Journal of Sustainability Science and Management
Volume 15 *Number* 8, December 2020: 114-121
eISSN: 2672-7226

CORRELATIONAL ANALYSIS OF AIR POLLUTION INDEX LEVELS ON DENGUE SURVEILLANCE DATA: A RETROSPECTIVE STUDY IN MELAKA, MALAYSIA

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Submitted final draft: 13 May 2020 *Accepted: 24 May 2020* http://doi.org/10.46754/jssm.2020.12.010

Abstract: Climatic factors such as temperature, humidity and rainfall have well-defined impacts in the transmission of dengue. However, the role of air pollution parameters on vector density has not been well addressed in the literature, especially in Malaysia. This study aims to elucidate the association between air pollution parameters on dengue vector density in Melaka, Malaysia. A sentinel station in Melaka was selected based on four-consecutive years of high dengue cases. Entomological data were collected using the conventional ovitraps. The number of larvae obtained was used to reflect the vector population size. Air pollution parameters namely O_3, CO, SO_2, PM_{10} and NO_2 were used in this study as air quality indicators. A retrospective study was conducted using data collected over a period of four years (2013 to 2016). Correlation and Autoregressive Distributed Lag Models were used to determine the degree of relationship between air pollution parameters and the density of dengue vector. Results from this study indicate that CO is the most abundant air pollutant that contributed to the density of *Aedes* mosquitoes (*r*: 0.310). Such findings can be used to develop a dengue outbreak forecasting model utilising air pollution index as a predictive tool.

Keywords: Dengue, positive ovitrap index, air pollution index, Malaysia.

Introduction

Dengue is a global public health concern especially in tropical countries (Costa *et al*., 2010; Gubler, 2012; Dickin *et al*., 2013). It is crucial to determine the various environmental factors that may contribute to escalating rises of dengue cases in an endemic region. Climatic factors such as humidity, temperature and rainfall have been associated with the spread of dengue as documented in various reviews. Nevertheless, to date, there is a limited finding on the impact of air quality on the density of dengue vectors. Principally, dengue activity depends on many factors such as herd immunity, travel, mosquito population, epidemic potential of circulating virus, and introduction of new virus serotypes or genotypes as well as climatic factors (Wilder-Smith *et al*., 2010a; Wilder-Smith *et al.,* 2010b). Moreover, in Malaysia, poor air quality predominantly occurs during the haze episodes, known as the trans-boundary haze due to smoke from open burning and wildfires in Indonesia, which in turn can affect the activity and mortality of mosquitoes.

There is currently no approved vaccine or anti-viral therapeutics available to treat dengue fever, therefore its control relies heavily on effective vector control measures. This can be made feasible through the prediction and identification of risk areas (Sair Arboleda *et al*., 2009). Vectors of *Aedes* mosquitoes are poikilothermic creatures and the life cycle is directly influenced by climatic conditions and environmental factors (Shop, 1991; Dhiman *et al*., 2010). Dengue is still on the rise in Malaysia, despite the close monitoring, surveillance and continuous efforts to combat its transmission. This could be due to several factors and challenges including the insufficient information available on the climatic conditions of the country, which may have a direct impact on the vector density.

Meteorological factors may affect fluctuations in mosquito population densities and extrinsic incubation of dengue virus activity (Hales *et al*., 2002). Differences in humidity, amount of rainfall and change in temperature could influence the seasonal and inter-annual variation of dengue in tropical and subtropical countries (Earnest *et al*., 2012). Nevertheless, the relationship between dengue vector densities and air pollution index (API) has not been explored in detail in the Malaysian setting. Horta *et al.* (2014) studied climate impact on dengue disease in Coronel Town Fabriciano, Brazil from 2004 to 2010. Their study found that dengue cases had a direct correlation with temperature and precipitation. Xu *et al.* (2013) reviewed the impact of climate on dengue disease in Singapore from 2001 to 2009. Results showed that temperature had a direct correlation with dengue cases. Cheong *et al.* (2013) reviewed climate impacts on dengue diseases in Selangor, Kuala Lumpur and Putrajaya, Malaysia, from 2008 to 2010. Their study found that dengue cases had a positive correlation with temperature and precipitation, and negative correlation with wind speed. However, there is no significant relationship between dengue and humidity cases. Therefore, this study aims to determine the urban air quality level based on the air pollution index on the dengue vectors density.

Materials and Methods

Study Site and Study Population

In this study, Melaka Tengah was selected as the main research site to examine the relationship between dengue vector densities with air quality variables. Melaka Tengah is a district in the state of Melaka x (Figure 1). The state of Melaka covers an area of 1,664 km^2 and situated on the southwestern coast of the Malay Peninsular opposite Sumatra, with the states of Negeri Sembilan to the north and west and Johor to the east. There are more than 503,000 residents in Melaka Tengah, composing of 303,000 Malays (58%), 169,000 Chinese (32%), 22,000 Indians (4%) and others (6%). The selection of this area is justified by several factors. Melaka Tengah has a high population density and has a significant

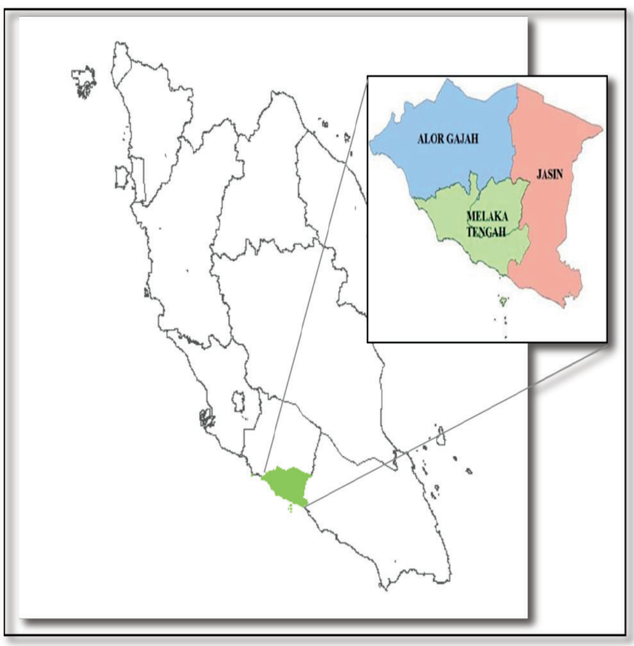

Figure 1: Geographical maps of (a) Location of Melaka (green colour) in Peninsular Malaysia and (b) boundaries between Melaka Tengah, Jasin and Alor Gajah districts in Melaka

public health implication in relation to the control and prevention of dengue. Furthermore, this area was selected due to its population distribution with a variety of urban areas, as well as the rural area, and has a significant public health implication towards the control and prevention of dengue outbreak.

Study Design

This study is a correlation analysis study, which assessed the relationship between dengue cases and vector density and API in Melaka, Malaysia from 1st January 2013 to 31st December 2016. Data were obtained from the Department of Environment (DOE) and Melaka Tengah District Health Office. Data on the level of air pollution indexes such as ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2), particulate matter (PM_{10}) and nitrogen dioxide (NO_2) concentration were obtained from the Melaka Department of Environment. Two dengue surveillance data were used in this study, namely dengue cases and vector density data. Both datasets were obtained from the Melaka Tengah District Health Office, Ministry of Health. Pearson correlation was used to determine the association between dengue and vector density and air pollution variables at various lags. It is because there is a possibility of a gap for the effects of pollution on a disease and vector density, for example, dengue cases occur not only on the same day (lag 0), but may equally occur as a result of the effects of earlier days (lag 1, lag 2...). Lag time was built for lag 0 (without lag) and Lag 1 (1 month) to Lag 3 (3 months) for each of the pollutants in this study. Data was analysed using the R software.

Data Collection and Management

Ethical approval for this study was obtained from the Medical Research & Ethics Committee (MREC) and the National Register Research Register (NMRR) Ethics (NMRR-17-3503-38568 (IIR). The process of data analysis was conducted in two phases. The first phase involved performing descriptive analysis of the temporal distribution of dengue cases and dengue density. The dengue surveillance data was extracted from e-Notification and e-Dengue (Version 2.0) database that was established in 2003, specifically for vector-borne disease notification. Data on air pollution index in the Melaka Tengah area were obtained from the *Alam Sekitar Malaysia Sdn. Bhd.* (ASMA) continuous air quality monitoring (CAQM) through the assistance from the Department of Environment (DOE). Each CAQM station is an integrated ambient air quality monitoring system designed to monitor ambient air for specific pollutants. API data was captured from air monitoring station sampling points located at i) *Sekolah Menengah Kebangsaan Bukit Rambai* and ii) *Sekolah Menengah Tinggi Melaka.*

Data for vector density was based on the ovitrap surveillance. The results were collected from *Cawangan Penyakit Bawaan Vektor Negeri Melaka* (CPBVNM). A total of sixty ovitrap containers were utilised and located at 30 premises. Ovitrap containers were labelled and placed at sentinel station, Taman Ayer Keroh Heights, Melaka (2°15’34.7”N 102°17’13.2”E). Two ovitraps were placed in each promise for indoor and outdoor sampling. Containers were placed upon obtaining the permission from the residence owner, and were inspected each day. Eggs collected were transported to the laboratory for analysis. The paddles with eggs were left to dry at room temperature for at least 24 hours before the eggs on the paddles were counted under the dissecting microscope. Positive ovitrap index (POI) was calculated to assess the density of Aedes mosquito with regard to their distribution and abundance. The POI was determined by dividing the total number of positive ovitrap with the number of recovered ovitrap during collection and multiplied with 100 to obtain the percentage value.

Results and Discussion

A set of monthly air pollution index data for the period ~~of~~ from 2013 to 2016 was used for this study. Figure 3 shows the histogram of monthly air pollution index in Melaka Tengah, Melaka in four-year periods (2013 to 2016). The highest monthly average of API index was observed in June, 2013 with an API index score of 577

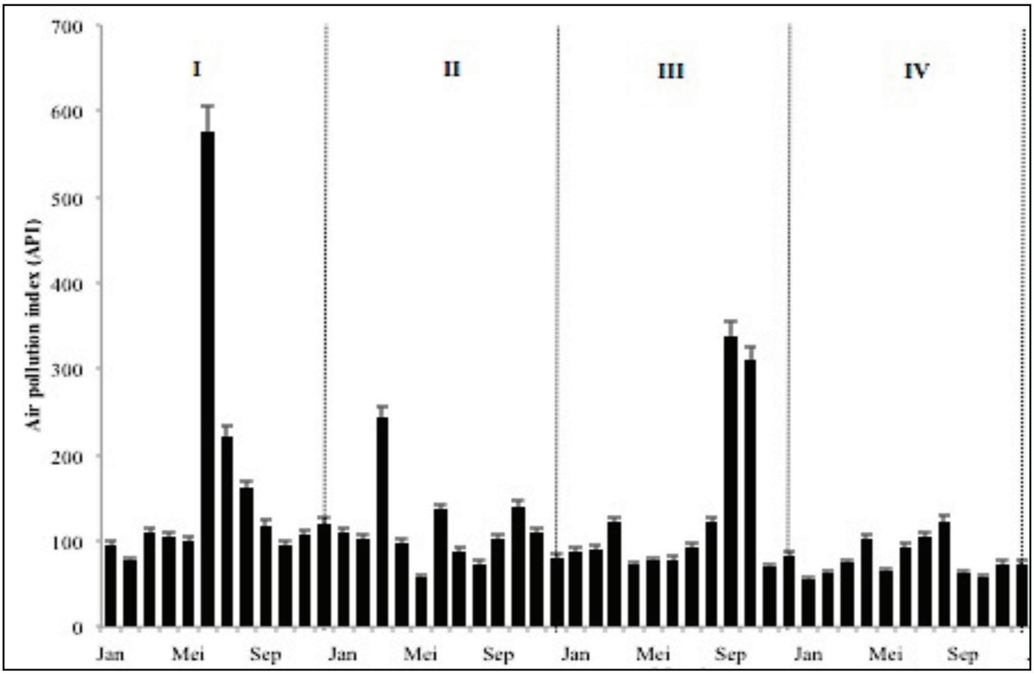

Figure 2: Profile of urban air quality level based on air pollution index (API) from 2013 to 2016. The graph has been divided into four fractions namely I, II, III and IV representing Years 2013, 2014, 2015 and 2016 respectively

(unhealthy condition), while the lowest was observed in January 2016 which score API index with 54 (healthy condition). This study found an increase in API over the years in the study location and the plot of monthly API for the four years showed increasing trends in all fractions. A distinct difference and a gradient among the averages of API were closely observed. Thus, it can be concluded that the API data does not indicate any specific trend and fluctuated throughout the year.

Distribution of Dengue Cases and Dengue Vector Density

Figure 3 shows plots of time series for air pollution index (API), and plots of the average (A) dengue case counts and (B) vector density by intervals of the API categories. The API was divided into seven fractions namely I, II, III, IV, V, VI & VII in which the representations are as follows: I - healthy, II & III - unhealthy, IV & V - hazardous and VI & VII - emergency. The results show that there is no apparent association between dengue cases and the air pollution index (Figure 3A). Results of time series for dengue vector density displayed an upward trend over the API score ranging from 50-200. Findings from this study revealed that the API did not play a significant role in influencing the distribution of dengue cases but it may have slightly influenced the density of dengue vector. The highest positive ovitrap index was recorded at the API below than 100.

The analysis of the air pollution index data with vector density data sets was pursued by applying a linear regression with an additional aim to analyze based on API parameters**:** A1- air pollution index, A2 - ozone, A3 - carbon monoxide, A4 - sulphur oxide, A5 - particulate matter and A6 - nitrogen oxide. The linear regressions were developed in order to identify which API parameters can be used as an indicator for prediction. The best API parameters were particulate matter, carbon monoxide and ozone which were obtained with R2 of 0.038, 0.030 and 0.012 respectively. The plots of values

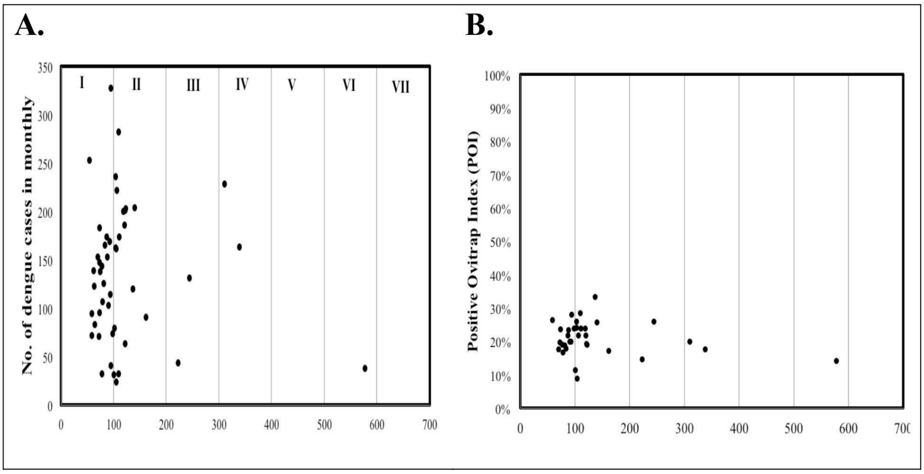

Figure 3: Air pollution time series plots. (A)Time series plots of dengue cases and (B) scatter plots of the average of positive ovitrap index (POI) by intervals of the API categories. Note: The API has been divided into seven fractions namely I, II, III, IV, V, VI & VII in which the representations are as follows: I: healthy, II & III: unhealthy, IV & V: hazardous and VI & VII: emergency

for particulate matter, carbon monoxide and ozone are shown in Figure 4, indicating that the parameters have low correlation because the residuals are contained in a vertical band and hence the variance increase.

A correlation analysis was used to find the relationship between air pollution variables with dengue vectors density. Initially, weekly API variables and weekly positive ovitrap index (POI) were used to assess this relationship.

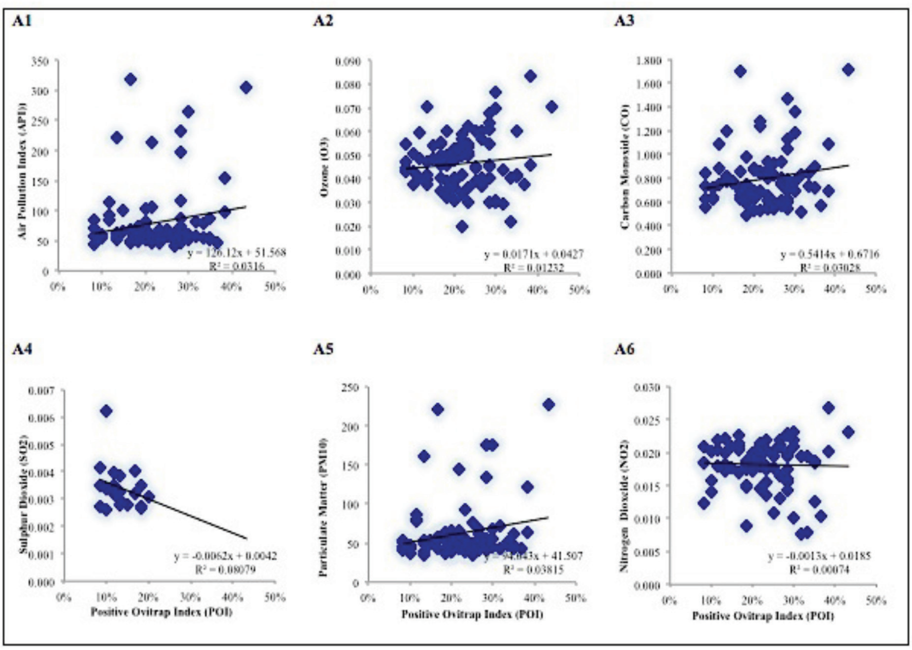

Figure 4: Scatter plot of API and API parameters with POI from 2015 to 2016 in Melaka Tengah district. Note: Each line graph indicates (A1) air pollution index, (A2) ozone, (A3) carbon monoxide, (A4) sulphur oxide, (A5) particulate matter (PM_{10}), (A6) nitrogen oxide

A Pearson's correlation (*r*) was conducted by manipulating the week of API variables into three different lag periods namely**:** (i) lag-0 week, (ii) lag-1 week and (iii) lag-2 week. The lag period was used to determine the plausible time relation between the densities of dengue vectors with API variables *(i.e* the time frame of API variables could be related to subsequent dengue vector density).

Table 1 shows the correlation between the vector density and the influential factors at significant lags. The significant correlation was selected based on Pearson correlation from lag 1 (Week 0) until lag 3 (week 3). The air pollution parameter exerts the effect on the vector density (POI) in which we can see that the CO reading will influence the vector density after 1 week (week 1) (*r*: 0.310). Meanwhile, the previous SO_2 concentration reading for a week (lag 1) (*r*: -0.693) will affect indirectly the density of dengue vectors. The 1-week lagged period may represent for dengue vector to develop from eggs to adult. Among the air pollution parameters, CO imparted the fastest effect on the density of the dengue vector. In addition, air pollution parameters such as PM_{10} and O_3 are equally correlated with the vector density variable. The correlation was established at various lags. Air pollution parameters that significantly affect the density of dengue vector are CO which are believed to come from the emitted fossil fuel combustion at power plants and other industrial facilities, as well as fuel combustion in mobile

Table 1: Correlation matrix of air pollution parameter variables in 2015-2016 with dengue vector density (POI) extracted from sentinel station in Melaka

		POI	API	O_3	CO	SO_2	PM_{10}	NO_2
0 – lag week	**POI**	1.000						
	API	0.178*	1.000					
	O_3	0.117*	0.084	1.000				
	CO	0.175*	0.723	-0.030	1.000			
	SO_2	-0.284*	0.176	0.277	0.148	1.000		
	PM_{10}	0.195*	0.928	0.044	0.799	0.050	1.000	
	NO_2	-0.024	0.383	0.190	0.529	0.458	0.457	1.000
1 – lag week	**POI**	1.000						
	API	0.195*	1.000					
	O_3	0.089*	0.084	1.000				
	CO	0.310*	0.722	-0.030	1.000			
	SO_2	-0.693*	-0.129	-0.084	-0.182	1.000		
	PM_{10}	0.191*	0.928	0.044	0.799	-0.122	1.000	
	NO_2	0.173	0.384	0.190	0.533	0.005	0.458	1.000
2 – lag week	POI	1.000						
	API	0.112*	1.000					
	O_3	0.018*	0.081	1.000				
	CO	0.197*	0.723	-0.037	1.000			
	SO_2	-0.673*	-0.125	-0.081	-0.172	1.000		
	PM_{10}	0.088*	0.928	0.042	0.800	-0.117	1.000	
	NO_2	0.082*	0.381	0.186	0.522	0.020	0.454	1.000

Note: *r- value* generStated from Pearson correlation and (*) indicates *p-value* < 0.05

sources such as locomotives, ships, and other equipment.

The relationship between vector density and air pollution parameters from 2013-2016 was investigated and identified through Pearson correlation. The lag time was equally applied to independent variables. The key air pollutant that significantly affected the density of dengue vector in this study was CO. The air pollutant was most probably emitted from fossil fuel combustion at power plants and other industrial facilities, as well as fuel combustion in mobile sources such as locomotives and ships. In Malaysia, mobile sources like the emission from motor vehicles, power plants, factories and open burning sites are major sources of air pollution.

An integrated data source is eminently useful in order to understand the temporal pattern and behaviour of the dengue fever (DF) cases. In this study**,** air pollution parameters were used to explore the relationship with the DF cases and dengue vector density. Epidemiological variables have at present been used to predict dengue fever outbreak retrospectively with some success (Massad *et al*., 2010; Dom *et al*., 2012; Dom *et al*., 2013). Several studies have been conducted to identify the relationship between air pollution and dengue cases (Oliver *et al*., 2014; Shahrin *et al*., 2012). However, most of the research did not identify any significant relationship between air pollution variables with dengue cases. Similar trends were also identified in this study. A study conducted by Oliver *et al.* (2014) ~~has~~ established a negative correlation between dengue and bushfire in Brazil. Identical pattern was also exhibited by Wilder-smith *et al.* (2010b) which explored dengue activity with haze episode. Uniformly, Massad *et al.* (2010) equally discovered a negative effect between dengue cases and API in Singapore.

Dengue vector density using positive ovitrap index (POI) has neither been proven nor disproven as valuable surveillance matrix. In this study, a correlation analysis between air pollution index parameters (API) and vector density surveillance using positive ovitrap index (POI) variables have established a positive correlation between both variables. This indicates that air pollution parameter index provides a prospective indicator for determining transmission period and thus, could offer a prior warning for dengue epidemic prediction. Therefore, further investigations are warranted to acknowledge the role of these factors in the dynamic chain of the disease transmission. It was believed that dengue transmission peaks may be related to an increase in the survival rate of the adult vector under favourable environmental conditions. The survival rate enables the infected female the possibility to complete the virus replication cycle, consequently becoming an infective vector.

Conclusion

The primary preventative measure to reduce dengue infections is the control of mosquito populations. For this reason, in this study**,** the relationship between vector density and air pollution was investigated and analysed from 2013 to 2016. However, this study only examined the effects of air pollutant variables on disease cases based on recorded data for a particular period of time. Therefore, the effects of air pollutants on those affected beyond the study period remain unknown. Findings from this study can be used as baseline data in developing an early warning forecasting system to predict potential dengue outbreaks in the district of Melaka, which could be beneficial for all relevant parties including the public health departments and the Health District Office. In addition to environmental management initiatives, community-based approaches must also be must be heightened in order to ensure optimal health and to mitigate the spread of diseases.

Acknowledgements

The authors sincerely thank the Ministry of Health, Malaysia and Department of Environment (DOE) for providing ground data on dengue surveillance data and air quality index data for this research work. University of Technology MARA and Ministry of Higher Education (MOHE) Malaysia are also duly acknowledged.

References

Cheong, Y. L., Burkart, K., Leitão, P. J., & Lakes, T. (2013). Assessing weather effects on dengue disease in Malaysia. *International Journal of Environmental Research and Public Health, 10,* 19-34.

Costa, E. A. P. D. A., Santos, E. M. D. M., Correia, J. C., & Albuquerque, C. M. R. D. (2010). Impact of small variations in temperature and humidity on the reproductive activity and survival of *Aedes aegypti* (Diptera, Culicidae). Revista Brasileira de Entomologia, *54,* 488-493.

Dhiman, R. C., Pahwa, S., Dhillon G. P., & Dash, A. P. (2010). Climate change and threat of vector-borne diseases in India: Are we prepared? Parasitology Research, *106,* 763-773.

Dickin, S. K., Schuster-Wallace, C. J., & Elliott, S. J. (2013). Developing a vulnerability mapping methodology: applying the water-associated disease index to dengue in Malaysia. *PLoS One, 8,* 635-648.

Dom, N. C., Ahmad, A. H., Latif, Z. A., Ismail, R., & Pradhan, B. (2012). Coupling of remote sensing data and environmental-related parameters for dengue transmission risk assessment in Subang Jaya, Malaysia. *Geocarto International, 28*, 258-272.

Dom, N. C., Hassan, A. A., Latif, Z. A., & Ismail, R. (2013). Generating temporal model using climate variables for the prediction of dengue cases in Subang Jaya, Malaysia. *Asian Pacific Journal of Tropical Disease, 3*, 352-361.

Earnest, A., Tan, S.B., & Wilder-Smith, A. (2012). Meteorological factors and El Nino Southern Oscillation are independently associated with dengue infections. *Epidemiology Infection, 140*, 1244-1251.

Gubler, D. J. (2012). The economic burden of dengue. *The American Journal of Tropical Medicine and Hygiene*, *86,* 743-744.

Hales, S., de Wet, N., Maindonald, J., & Woodward, A. (2002). Potential effect of population and climate changes on global distribution of dengue fever: An empirical model. *Journal of Public Medicine, 360,* 830-834.

Horta, M. A., Bruniera, R., Ker, F., & Catita, C. (2014). Temporal relationship between environmental factors and the occurrence of dengue fever. *International Journal of Environmental Health Research, 24,* 471-481.

Massad, E., Coutinho, F. A., Ma, S., & Burattini, M. N. (2010). A hypothesis for the 2007 dengue outbreak in Singapore. *Epidemiology Infection, 138*, 951-957.

Olívêr, L., Burattini, M. N., Coutinho, F. A., Coelho, G. E., & Struchiner, C. J. (2014). A negative correlation between dengue and bushfires in Brazil. *Journal of Environmental Health, 76,* 66-67.

Sair Arboleda, Jaramillo O., & Nicolas, A. (2009) Townsend Peterson. Mapping environmental dimensions of dengue fever transmission risk in the Aburrá Valley, Colombia. *International Journal of Environmental Research and Public Health, 20,* 3040-3055.

Shahrin, S.A., Sani, J. A. M., Hassan, M. R., Safian, N., Aizuddin, A. N., & Hod, R. (2012). Relationships between *Aedes* indices and dengue outbreaks in Selangor, Malaysia. Dengue, *36*, 166.

Shop, R. (1991) Global climate change and infectious diseases. *Environmental Health Perspective, 96*, 171-174.