). Briefly, VA is managed by private company, whereas IL is the quarters for the University of Malaya security staffs. The distance between the 2 apartments is approximately 3 km, with both study areas about 7 km from the city center.

**Indoor surveillance using mosquito larval trapping device**

The mosquito larval trapping device (MLTD) used in this study was a cylindrical plastic container (24 cm long × 13.5 cm wide) weighing 200 g. A total of 560 MLTDs were used within the surveillance period in each apartment. All MLTDs were half-filled (approximately 800 to 1,000 ml) of nonchlorinated tap water. Since the surveillance was conducted inside the apartment units in the present study, the use of grass hay infusion water was not suitable due to the presence of unpleasant odors. Based on our personal communication with the residents before conducting the study, they preferred nonchlorinated water than grass hay infusion. Therefore, the nonchlorinated water was used in this study instead of grass hay infusion. The water was produced from the fermentation of normal tap water (4 to 7 days) in the laboratory, which allows chlorine particles to precipitate at the bottom of the container with nonchlorinated water at the top. Only 1 unit of MLTD was placed in the kitchen area, particularly under the water sink, based on data from a preliminary study (1 MLTD in 1 apartment unit). The larval samples were collected weekly from house-to-house for a period of 28 wk (i.e., January to July 2012). During the weekly sample collection, all larvae from each MLTD were transferred using Pasteur pipette into a new plastic container containing 5 ml of tap water. In addition, water in each MLTD was also changed each week throughout the surveillance period.

**Preliminary study**

Prior to this study, a preliminary study (pilot test) was conducted in both apartments in order to determine and identify the most suitable MLTD placement site inside the apartment units. Four locations (dining room, master bedroom, kitchen, and toilets) were evaluated, with 1 MLTD in each location.
Larval identification

The larvae collected were transported to the laboratory and maintained until they reached 4th instar for identification to species, using light microscope. The larvae (i.e., *Ae. aegypti* or *Ae. albopictus*) were identified based on 3 main characteristics of their 8th body segment (comb scales, pectinate teeth, and ventral brush) (WHO 1995). The numbers of larvae were recorded individually from each MLTD.

Meteorological data collection

The meteorological data, such as rainfall, maximum and minimum temperature, and relative humidity, were obtained from the University of Malaya weather station. This weather station was selected because it is the nearest station to our study sites (approximately <7 km). These data were recorded within the same period of the larval collection, which started from the 1st week to the 28th week (January to July 2012).

Data analysis

The data entry and analysis were conducted using Microsoft Excel (Albuquerque, NM) and Statistical Package for the Social Sciences software program for Windows version 18 (SPSS, Chicago, IL). To describe data, mean and standard error for continuous variables (e.g., number of larvae) and proportion for categorical variables (e.g., percentage of MLTD positive) were computed. Crude association of the binary outcome variable with each independent variable was assessed using Student *t*-test. The correlation between each variable (e.g., number of larvae, floor level, and meteorological data) were examined using Spearman’s correlation coefficient test. The level of statistical significance was set at *P* < 0.05 for all analyses.

Ethical consideration

The protocol of this study was approved by the Medical Ethics Committee of the University of Malaya Medical Centre, Malaysia (Reference Number: 788.74). Before the commencement of the study, meetings were held with the administrative officer of VA and IL apartments to explain the objective and methodology of the study. For residents who agreed to participate, an oral briefing was given by the investigators on the purpose and protocol of the study. Their participation was voluntary and they could withdraw from the study at any time without giving any reasons.

RESULTS

Prior to this study, a pilot test was conducted in both apartments in order to determine the MLTD placement sites inside the apartment units. With the exception of MLTDs placed in the kitchen area, our preliminary observation indicated no larvae present in the MLTDs placed the dining room, master bedroom, and toilets. The area under the kitchen sink appeared to be the most suitable location to place the MLTD. Although no statistical significance was observed among these 4 locations given the short duration of our preliminary study period (4 wk), all MLTDs were placed under the kitchen sink area throughout our study period.

Of the total 3,052 *Aedes* larvae collected, 2,981 (97.7%) were *Ae. aegypti* and 71 (2.3%) *Ae. albopictus*, based on the main characteristics of their 8th body segment. In VA, 97.7% (1,310) of 1,341 *Aedes* larvae were identified as *Ae. aegypti* (Table 1). Meanwhile, 97.7% (1,671) of 1,711 *Aedes* larvae (1,711) collected in IL were *Ae. aegypti* (Table 1). Likewise, IL (40 out of 1,711) had higher numbers of *Ae. albopictus* than VA (31 out of 1,341). For *Ae. aegypti*, the mean numbers of larvae collected were higher in IL (151.91 ± 29.01) compared to VA (100.77 ± 22.97). Similarly, the mean numbers of *Ae. albopictus* larvae were also higher in IL (3.64 ± 3.13) than in VA (2.38 ± 1.56) (Table 1).

Both mixed and single breeding of *Ae. aegypti* and *Ae. albopictus* were compared between VA and IL (Table 2). For single breeding of *Ae. aegypti* larvae, 92.4% (1,582; 143.82 ± 28.88) and 93.7% (1,256; 96.62 ± 22.72) was recorded in IL and VA, respectively. However, VA (15, 1.1%; 1.15 ± 0.93) had a higher number of a single breeding of *Ae. albopictus* larvae found in the MLTD compared to IL (10, 0.6%; 0.91 ± 0.51). For mixed breeding of *Aedes* larvae, a higher number was found at IL (119, 7.0%; 10.82 ± 4.64) than at VA (70, 5.2%; 5.38 ± 2.41). However, there was no significant difference (*P* > 0.05) in the mean number of larvae of the 2 species at both apartments (Table 2).

As shown in Table 3, *Ae. aegypti* was found at each floor level of both apartments, indicating that the species could be found breeding at each level of the apartment and not restricted by the height of the building. In contrast, *Ae. albopictus* was only found on the 3rd and 11th floors of VA and on the 2nd, 8th, and 10th floors of IL. It was also noted that both *Ae. aegypti* and *Ae. albopictus* could be found at higher levels of both apartments. However, there was no significant correlation (*P* > 0.05) in the mean number of *Ae. aegypti* and *Ae. albopictus* larvae between floor levels for all types of breeding patterns (i.e., single or mixed) for both apartments (Table 3).

Our results also indicated that the number of larvae proportionally increased as the amount of rainfall in the previous week increased (*R*; Fig. 1a). There was a significant positive correlation between the number of larvae collected and...
R₃ (the amount of rainfall collected on the previous 3 wk before R₀) for both apartments (VA: \( r = 0.417, P = 0.027; \) IL: \( r = 0.660, P = 0.000 \)) based on the Pearson’s correlation test (Table 4). Although there was a numerically positive correlation between the number of larvae and R₃ (i.e., as shown in Table 4) in both apartments, this finding, however, was not statistically significant. In contrast, there was a significant positive relationship between the number of larvae and R₂ recorded at VA \( (r = 0.445, P = 0.018) \), but not for IL. For the relationship between the number of larvae and R₂, there was a significant relationship for IL \( (r = 0.415, P = 0.028) \), but not for VA.

The results on the effect of temperature on Aedes larvae (Fig. 1b) showed that the highest numbers of larvae were collected at week 7 (maximum temperature of 33.8°C and minimum 22.7°C) and week 11 (maximum temperature 34.4°C and minimum temperature 23.6°C). It was observed that the maximum temperature was recorded in week 23 and week 25 while the minimum temperature was recorded in week 4 (i.e., 22°C). The number of Aedes larvae collected was negatively associated with the minimum temperature at both apartments (VA: \( r = -0.049; \) IL: \( r = -0.158 \)). In contrast, positive correlation was observed between the maximum temperature and number of larvae (VA: \( r = 0.064; \) IL: \( r = 0.093 \)). There was no significant difference \( (P > 0.05) \) between the number of Aedes larvae collected and temperature at both apartments (Table 4). With regard to the relationship between RH and Aedes larvae collected, there was a positive association in the number of Aedes larvae in both VA and IL apartments (Fig. 1c). The highest RH (86%) was recorded during week 10 of this study period, whereas the 1st week had the lowest humidity (74.9%). There was a significant difference between RH and the number of larvae collected in both apartments (VA: \( r = 0.380, P = 0.046; \) IL: \( r = 0.401, P = 0.034 \) (Table 4).

**DISCUSSION**

Currently, vector field surveys using mosquito eggs or larval traps is among the common technique used by local health authorities since this method provides better evaluation of mosquito abundance as well as in predicting the mosquito population densities in dengue-prone areas. Based on our findings, *Ae. aegypti* was a predominant *Aedes* sp. found in the MLTD surveillance in both study areas (VA = 97.69%; IL = 97.66%). These findings were in parallel with the previous study by Wan-Norafikah et al. (2010), who reported the dominance of *Ae. aegypti* (87.85%) found in a preliminary ovitrap study among high-rise apartments in Putrajaya, Malaysia. These findings were also supported by a previous study by Lau et al. (2013), which reported that high density of *Ae. aegypti* was found in 4 multiistory buildings in Kuala Lumpur and Selangor. Results also indicated a lesser number of *Ae. albopictus* found in the present study, and these results were similarly reported by Wan-Norafikah et al. (2010). The current study showed that the infestation of a single breeding of *Ae. aegypti* was higher at VA and IL. In general, *Ae. aegypti* is an urban domestic mosquito, which

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**Table 1.** Overall number of larvae of *Aedes aegypti* and *Ae. albopictus* collected in mosquito larvae trapping device (MLTD) from Vista Angkasa (VA) and Inderaloka (IL).

<table>
<thead>
<tr>
<th>Study area</th>
<th>Total positive MLTD (n = 560)</th>
<th>Total no. of larvae</th>
<th>%</th>
<th>Mean ± SD</th>
<th>Total no. of larvae</th>
<th>%</th>
<th>Mean ± SD</th>
<th>Total no. of larvae</th>
<th>%</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>VA</td>
<td>248</td>
<td>1,310</td>
<td>97.7</td>
<td>100.77 ± 22.97</td>
<td>31</td>
<td>2.3</td>
<td>2.38 ± 1.56</td>
<td>42.3</td>
<td>41.8:1</td>
<td></td>
</tr>
<tr>
<td>IL</td>
<td>279</td>
<td>1,671</td>
<td>97.7</td>
<td>151.91 ± 29.01</td>
<td>40</td>
<td>2.3</td>
<td>3.64 ± 1.31</td>
<td>41.8:1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Table 2.** Comparison of mixed and single breeding of *Aedes aegypti* and *Ae. albopictus* collected in mosquito larvae trapping device from Vista Angkasa (VA) and Inderaloka (IL).

<table>
<thead>
<tr>
<th>Study area</th>
<th>Total no. of larvae</th>
<th>%</th>
<th>Mean ± SD</th>
<th>Total no. of larvae</th>
<th>%</th>
<th>Mean ± SD</th>
<th>Total no. of larvae</th>
<th>%</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>VA</td>
<td>1,256</td>
<td>93.7</td>
<td>96.62 ± 22.72</td>
<td>15</td>
<td>1.1</td>
<td>1.15 ± 0.93</td>
<td>70</td>
<td>5.2</td>
<td>5.38 ± 2.41</td>
</tr>
<tr>
<td>IL</td>
<td>1,582</td>
<td>92.5</td>
<td>143.82 ± 28.88</td>
<td>10</td>
<td>0.6</td>
<td>0.91 ± 0.51</td>
<td>119</td>
<td>7.0</td>
<td>10.82 ± 4.64</td>
</tr>
</tbody>
</table>

**Student t-test (P):** 0.07 0.13 0.16
can mainly be found near the vicinity of human habitation, as the adult mosquitoes need humans for their blood meals (Cheong 1986, Lee 1992). They are likely to oviposit in artificial containers (earthen jar and plastic containers), which contain relatively clear water but not necessarily clean water (Hasanuddin et al. 1997). In nature, adults *Ae. aegypti* typically lay eggs in receptacles such as in tree holes (Lee et al. 1987). Additionally, this species is closely associated with a well-defined range of immature habitats preferably from small to large artificial containers (Parker et al. 1983). As concluded by Chadee et al. (2004), the high density of *Ae. aegypti* found in the high-rise apartments might be due to the presence of biotic and abiotic elements that play a significant role in providing a complete ecosystem for the adult *Aedes* mosquitoes to increase their population in these areas. Biotic elements consist of humans, plants, and pet animals, while elements such as temperature, humidity, rainfall, and housing structure are categorized as abiotic.

<table>
<thead>
<tr>
<th>Level</th>
<th>Height (m)</th>
<th>Mixed breeding</th>
<th>Single breeding</th>
<th>Total</th>
<th>Mixed breeding</th>
<th>Single breeding</th>
<th>Total</th>
<th>Single breeding</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0–3.0</td>
<td>1.64 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>1.64</td>
<td>1.64 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>1.64</td>
<td>0.00 ± 0.00</td>
<td>1.64</td>
</tr>
<tr>
<td>2</td>
<td>3.1–6.0</td>
<td>1.31 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>1.31</td>
<td>1.31 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>1.31</td>
<td>0.00 ± 0.00</td>
<td>1.31</td>
</tr>
<tr>
<td>3</td>
<td>6.1–9.0</td>
<td>0.86 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.86</td>
<td>0.86 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.86</td>
<td>0.00 ± 0.00</td>
<td>0.86</td>
</tr>
<tr>
<td>4</td>
<td>9.1–12.0</td>
<td>0.56 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.56</td>
<td>0.56 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.56</td>
<td>0.00 ± 0.00</td>
<td>0.56</td>
</tr>
<tr>
<td>5</td>
<td>12.1–15.0</td>
<td>0.41 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.41</td>
<td>0.41 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.41</td>
<td>0.00 ± 0.00</td>
<td>0.41</td>
</tr>
<tr>
<td>6</td>
<td>15.1–18.0</td>
<td>0.31 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.31</td>
<td>0.31 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.31</td>
<td>0.00 ± 0.00</td>
<td>0.31</td>
</tr>
<tr>
<td>7</td>
<td>18.1–21.0</td>
<td>0.25 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.25</td>
<td>0.25 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.25</td>
<td>0.00 ± 0.00</td>
<td>0.25</td>
</tr>
<tr>
<td>8</td>
<td>20.1–24.0</td>
<td>0.21 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.21</td>
<td>0.21 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.21</td>
<td>0.00 ± 0.00</td>
<td>0.21</td>
</tr>
<tr>
<td>9</td>
<td>24.1–27.0</td>
<td>0.18 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.18</td>
<td>0.18 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.18</td>
<td>0.00 ± 0.00</td>
<td>0.18</td>
</tr>
<tr>
<td>10</td>
<td>27.1–30.0</td>
<td>0.15 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.15</td>
<td>0.15 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.15</td>
<td>0.00 ± 0.00</td>
<td>0.15</td>
</tr>
<tr>
<td>11</td>
<td>30.1–33.0</td>
<td>0.13 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.13</td>
<td>0.13 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.13</td>
<td>0.00 ± 0.00</td>
<td>0.13</td>
</tr>
<tr>
<td>12</td>
<td>33.1–36.0</td>
<td>0.14 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.14</td>
<td>0.14 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.14</td>
<td>0.00 ± 0.00</td>
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<tr>
<td>13</td>
<td>36.1–39.0</td>
<td>0.17 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.17</td>
<td>0.17 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.17</td>
<td>0.00 ± 0.00</td>
<td>0.17</td>
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</table>
components. These existing ecological factors could create convenient conditions for adult mosquitoes even at various levels of high-rise buildings, where the adults can obtain their blood sources most probably from humans or pets, resting places after bloodfeeding activities, and water for their aquatic requirements. In addition, high infestation of *Aedes* mosquitoes found in this study is facilitated by high density of human populations present in the 2 high-rise apartment buildings, providing ample sources of blood meals. Instead of being a principal host in the transmission of dengue virus, feeding on human blood can increase the longevity of the virus survivorship (Lee et al. 1987, Suwonkerd et al. 2006).

The low infestation of *Ae. albopictus* found in the apartment units in our study was expected. This finding is in concordance with a report by Wan-Norafikah et al. (2010). Higa et al. (2001) indicated that *Ae. albopictus* has a preference for living and staying in vegetated areas, feeds on blood sources, and rests outdoors even in domestic environments. Hawley (1998) also reported that this species is well adapted to peri domestic environments and has a tendency to oviposit in both artificial and natural containers near to human dwellings. One of the possible reasons for the presence of *Ae. albopictus* inside the house may be the consequence of deforestation that recently occurred at VA and IL. The distance of deforestation sites to the study areas is <100 m. As a result of deforestation, the lack of vegetation could have forced adult *Ae. albopictus* to adapt to domestic and semidomestic environment with the existence of artificial breeding containers inside the houses (Gubler et al. 2001, Delatte et al. 2008). This is evident as our results showed that there were mixed population of *Ae. aegypti* and *Ae. albopictus* at VA and IL but with lower percentages. Passos et al. (2003) and Honorio et al. (2003) reported that larvae of *Ae. albopictus* have a tendency to cohabit with *Ae. aegypti* larvae in the same containers.

The present study also showed that both *Ae. aegypti* and *Ae. albopictus* can be found on higher floors in both study areas. Both VA and IL have different building heights, with VA being higher, consisting of 13 floors (0.0–39.0 m) versus IL having 11 floors (0.0–33.0 m). According to Wan-Norafikah et al. (2010) and Lau et al. (2013), the presence of *Aedes* mosquitoes at higher levels of buildings might be due to transportation of this dengue vector by humans using either lifts or stairways. This finding was in line with the previous study by Liew and Curtis (2004), who reported the detection of ovitrap infested with rubidium-marked eggs of both *Aedes* species between the 3rd and 21st levels of the condominium building in Singapore. In another study, Chadee (2004) reported that *Ae. aegypti* can be found up to 60.0 m (21st level) in high-rise apartment buildings. Besides that, the results also suggested that the possibility of *Ae. aegypti* and *Ae. albopictus* coexisting in the same container at higher levels in high-rise apartments. However, analysis using Spearman’s rank correlation coefficient showed that there was only a weak relationship with no significant difference between the mean number of Aedes larvae and the level of floors (height) at both VA and IL. In fact, these findings were in parallel with previous studies conducted by Wan-Norafikah et al. (2010) and Lau et al. (2013), who reported a poor correlation between the mean number of larvae of *Aedes* sp. and the height of levels among high-rise apartments in Putrajaya, Selangor, and Kuala Lumpur, respectively.

Of the ambient environmental factors, we found the mean number of *Aedes* larvae collected at VA and IL to be positively associated with RH, an observation previously reported in several studies (Guzman and Kouri 2003, Goncalves Neto and Rebelo 2004, Chakarvati and Kumaria 2005, Ratho et al. 2005, Wiwanitkit 2005, Ziecler et al. 2008). Generally, relative humidity affects the infestation, mating, longevity, mosquito

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<table>
<thead>
<tr>
<th>Study area</th>
<th>Rainfall(^1) (mm)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R(_0)</td>
<td>R(_1)</td>
</tr>
<tr>
<td>VA</td>
<td>0.103</td>
<td>0.445*</td>
</tr>
<tr>
<td></td>
<td>0.602</td>
<td>0.018*</td>
</tr>
<tr>
<td>IL</td>
<td>0.140</td>
<td>0.161</td>
</tr>
<tr>
<td></td>
<td>0.477</td>
<td>0.413</td>
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</tbody>
</table>

\(^1\) R\(_0\) = the amount of rainfall collected during the 1st to 28th week of the surveillance period; R\(_1\) = the amount of rainfall collected during the previous week before R\(_0\); R\(_2\) = the amount of rainfall collected during the previous 2 wk before R\(_0\); R\(_3\) = the amount of rainfall collected during the previous 3 wk before R\(_0\).

\(^2\) * Significant at 5% (0.05).
oviposition, and feeding behavior as well as rapid replication of the viruses (Hales et al. 2002). As concluded by Rohani et al. (2011), any species of mosquitoes at high humidity could have a longer live span and disperse farther. Besides that, evaporation rates of mosquito larval habitats are also influenced by these climatic factors. The study also noted that when rainfall and temperature were higher regardless to any specific weeks, humidity also increased at the same time. These combined conditions could provide habitats conducive to the growth and survival of vector populations (Nakhapakorn and Tripathi 2005).

Rainfall has been described as the most important physical factor affecting Aedes biology. According to Micieli and Campos (2003), high amount of rainfall has been strongly associated with the abundance of Ae. aegypti and its reproductive process. Precipitation, as results from rainfall, is an important factor in the transmission of dengue. All mosquitoes have aquatic larval and pupal stages and therefore require water for immature development (Lindsay and Mackenzie 1997). In addition, the pattern of rainfall may also involve the abundance of mosquito larvae. Extremely heavy rainfall may flush mosquito larvae away from their habitats or kill them outright (Promprous et al. 2005). More frequent, lighter rains may replenish existing larval/pupal sites and maintain higher levels of humidity that assist in the dispersal and survival of adult mosquitoes. The present study also showed that the amount of rainfall of the previous week showed positive relationship with the abundance of mosquito larvae in both apartments. This could be suggested that, as the amount of rain increases, so does the abundance of mosquito larval population. Our findings with regards to the association between rainfall and the abundance of Aedes larvae are generally in agreement with previous studies conducted in Malaysia (Rohani et al. 2011, Malinda et al. 2012) and Singapore (Loh and Song 2001). Likewise, Indaratna et al. (1998) indicated that high rainfall was strongly associated with the emergence of many vector breeding sites. In addition, adult Aedes mosquito is able to bite and lay eggs frequently, thus increasing their population size. High rainfall can also increase the population of larvae since Aedes spp. need approximately 6 to 10 days for eggs to develop and grow to the immature larval stage (Lee 1992).

Temperature is another important determinant that influences the abundance of mosquito larvae, a finding that was in line with our observations. High temperature favors the adults to bite more frequently and it also provides more mosquito breeding habitats (Ratho et al. 2005). Likewise, temperature potentially affects the spread of dengue pathogens via each stage in the mosquito life cycle. Lu et al. (2009) found that the survival of Aedes mosquitoes either in the adult or immature stage could be adversely affected by lower temperature. In addition, minimal temperature can be used as an important indicator in determining the level of vector infestation (Donaílio and Glasser 2002), while higher temperatures might assist survival of mosquito larvae. In addition, increasing temperatures may accelerate the mosquito’s rate of development and, consequently, might increase the abundance of mosquitoes (i.e., adult or larval stage) (Rohani et al. 2011).

The findings of the current study also indicated that number of Aedes larvae (i.e., Ae. aegypti and Ae. albopictus) in IL was higher compared to VA. This could be due to several factors, for instance the presence of artificial breeding sites (i.e., containers, used bottles, cans, tins, and plastic food containers) that were found at the vicinity of the apartments, which the adult Aedes mosquito may have used to oviposit. From our personal observations during each visit to both apartments, high numbers of artificial larval/pupal habitats were observed in IL compared to VA. Lee et al. (1987) reported that the distribution of Ae. aegypti and Ae. albopictus in human habitation could be influenced by the presence of artificial breeding containers. In addition, we also noticed the presence of stagnant water in several locations surrounding the apartment, such as drainage systems and parking lots. Likewise, pools of water were also observed at staircases, lifts, and corridors of the building. Chen et al. (2005) indicated that stagnant water could provide better conditions for immature habitats. In addition, the growth of immature stages to adults can be accelerated by feeding on the organic matter or microorganisms that are present in stagnant water. Other reasons that may contribute to the higher number of Aedes infestation in IL could be its close vicinity to forested areas. This can provide additional breeding sites for the Aedes populations, especially Ae. albopictus as this species can inhabit both indoor or outdoor areas such as forest edges that are near to the housing area (Hawley 1998). Therefore, the high abundance of Aedes larvae found in the apartment units was probably due to the high density of Aedes mosquitoes that have been recruited from the outside of the apartment units.

General sanitation or the level of cleanliness at VA was generally better than at IL as the former is managed by a privatized administration. From our observations, several areas including ground floor, corridors, staircases, and parking lots were cleaned daily by the cleaners. There were a small number of artificial breeding containers found in VA; however, the numbers were much lower in comparison to IL. The presence of a small number of artificial breeding sites in VA may
suggest that the *Aedes* mosquitoes most likely stayed inside the apartment units. Other potential factors that contributed to high density and infestation of *Aedes* mosquitoes are the human aspect that includes their activities and behavior, which are not discussed in detail in this study but may need to be considered in future investigations. The habit of adding water to containers for water-storage purposes (i.e., drinking, cooking, or bathing), ornamentation (fountains), or watering plants could facilitate the propagation of *Aedes* mosquitoes in terms of immature sites. Increase in population size of the vectors can favor the transmission of dengue virus among the populations and the occurrence of dengue outbreaks especially during the dry season (Eamchan et al. 1989).

In conclusion, the study showed the adaptation of *Ae. aegypti* to high-rise buildings, with the invasion of *Ae. albopictus* inside the apartment units, where both species can enhance the transmission of dengue virus. Although IL is known as an area with no reported dengue cases or outbreaks, the higher infestation of *Aedes* was found in this area compared to VA (high-dengue-incidences area), with regard to the higher number of *Aedes* larvae. This could motivate the local health authorities to conduct more efficient vector control programs with the integration among larval and adult surveys, chemical, and biological control strategies. Furthermore, other components such as personal dengue protection with a combination of knowledge, attitude, and practices should be considered to alert the public about the risk of acquiring dengue. The participation from the communities through public awareness campaign should be encouraged in suppressing the numbers of dengue incidence and outbreaks by eliminating infected and/or uninfected *Aedes* mosquitoes.

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