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Original paper

Arboviral vectors dispersal and density in storey buildings: the association of light intensity and air temperature

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ABSTRACT. *Aedes* mosquito is the most common arboviral vector in the tropic and subtropic regions that it was dispersed in high-rise buildings up to many storeys. A study reported that similar condition in Indonesia is still limited, although the high-rise buildings are also growing rapidly throughout the country. This study aimed to understand the dispersal and density index of *Aedes* mosquitoes among storey buildings at the campus of Universitas Muhammadiyah Semarang, Indonesia. A cross-sectional study was conducted among four of nine-storey buildings. Eight ovitraps were placed in each storey to collect the mosquito eggs by placing them along the building corridor and near the toilet rooms. Ovistrip from each ovitrap was collected every three days, and the attached mosquito eggs were observed and counted under a microscope in the laboratory to calculate the density index. *Aedes* mosquitoes were found in all buildings up to the highest storey where the Ovitrap Index (OI) is the opposite of height, while the Eggs Density Index (EDI) differs according to the location of the building. OI at the 1st and 4th floor ranged between 63–100% and 38–50%. Eggs density was associated with the light intensity and air temperature. Two *Aedes* species were identified where *Aedes aegypti* was more dominant than *Aedes albopictus*. All high-rise buildings are exposed to *Aedes* mosquitoes, thus opening up opportunities for dengue virus transmission. Further study is necessarily conducted to understand the inter-storeys migration pathway of mosquitoes, preference habitats, and the highest storey exposed for control.

Keywords: arboviral vectors density, vertical dispersal, storey building, light intensity, air temperature

Introduction

Aedes aegypti and *Aedes albopictus* are the competent vectors for arboviruses such as dengue (DENV), chikungunya (CHIKV), Zika (ZIKV), and yellow fever (YFV) [1,2], even *Ae. albopictus* is competent in transmitting West Nile virus (WNV). These arboviruses posed a threat to global spread [3] over a wide geographic area along with the development of global transportation systems, arthropod adaptation to the effects of urbanization, mosquito vector population density, and land use [4,5], and also climate change [6]. Three of these arboviral types, namely DENV, CHIKV, and ZIKV showed the dynamics of emerging and re-emerging transmission in the Pacific region [7,8].

In addition to the human host density [9], the presence of *Aedes* mosquitoes was a determining factor for arboviral infection [10], where the mosquito population density increased the risk of viral infection [11]. Since antiviral drugs were not yet available and vaccines for several types of arboviruses (DENV, ZIKV, and CIKV) were still under development [12,13], efforts to prevent the transmission of these arboviruses relied on the *Aedes* mosquito control measures where the *Aedes* population density was the achievement indicator. Studies reported a high population density of *Aedes* mosquitoes in the tropical region [14–17], especially indoors [18]. On the other hand, the geographic distribution of these arboviral vectors was also expanding to tropical and subtropical countries [19].

A study reported that the dispersal of *Aedes* mosquitoes differed according to environmental conditions with a range from 52.8 to 58.0 m [20]. However, another study concluded that *Aedes* mosquitoes could spread easily both horizontally and vertically in high-rise buildings, especially in seeking blood feed and breeding places [21]. Monitoring the distribution of *Aedes* mosquitoes has also been carried out in specific residential areas, including high-rise buildings. Several studies in Asian and African countries have reported the dispersal and density of *Aedes* mosquitoes in this particular residential environment. Studies in Malaysia reported the distribution of *Aedes* mosquitoes to the highest levels in high-rise buildings in campus areas [22,23] and high-rise apartments and flats in Selangor [24], Malacca [25], Kuala Lumpur, and Johor [26] where *Ae. albopictus* was more dominant than *Ae. aegypti*. The density index of *Aedes* is inversely proportional to the height level of the building. In contrast, another study in Sri Lanka reported that *Ae. aegypti* was more dominant than *Ae*. *albopictus*, where the highest density of mosquito eggs was found on the 6th floor [27]. A similar study in Indonesia reported that two genera of mosquitoes were detected in the campus area where *Culex* spp. was more dominant than *Aedes* spp., adult *Culex* spp. was found in all buildings while *Aedes* spp. in both adults and eggs stage were only found in dormitories, and the density of *Aedes* spp. with the highest egg was found at level 1 [28]. One study in the Gambia areas found a very low density of *Aedes* mosquitoes compared to other species [29].

The presence of mosquitoes in high-rise buildings was thought to be associated with the seeking for blood feed and the breeding places [26], and the other factor included the increase in CO_2 levels related to the density of people [29]. High-rise buildings are also found in Indonesia, especially in urban areas which are generally dengue-endemic areas, including Semarang City. This study is aimed to determine the dispersal and density of *Aedes* mosquitoes in high-rise buildings, in Semarang City.

Materials and Methods

Study site

We conducted a cross-sectional study for three months from October to December 2021 among four of nine high-rise buildings on the campus of Universitas Muhammadiyah Semarang, Semarang, Central Java Province, Indonesia. Four high-rise buildings that consist of four storeys or more were selected to be studied, namely Dormitory, Health Laboratory (Health-Lab), nursing research centre (NRC), and Medical Faculty (F-Med). The four buildings have a similar structure, namely 50–60 meters long, 25–40 meters wide, and a storey height of 4.5 meters. There is a four-meter corridor in the centre of each storey building and eight toilet rooms (four for male and four for female separately).

Oviposition trap (*ovitrap*) *placement*

As many as eight ovitraps were placed solitary in each storey of the selected buildings. Ovitrap was made from used milk cans with a volume of 350 ml, opened at the top, trimmed, and painted black. The can was filled with water three-quarters high, and a 3 cm width ovistrip (filter paper) was attached to the wall of the can with a paper clip just above the waterline, as a place for mosquitoes to lay their eggs.

Data collection

The collected data consisted of building, storey, physical factors (indoor lighting, air temperature, and humidity), density of mosquito's eggs, and mosquito species. Physical factors were measured in each ovitrap location. Light intensity was measured by using a lux meter (DX-100 Digital Lux meter, Takemura Electric Works Ltd). Air temperature and relative humidity were measured by using a hygrometer (HAAR-SYNT HYGRO). The existence of mosquito eggs in each ovitrap was detected by observing the filter paper microscopically and counting the eggs by the Manual Hand Tally counter. The density of mosquito eggs was calculated in two formulas, namely ovitrap index (OI) and Eggs Density Index (EDI). OI represents the percentage of ovitrap with egg(s) in ovistrip, while the EDI represents the mean of eggs among ovitraps. Mosquito species were identified by using the Walter Reed Bioinformatics Units (WRBU) guideline. The external environmental condition (vegetation) of each building were observed and stated qualitatively.

Data analysis

All numeric data were analysed descriptively in statistical parameters of minimum, maximum, mean, deviation standard, and bar chart. The data of

Table 1. Distribution of Ovitrap Index of *Aedes* sp. among storey building

Building	Ovitrap Index (%)			
	Minimum	Maximum	Mean	SD
Dormitory	38	100	72.25	27.55
Health-lab	30	88	56.50	21.75
NRC	50	75	65.75	11.93
F-Med	38	63	50.50	14.43

Explanations: there was no significant different of ovitrap index based on the building (*P*=0.259). This data is indicated that all buildings have a risk of dengue transmission

physical factors, OI, and EDI were compared based on the building and storey. Light intensity, air temperature, and relative humidity were correlated with the OI and EDI. Statistical analysis was performed by using the SPSS of the 16th version.

Ethical approval

The protocol of this study was reviewed by the Ethics Committee of Health Research of Public Health Faculty of Universitas Muhammadiyah Semarang and obtained the certificate number: 587/KEPK-FKM/UNIMUS/2021.

Results

In total, mosquito eggs were found in all storey buildings (the sites of study) although in different densities. The highest density of mosquito eggs was found in the dormitory, while the lowest density was in the F-Med building, although the statistical analysis did not show a significant difference (Tab. 1). The first floors in all storey buildings are the area with the highest exposure to mosquito eggs, and the egg density decreases gradually according to the elevation of storey. This phenomenon was demonstrated by both OI and EDI (Fig. 1). The results of the statistical analysis of mosquito eggs density (Tab. 2) showed the significant differences in EDI based on the building (*P*=0.006), storey (*P*=0.000), and the interaction of building and storey (*P*=0.000).

The results of the data analysis of physical

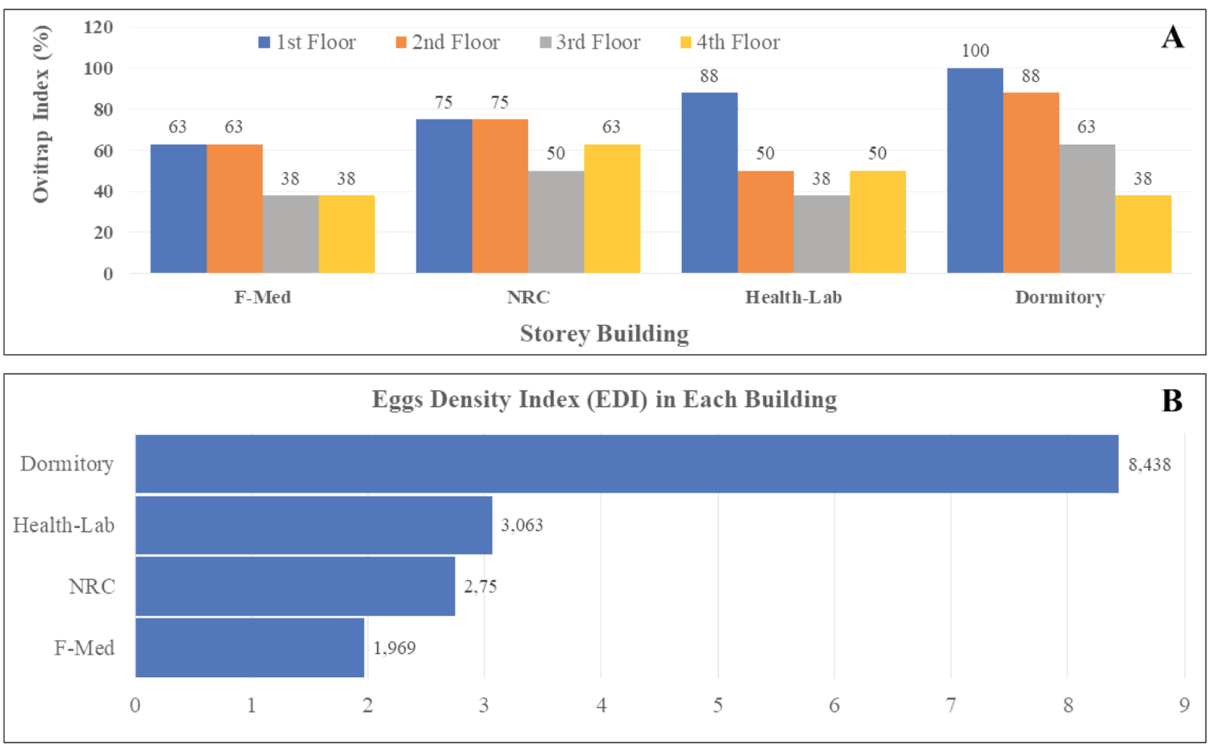

Figure 1. The distribution of *Aedes* mosquitoes in storey buildings: (A) the variation of Ovitrap Index (OI), and (B) the Eggs Density Index (EDI) of *Aedes* mosquitoes, based on the building and storey

Table 2. The density and vertically dispersal of *Aedes* mosquito among the storey buildings

	Storeys#	Eggs Density Index			
		Min	Max	Mean	SD
Dormitory	1st	6	43	18.37	11.698
	2nd	0	24	10.13	7.772
	3rd	0	10	3.63	3.926
	4th	0	7	1.63	2.682
Health-Lab	1st	0	16	5.87	5.276
	2nd	0	10	3.00	3.964
	3rd	0	8	2.00	3.071
	4th	0	4	1.38	1.598
NRC	1st	0	22	5.50	7.329
	2nd	0	7	2.50	2.563
	3rd	0	8	1.88	2.850
	4th	0	4	1.13	1.356
F-Med	1st	0	43	4.38	4.534
	2nd	0	24	1.75	2.053
	3rd	0	10	1.13	1.642
	4th	0	7	0.63	0.916

Explanations: statistical analysis of mean difference of EDI based on buildings (P=0.006*), storey (floor levels) (P=0.000#), and interaction of building and storey (P=0.000*#)

Table 3. Physical factors variation based on storey buildings

	Statistics	Physical factors		
		Lighting (Lux)	Temperature (°C)	Relative humidity (%)
Dormitory	Min	49.00	26.56	62.00
	Max	126.00	27.22	65.00
	Mean	92.25	26.97	63.25
	SD	30.07	0.26	1.11
Health Lab	Min	57.00	26.76	61.00
	Max	103.00	27.24	76.00
	Mean	73.00	27.08	70.50
	SD	18.22	0.19	5.77
NRC	Min	59.00	26.66	69.00
	Max	198.00	27.46	74.00
	Mean	122.25	27.06	70.75
	SD	62.68	0.29	2.08
F-Med	Min	47.00	27.12	62.00
	Max	97.00	27.79	64.00
	Mean	71.50	27.45	62.75
	SD	22.56	0.25	0.84
Total	Min.	47.00	26.56	61.00
	Max.	198.00	27.79	76.00
	Mean	89.75	27.14	66.81
	SD	42.51	0.31	4.93

Table 4. Correlation between physical factors and eggs density among storey buildings

Physical factors	r	*P*
Temperature	-0.477**	0.000
Relative humidity	-0.154	0.083
Light intensity	-0.319**	0.000

***P*=0.01 (2-tailed)

factors showed a slight variation, and there was no significant difference based on the building and the storey. The minimum and maximum average of light intensity, temperature, and relative humidity were 71.5 lux (F-Med building) and 122.25 lux (NRC building), 26.97°C (Dormitory building) and 27.45°C (F-Med building), and 62.75% (F-Med building) and 70.75% (NRC building) (Tab. 3). Physical factors data showed the optimum range for the life of the *Aedes* mosquito. However, the results of statistical analysis showed a significant correlation between light intensity (*P*=0.000) and air temperature (*P*=0.000) with EDI (Tab. 4 and Fig. 2). The description of the external environmental factors of each building showed different conditions. The dormitory is located in a densely vegetated area with tall trees, and there are more occupants. In contrast, the F-Med building is located in an open area with very sparse vegetation with the small and low trees. The other buildings, the NRC and the Health lab are in similar condition. Both buildings are surrounded by mini-gardens with medium vegetation density and small and low trees. Identification of progeny mosquitoes from all buildings and storeys found two species of *Aedes* mosquitoes, namely *Ae. aegypti* which was spread in all buildings, and *Ae. albopictus* which was only found in the dormitory.

Discussion

Mosquito exposure in storey building

Aedes mosquitoes were found in all high-rise buildings (fourth level in this study). This situation was per the findings of the other studies where *Aedes* mosquitoes were found in various high-rise buildings, even up to the 21st floor [26]. This finding indicated that the environmental conditions in the high-rise building supported the life cycle of the *Aedes* mosquito [30]. The measurement results of physical factors in the high-rise buildings, namely lighting intensity, air temperature, and humidity indicated that the environmental conditions were suitable for the life cycle of the *Aedes* mosquito. The conditions correspond to the optimum temperature for *Aedes* mosquitoes, namely 26°C with a range of 16–32°C for *Ae. aegypti,* and the lowest and highest optimum temperature of 15°C and 35°C for *Ae. albopictus* [31].

The density of mosquitoes

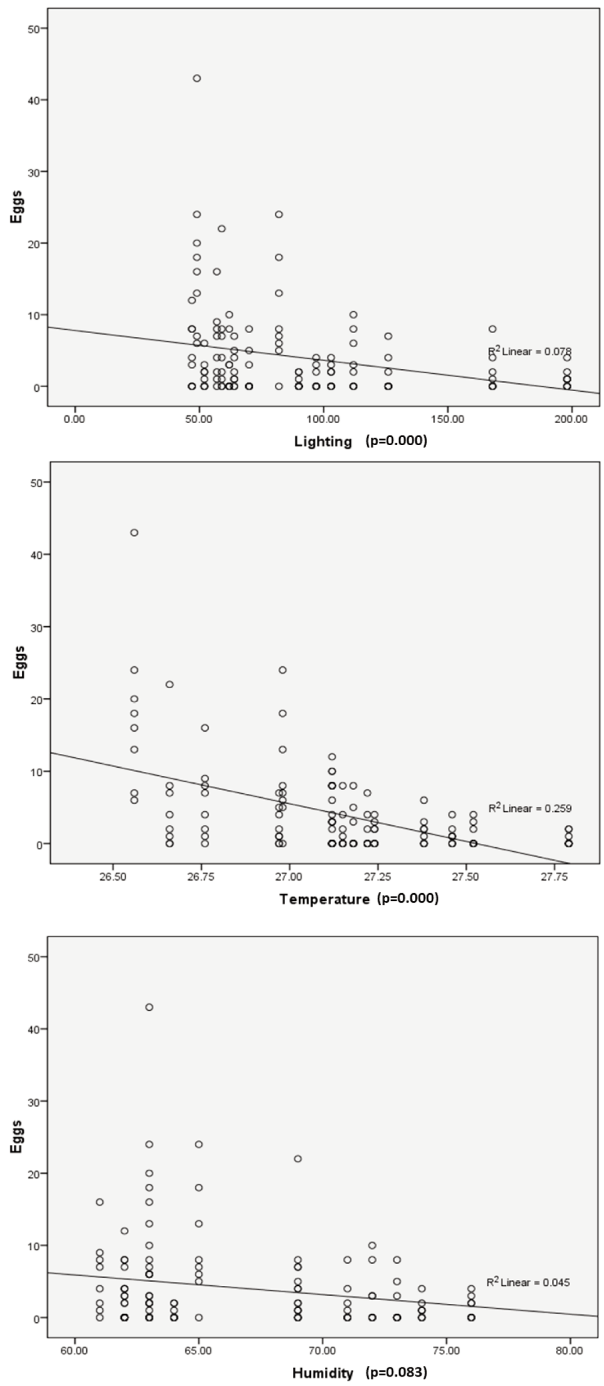

Figure 2. Physical factors associated with the egg density among storey buildings

The dormitory was exposed to *Aedes* eggs with the highest density among other buildings. This building is surrounded by tall and shady trees so that the courtyard and spaces in the inner part of the building up to the third level are half shady. The dormitory building is also adjacent to the cemetery with a distance of less than 100 m. These conditions present suitable physical factors for the survival and reproduction of *Aedes* mosquitoes [32]. The interplay between high-rise buildings and the surrounding environment forms new habitats that are suitable for the life of the *Aedes* mosquito [30]. In addition to vegetation factors, the dormitory environment also forms a complex micro-ecosystem between biological and physical factors and human density and activities. The number and activity of people in this building are higher than those in Health-Lab, NRC, and F-Med. The density of people affects the production of CO_2 and this compound is a good attractant for mosquitoes [33–35]. The outside environmental factor, the existence of a cemetery, and idle land are the factors supporting the availability of suitable habitats for *Aedes* mosquitoes, especially *Ae. albopictus* [36].

The dispersal of mosquitoes

Exposure to mosquitoes with the highest density was found on the first level of all buildings with an inverse relationship between the building level and the density of mosquito eggs. This phenomenon is similar to the other findings in various countries [26]. In addition to the vegetation aspect, the density of *Aedes* eggs is influenced by the interaction of various complex physical factors of indoor and outdoor buildings. The high vector density on the first floor is related to the following factors: (i) the nature of mosquitoes which generally fly at an altitude of less than one meter from the ground [29], and (ii) the CO_2 concentration is higher on the lower floors because the number and activity of occupants are higher and lower air movement in these places due to obstruction by trees, (iii) the lower light intensity where *Aedes* mosquitoes prefer dim places with high humidity, and (iv) the ease of indoor-outdoor interaction. There are very few micro-breeding places inside the building, especially only squat toilets which are not covered so mosquitoes need natural breeding places outside the building. This possible phenomenon can only happen on the first floor where the existence of the flower gardens around the building may provide a little standing water for larval breeding, in addition to water channels.

The species of mosquitoes

Two species of mosquitoes identified as the primary and secondary vectors of dengue viruses were *Ae. aegypti* and *Ae. albopictus*. Although this finding was in line with the other studies that the main species of mosquitoes in the dengue endemic areas were *Ae. aegypti*, we found that *Ae. albopictus* was only identified from the dormitory building. This is supported by the environmental conditions of the dormitory building following the habitat of *Ae. albopictus*, including the cemetery behind the building. The cemetery is one of the typical habitats of *Ae. albopictus* [36]. The presence of these two species in the dormitory environment made this area susceptible to transmission of dengue, Zika, and chikungunya as reported in other areas [2,11,37].

The associated factors of egg density

In this study, lighting and air temperature were significantly associated with *Aedes* egg density. This finding is consistent with reports from several studies that the presence of visible light increases the number of mosquitoes that enter the house [35]. Not limited to exposure to visible light, mosquito density in the house is influenced by the interaction of various complex factors including air temperature, area and type of ventilation, as well as CO_2 concentration [29,34,35,38]. Maximum exposure to natural light in the tropics increases the indoor air temperature. This condition triggers high CO_2 production in dense housing and high activity of people. The CO_2 compound is a good attractant for mosquitoes. The CO_2 concentration is higher in buildings with low ventilation areas or those rarely opened. Although this study has not revealed the migration pathways of mosquitoes from the lower floor to the upper level the other studies stated that the elevator, lift, or stairs have an important role in the inter-storey spread of mosquitoes in high-rise buildings [21–23]. This needs to be scientifically proven so that control efforts can be carried out. This finding has significance for managers and residents of high-rise buildings to pay attention and vigilance against exposure to arboviral vectors and take protective measures.

In conclusion, the eggs of *Aedes* mosquitoes were found in all studied storey buildings with a significant decrease according to the elevation in storey levels. The egg's density was significantly associated with the light intensity and air temperature, but not relative to humidity. Two *Aedes* species were identified, namely *Aedes aegypti* and

Aedes albopictus. Further investigation on the favourable mosquito migration pathway, the highest storey exposed, and local mosquito habitats are necessarily identified for controlling.

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