Environmental factors of the home affect the density of Aedes aegypti (Diptera: Culicidae)

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ABSTRACT *The transmission of Dengue Hemorrhagic Fever (DHF) by Aedes aegypti and Aedes albopictus mosquitoes is influenced by climate change and several environmental factors, namely light intensity, CO2, temperature, humidity, housing condition, drainage, and vegetation. This study aims to identify the relationship between environmental factors and dengue vector population density. This research applies an observational analytic study with a cross-sectional design. The study was conducted in 2012, in the city of Yogyakarta, Indonesia, in 39 houses in the Kricak Village and in 50 houses in the Prenggan Village. Data were collected by observation, interview, and completing checklists, as well as by measuring environmental variables. The differential effect of various factors influencing mosquito density was tested using an independent sample t-test for physical environmental factors and chi-square test for the variable physical condition of the house, biologically relevant environmental factors, drainage, residential density, and the distance between houses. The probability value was p <0.05. The results showed that differences in the physical environment, the physical condition of the house, residential density, and vegetation, all affect the density of dengue vector mosquitoes in the villages of Kricak and Prenggan. The need of raising public awareness about healthy living and care for the environment, along with advocacy to stakeholders, is important for vector density control.*

INTRODUCTION

Dengue is a global health problem, with approximately 22,000 deaths reported per year, accounting for 40% of the population in 100 tropical and subtropical countries (WHO, 2010; Bhatt et al., 2013; Corbel et al., 2013). Mosquitoes residing around human dwellings include *Aedes aegypti, Aedes albopictus*, and *Culex quinquefasciatus* mosquitoes (Tabachnick, 1991). Mosquito density is affected by the presence of mosquito resting and breeding sites, as well as mosquito foraging sites (Stojanovich and Scott, 1965). Factors causing mosquitoes to approach humans are the CO2 produced by of the human body, amino acids, warmer ambient temperatures, and humidity (Gubler et al., 1979). *Aedes aegypti* mosquitoes prefer indoor places to rest and hide in hanging clothes (Perich et al., 2000; Scott and Morrison, 2010).

Vector-borne diseases such as dengue are important because of their ability to be transmitted is critically affected by climate change, and in particular, temperature, humidity, water surfaces, and wind currents (Dom et al., 2012; Alshehri, 2013). Environmental factors, namely residential density, water reservoirs, and rarely opened doors and windows, are factors that facilitate the breeding of mosquitoes (Clements, 1999). Thus, investigation of the effect of environmental conditions on the population density of mosquito vectors of dengue is critically important.

MATERIALS AND METHODS

This research applies an observational analytic study with a cross-sectional design. The study was conducted in 2012, in two villages in Yogyakarta, Indonesia, specifically Kricak Village with a high mosquito density and Prenggan Village with a lower mosquito density. The sample size was determined *a priori*: 39 houses in the Kricak Village and 50 houses in the Prenggan Village were examined in a proportionally random fashion. Independent variables include biologically relevant environmental factors (quantity of vegetation, vegetation height, vegetation density, extent of vegetation), physical environment factors (lighting, CO2, indoor and outdoor air temperatures, and indoor and outdoor humidity), the physical condition of the house (flooring, wall, ceiling, door, ventilation, and bedroom window), drainage, residential density, and the distance between houses. The dependent variable was the density of the mosquito population. Data were collected by observations, interviews, and checklists, as well as measurements of environmental variables. The differential effect of various factors influencing mosquito density was tested using an independent sample t-test for physical environmental factors and chi-square test for the variable physical condition of the house,

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biologically relevant environmental factors, drainage, residential density, and the distance between houses. The probability value was $p < 0.05$.

RESULTS AND DISCUSSION

Respondent characteristics

Most respondents in the Prenggan and Kricak Village were of male gender (80% and 82.1%, respectively). Most village residents in Prenggan Village have finished primary school (36%), while in Kricak Village, most have finished high school (43.6%). Most of the population in Prenggan Village are self-employed (40%), while residents in Kricak Village work as laborers (28.2%), are self-employed (23.1%), or are in the private sector (23.1%). Average age in the two villages was almost identical: the average age was 55.88 in Prenggan Village and 55.95 in Kricak Village, as summarized in Table 1.

Table 1. Characteristics of respondents from Prenggan Village and Kricak Village

		Villages			
		Prenggan		Kricak	
Variables		n	%	n	%
Gender					
	Male	40	80.0	32	82.1
	Female	10	20.0	7	17.9
Educational background	Unschooled	2	4.0	5	12.8
	Elementary	18	36.0	13	33.3
	Junior high	10	20.0	3	7.7
	Senior high	12	24.0	17	43.6
	College	8	16.0	1	2.6
Occupation					
	Unemployed	6	12.0	5	12.8
	Farmer	1	2.0	0	0
	Labor	5	10.0	11	28.2
	Self-employed	20	40.0	9	23.1
	Private sector	11	22.0	9	23.1
	Teacher	2	4.0	0	0
	Civil servant	3	6.0	1	2.6
	In retirement	2	4.0	4	10.3
Age (years)					
	Sample size	50		39	
	Mean	53.88		55.95	
	Std. Dev.	13.68		13.31	

Mosquito density

There were significant differences in the density of mosquitoes between Prenggan Village and Kricak Village (Table 2): the average density of mosquitoes in Prenggan Village was lower (1.30) than in Kricak Village (6.89). From the preceding results, factors influencing differences in mosquito density in the two villages were investigated further through observations made of the physical environment, housing conditions, and environmental and biological factors.

Table 2. Mosquito density analysis in Prenggan Village and Kricak Village

Mosquito density	Villages	
	Prenggan	Kricak
Sample size	50	39
Mean	1.30	6.89
Std. Dev.	1.50	5.54
p-value	0.000	

Environmental factors

Results of the light intensity tests showed that Kricak Village had an average light intensity of 59.59 lux, whereas Prenggan Village had an average value of 66.96 lux; however, this difference in light intensity was not significantly different (Table 3). Light intensity is a major factor affecting *Aedes aegypti* bionomics. Lower light intensities (<19 lux) provide prime conditions for mosquitoes (Silver, 2007). Low levels of light penetrating rooms generate a dark environment in homes. These low light environments are favored resting sites for mosquitoes. Houses in Kricak Village with higher mosquito densities have generally poor lighting and therefore have an increased risk of mosquito breeding compared to houses in Prenggan Village.

Significant differences were detected in CO2 levels between Kricak Village (average of 1.84%) and Prenggan Village (average of 1.49%). Carbon dioxide (CO2) is an important product of human respiration and is known to be an attractant for mosquitoes. Humans with higher metabolic rates (e.g., obese people, pregnant women) produce more carbon dioxide, and hence, are more likely to be targeted by foraging mosquitoes. Carbon dioxide is thought to act as a *kairomone* for mosquitoes. Other substances acting as mosquito attractants include amino acids, warm ambient temperatures, and high levels of humidity (Gubler et al., 1979).There were significant differences detected between indoor and outdoor air temperatures in Kricak Village (average of 29.08°C and 30.05°C, respectively), compared to temperatures in Prenggan Village (average of 27.33°C and 28.36°C, respectively). The time required for mosquitoes to develop from egg to adult form depends mostly on ambient temperature (Mohammed and Chadee, 2011; Muturi et al., 2012). *Aedes aegypti* mosquitoes live in an environment with a temperature of 25-27°C, which is the optimal temperature for mosquito larvae development (Christophers, 1960; Farnesi et al., 2009; Balenghien et al., 2010). The results showed that the average temperature in the two villages is not optimal for the development of mosquito larvae, as shown in Table 3.

There were no significant differences in indoor humidity, yet there were significant differences in outdoor humidity between Kricak Village (average of 82.74% and 85.18%, respectively) and Prenggan Village (average of 84.38% and 86.41%, respectively). Optimum humidity levels ranging from 60-80% allow mosquitoes to remain alive (Christophers, 1960; Impoinvil et al., 2007; Arsunan and Ibrahim, 2014). Mosquitoes are sensitive to ambient moisture, as dry conditions decrease the ability of mosquitoes to survive in nature (Alshehri, 2013; Ibarra et al., 2013). The results showed that the humidity level in both villages may promote the breeding of dengue vectors. Measurements of humidity levels may robustly predict the spread of dengue (Phillips, 2008).

Table 3. Environmental factor analysis in Prenggan Village and Kricak Village

Variables	Villages	n	Mean	Std. Dev.	p-value
Light intensity (lux)	Prenggan	50	66.96	63.90	0.607
	Kricak	39	59.59	68.89	
Room CO_2level (%)	Prenggan	50	1.49	345.36	0.000
	Kricak	39	1.84	489.84	
Indoor air temperature (°C)	Prenggan	50	29.08	1.47	0.000
	Kricak	39	27.33	1.28	
Outdoor air temperature (°C)	Prenggan	50	30.05	1.86	0.154
	Kricak	39	28.36	.94	
Indoor humidity (%)	Prenggan	50	84.38	3.12	0.103
	Kricak	39	82.74	6.50	
Outdoor humidity (%)	Prenggan	50	86.41	2.61	0.000
	Kricak	39	85.18	4.05	

Physical condition of the houses

Most houses in the villages of Prenggan and Kricak are built with plastered/tiled/ceramic floors (94% and 89.7%, respectively), yet the statistical analysis results showed no significant difference in this percentage. Thus, flooring conditions may not be responsible for the differential density of mosquitoes in the study area. Plain ground flooring will most likely be humid during the rainy season; therefore, covering floors with water-resistant materials such as cement, tile, ceramic and terrazzo is encouraged (CDC, 2006). There were no significant differences in the condition of the walls in Prenggan Village and Kricak Village (Table 4).

Table 4. Housing physical condition analysis in Prenggan Village and Kricak Village

		Villages				
		Prenggan		Kricak		
Variables		n	%	n	%	p-value
Flooring						
	Plain ground	3	6.0	4	10.3	
	Plastered/tiled/ceramic	47	94.0	35	89.7	0.695
Wall						
	Partially plastered wall	21	42.0	11	28.2	
	Complete water-resistant wall	29	58.0	28	71.8	0.191
Ceiling						
	None/several rooms	41	82.0	23	59.0	0.019
	Every room	9	18.0	16	41.0	
Door						
	Main door only	24	48.0	24	61.5	
	Main door and room doors	26	52.0	15	38.5	0.284
Ventilation						
	None	40	80.0	39	100.0	0.002
	Wire net installed	10	20.0	0	0.0	
Bedroom window	None	31	62.0	22	56.4	0.666
	Several windows	19	38.0	17	43.6	

Nevertheless, most houses in both villages (42% and 28.2%, respectively) use partially plastered walls (wood/bamboo), which makes it easier for mosquitoes to enter the house and increases the risk of dengue transmission (Powell and Tabachnick, 2013). The study showed that there were significant differences in the ceiling condition of houses in the two villages, although the majority of homes do not have ceilings (Table 4). These results suggest that the condition of the ceiling does not affect mosquito population density in the study area. In contrast, another study showed that the absence of a ceiling may potentially facilitate the entry of mosquitoes in houses (Getis et al., 2003). Houses in the Prenggan Village with lower mosquito density have conditions that facilitate entry of mosquitoes compared to houses in Kricak Village with higher mosquito density, but this difference is not statistically significant (Table 4). The door functions as an air vent and provides an opening for mosquitoes to entire the house. Open doors may provide opportunities for mosquitoes to enter the house and to rest and bite residing humans (Ritchie et al., 2004; Garcia-Rejon et al., 2008).

Most sample houses in Kricak Village do not have installed wire net ventilation, while in Prenggan Village, several houses (20%) have wire net ventilation installed. This difference between the two villages was statistically significant, as shown in Table 4. In both villages, the majority of the houses do not have bedroom windows. The window acts as a means of ventilation and as a source of entry for light. Lack of ventilation leads to increased levels of CO_2, attracting mosquitoes inside the house (Garcia-Rejon et al., 2008).

Drainage, residential density and distance between houses

There were no significant differences observed in the drainage conditions between Prenggan Village and Kricak Village, yet most houses in both villages have closed drainage systems (56.4% and 48%, respectively). Residential density was higher at Kricak Village than at Prenggan Village and this difference was statistically significant (Table 5).

Table 5. Drainage, residential density and distance between houses analysis in Prenggan Village and Kricak Village

		Villages				
		Prenggan		Kricak		p-value
Variables		n	%	n	%	
Drainage	Closed (flowing waterways, not flooded)	22	56.4	24	48.0	0.578
	Moderate (untidy waterways)	7	17.9	8	16.0	
	Open (no waterways and flooded)	10	25.6	18	36.0	
Residential density (m^2 per person)	≥ 10	22	56.4	37	74.0	0.000
	< 10	17	43.6	13	26.0	
Distance between houses	Far (> 10,5 m)	0	0.0	1	2.0	0.070
	Moderate (5,5–10 m)	1	2.6	0	0.0	
	Close (2,5–5 m)	11	28.2	5	10.0	
	Very close	27	69.2	44	88.0	

Houses with higher residential densities have an increased chance for mosquitoes to transmit disease, given the habit of mosquitoes to bite multiple times within a short flight distance (WHO, 1997). The results are consistent with other studies, showing that human population density is closely correlated with the presence of dengue vector (Harrington et al., 2005; Nkuo-Akenji et al., 2006). Thus, no effective prevention of vector breeding will cause an increased burden of dengue disease (WHO, 2010). There were no significant differences observed in the distance between houses in both villages. The presence of disease-carrying mosquitoes in one house will eventually begin transmission cycles to people residing inside the house, to people surrounding the house within the flight range of the mosquitoes, and to people visiting the house (Ritchie et al., 2004; Rodrigues et al., 2015).

Vegetation

Significant differences were detected in the quantity, height, density, and vastness of the vegetation between Kricak Village and Prenggan Village, as summarized in Table 6.

Table 6. Vegetation analysis in Prenggan Village and Kricak Village

Variables		Villages				p-value
		Prenggan		Kricak		
		n	%	n	%	
Quantity of vegetation (unit)	≤ 1	15	12.8	10	20.0	0.024
	2	0	0.0	7	14.0	
	≥ 3	34	87.2	3	66.0	
Vegetation height (meters)	1–2	28	71.8	18	36.0	0.001
	3–4	6	15.4	9	18.0	
	5–6	5	12.8	12	24.0	
	≥ 7	0	0.0	11	22.0	
Vegetation density	Rare	33	84.6	0	0.0	0.000
	Uneven distribution	3	7.7	15	30.0	
	Evenly distributed	3	7.7	35	70.0	
Vegetation vastness (percent soil per garden)	≥ 50	39	100.0	12	24.0	0.000
	< 50	0	0.0	38	76.0	

The results showed that Prenggan Village did not have the vegetation conditions optimal for mosquito breeding compared to Kricak Village. Mosquitoes also depend on vegetation density in both higher and lower places. Vegetation tends to provide shade and adequate moisture, while ground vegetation is more likely to provide a place for mosquitoes to rest and breed (Nkuo-Akenji et al., 2006; Cheong et al., 2014). Dense plantation areas around the house may not be penetrated by sunlight, causing the environment to become shady and moist. Such conditions favor the presence of mosquitoes, and hence, increase the population of mosquitoes around the house.

CONCLUSION

Differences were observed in the physical environment. Significant differences detected between the two villages in the variables potentially affecting mosquito density include CO2, indoor air temperature, and outdoor humidity. Significant differences were not detected in light intensity, outdoor air temperature, and indoor humidity. Additional differences were also observed in the physical conditions of the housing (ceiling and ventilation) between Kricak Village and Prenggan Village, whereas the flooring, wall, door, and bedroom windows did not differ between the two villages. Residential density between Kricak Village and Prenggan Village significantly differed, while drainage conditions and distance between houses did not significantly differ. Additional differences were observed in the vegetation conditions that likely affect mosquito population density. Specifically, the quantity, height, density, and vastness of the vegetation differed between Kricak Village and Prenggan Village.

SUGGESTION

General suggestions for future development involve raising public awareness about healthy living and care for the environment through variety of ways, along with advocacy to stakeholders. This may be achieved by (1) educating residents on how to prevent dengue through the media, (2) educating the public about healthy housing in an effort to reduce mosquito densities, (3) enabling operational working groups at all levels, (4) increasing dengue vector surveillance by local governments and health centers, and (5) conducting additional research on the factors that influence differences in mosquito density in other areas in the city of Yogyakarta. This research should be encouraged through behavioral studies of community mobilization, surveillance programs and geographical condition mapping.

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