SYSTEMATIC REVIEW

A Systematic Analysis of the Effects of Climate and Environmental Exposures on Dengue Cases From 2010 to 2020

Muhamad Khushairi Muhd Nor [1], Nazri Che Dom[1,2], Samsuri Abdullah[3], Hasber Salim[4]

[1] Centre of Environmental Health and Safety, Faculty of Health Sciences, Universiti Teknologi MARA Selangor, Malaysia
[2] Integrated of Mosquito Research Group (I-Merge), Faculty of Health Sciences, Universiti Teknologi MARA, Selangor, Malaysia
[3] Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, Kuala Nerus, Terengganu, Malaysia.
[4] School of Biological Sciences, Universiti Sains Malaysia, Penang, Malaysia

ABSTRACT

Introduction: This study aims to identify the climatic and environmental factors in influencing the occurrence of dengue cases. **Methods:** A systematic review is conducted in January 2021 and 581 potentially relevant records were searched among Scopus and Web of Science. All articles were retrieved in English language. After quality assessment and cross-checking by two independent researchers, finally, a total of 19 articles are eligible for this systematic review based on the quality appraisal assessment by two independent researchers in the field. **Results:** Temperature, land surface temperature, relative humidity, rainfall amount, sunshine, hours of sunshine, land use, high density of buildings, high population density, air quality parameters and vegetative index were positively correlated on dengue cases. Wind run shows negative correlation on dengue cases. **Conclusion:** According to the results of the study, further investigation on climatic and environmental factors towards dengue cases are important in order to enhance their relationship.

Keywords: *Aedes* mosquito, Dengue, Climatic, Environmental, Air quality

Corresponding Author:
Nazri Che Dom, PhD
Email: nazricd@uitm.edu.my
Tel: +603-32584447

INTRODUCTION

Change in climate can affect natural environment and in turn, can increase the rate of dengue virus transmission (1). Climate factors such as temperature, relative humidity and rainfall amount are significantly associated with the life cycle of dengue mosquitoes which resulted in high occurrence of dengue cases (2–4). Dengue is a climate-sensitive infectious disease which is caused by dengue viruses serotype 1 to 4 (DENV1-4), transmitted by *Aedes* mosquitoes. Severe dengue can lead to fatal complications because of fluid accumulation, plasma leaking, severe bleeding and respiratory distress (5). In view of the fact that dengue still does not have any specific treatment, the only control measure available is vector control. The vector control measure depends on many factors such as climate and environmental factors which can be a predictive tool in assessing the potential risk areas when the outbreak of dengue will occur (6,7). Predominantly, dengue cases depend on many factors such as travel history, herd immunity among community, mosquito abundance, epidemic potential of circulating virus as well as climatic and environmental factors. Global warming has caused change in climate and environment which include the sea level rise, temperature and changes in precipitation patterns. These changes can influence the dengue epidemiology through biological aspects of mosquitoes and incubation periods of DENV (8). Change in climate and environment can potentially increase the transmission of dengue cases by vectors such as *Aedes aegypti* mosquitoes. This species will be adapted along with other factors such as domestic environment, rainfall, humidity, dissemination of virus serotypes and temperature.

In the 21st century, dengue has become a major global health issue. Almost half of the population is at risk of infection and the development of vaccines are still on clinical trials (9). World statistics of dengue cases have been increasing tremendously from 505, 430 cases

in 2000 to 4.2 million in 2019 (5). It shows that over the decade, the increment is about twice of the cases. The distribution of dengue cases involves more than 100 countries in the world and the largest number of dengue cases was recorded globally in 2019, which accumulated to 4.2 million.

The statistics show the importance addressing the issue of dengue and the impact of climatic and environmental factors on its occurrence and prevalence. Therefore, it is very crucial to identify the climatic and environmental factors that can contribute to the increasing of the dengue cases which will imperil human health. Given the fact about dengue as a major health problem, we design this systematic review in order to identify the correlation of dengue cases, climatic and environmental factors.

METHODS AND MATERIALS

Search Strategy: A systematic review was conducted in January 2021 using the electronic databases Scopus and Web of Science. The search was limited to journal articles published in English from 2010 to 2020. Articles underwent the process of identification, screening and eligibility through assessing the title and abstract which addressing the environmental factors or climatic factors corresponding to dengue cases. We applied a combination of the search terms: ((association* OR relationship* OR correlation*) AND (dengue case* OR dengue fever*) AND (air pollution index* OR air quality index) AND (climatic factor* OR environmental factor)), (association AND dengue cases) AND (environmental factors) in the automated searches. Articles were inspected accordingly based on the criteria. Two researchers, one who has background in Occupational Safety and Health Management (OSHM) and the other one who has background in applied entomology study for more than 10 years, worked independently on selection of the relevant articles by using the same search terms and cross-checking reference lists. Any further disagreement between two researchers was performed by a third member of the research team who has background in environmental technology study which resolve and evaluate that particular issue.

Inclusion and Exclusion Criteria: Researchers assessed all published studies during the 2010 to 2020, which focused on the association between dengue and environmental factors such as air pollution index, air pollution quality, particulate matter or climatic factors such as relative humidity, temperature, heat, rainfall amount, sunshine, hours of sunshine and wind run. The inclusion criteria were including epidemiological (ecological and cross sectional) studies, English as study language, and in the peer-reviewed journals that assessed at least one dengue and/or environmental factor in the title. Exclusion criteria were including studies which assessed the other environmental related diseases (such as Zika, Chikungunya and Malaria). Reviews, laboratory, empirical studies and qualitative studies, unpublished literature, studies with confusing results, studies with exhibiting bias or inconsistencies result, articles in proceedings of symposium or conferences that were exposed to selection or information bias in results were excluded.

Quality Appraisal: In quality appraisal, quality assessment process is conducted in order to evaluate all the identified articles. A check list of assessment is developed and adapted from a study by Alsolai & Roper (10). The main objective of this quality assessment is to evaluate selected studies which are relevant and answer all the research questions and fulfilled the inclusion and exclusion criteria of the study. Quality assessment was performed by two experts whom specializes in applied entomology and environmental technology study from Universiti Teknologi MARA (UiTM) and Universiti Malaysia Terengganu (UMT), respectively. Each question was scored in accordance as: Yes represents 1.0, Partly represents 0.5 and No represents 0. Total of scoring will determine the level of articles as Excellent ($10.5 \leq$ scores ≤ 13), Good ($6.5 \leq$ scores ≤ 10), Fair ($3 \leq$ scores ≤ 6) and Fail ($0 \leq$ scores ≤ 2.5. Having discussed with the experts on any disagreement during scoring, researchers decided only articles ranked as excellent and good will be included and analysed at the final stage of review. Eventually, there were 19 articles were categorized as good and excellent and fulfilled the eligibility criteria, meanwhile 6 articles were removed and excluded from the study as their ranking were fair and fail.

Data Extraction: Data were extracted based on the quality assessment results. The records were entered into EndNote 8 (Thomson Reuters, New York, USA) and the duplication of articles were removed. The full review of the related articles based on the title and abstract was processed for final selection of articles. The methodological quality of selected articles was conducted based on the quality appraisal which were performed in sub section of quality appraisal. Extraction of articles were performed when each article contains authors, objectives, study areas, samples size, study type, statistical analysis used, climatic environmental variables and main results.

Selection process of articles was based on the process of identification, screening and eligibility as depicted in Figure 1. Altogether, 581 potentially relevant records were identified from two different databases and their references during the initial searches. After removing duplicates in Endnote software, 305 articles remained for the screening process which assessed through title and abstract. During the screening process, 259 records were removed and 46 records were assessed by full text. In the evaluation process of full text, 21 texts were removed and 25 full text articles were assessed for eligibility criteria. Finally, after excluding 6 articles, 19 full articles were included in this systematic review.

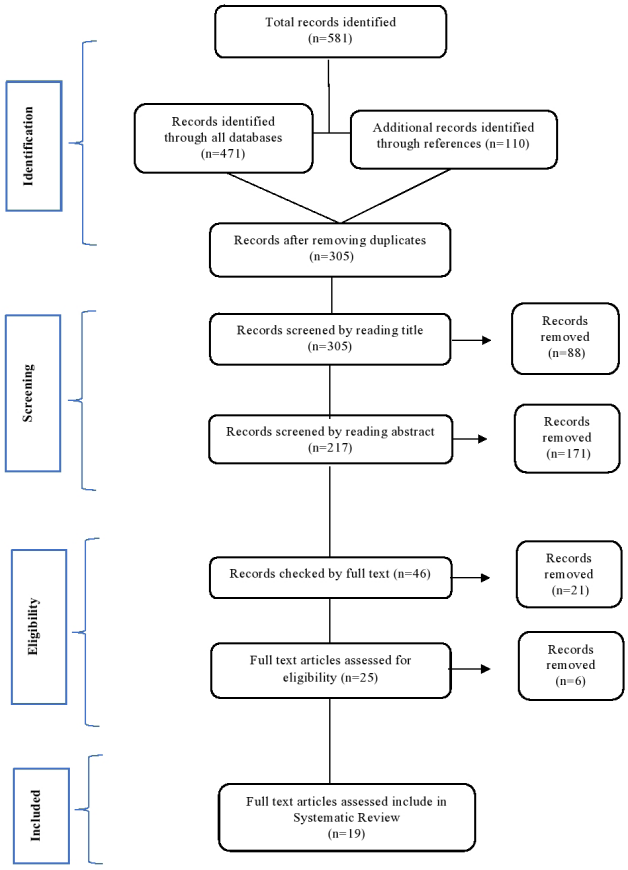

Figure 1 : Flow diagram of the study selection for the review process

RESULTS

Overall, out of 19 articles that were obtained from the review process, there were 15 studies conducted in Asian countries which were 5 from India, 3 from Malaysia, 2 from Indonesia and Thailand, respectively and a study from China, Vietnam and Taiwan, respectively. There were 2 studies from South America and one study each from Africa and Middle East country, respectively.

Table 1 shows the characteristics (Article ID, title and authors, objectives, study location, samples and study period, type of analysis, variables used and results of the study) for all the selected articles. Most of the articles used variables such as temperature, land surface temperature (LST), rainfall amount, total weekly rainfall, rainy days, wet days, relative humidity, daytime humidity, night time humidity, wind run, sunshine, sunshine hours, air quality parameters (Coarse particulate matter (PM10), Ozone (O3), Carbon monoxide (CO), Sulphur dioxide (SO2), Nitrogen dioxide (NO2)), land use, high density of buildings, population density and vegetative index. Statistical analyses were performed using yearly data ranging from 1 to 18 years. Eleven articles evaluated the relationship of climatic factors and dengue cases, 5 articles investigated on environmental factors and 4 articles assessed both factors (climatic and environmental) on dengue incidence. Two articles used advanced statistical modelling of non-linear relationships between

Table I Characteristics of selected articles

Article ID	Title & Author(s)	Objective(s)	Location	Samples and study period	Type of analysis	Variables	Main results
ID 1	Analysis of effects of meteorological factors on dengue incidence in Sri Lanka using time series data Goto et al. (21)	To examine the effects of meteorological factors on dengue incidence by time series analysis of weekly data	Ratnapura, Colombo and Anuradhapura	Weekly average maximum temperature, total rainfall and number of dengue cases from 2005 to 2011	Descriptive analysis, Linear regression analysis	Weekly average maximum temperature and total rainfall	All the variables did not have significant with dengue cases but total rainfall slightly influenced with dengue cases
ID 2	A study of the correlation between dengue and weather in Kandy City, Sri Lanka (2003 – 2012) and lessons learned Ehelepola et al. (11)	To identify a between dengue and weather in Kandy City, Sri Lanka	Kandy, Sri Lanka	Data dengue cases and weather data from 2003 to 2012	Wavelet time series analysis and cross-correlation coefficients	Rainfall, temperature, humidity, hours of sunshine and wind	All variables correlated with dengue except for wind
ID 3	Ecological factors associated with dengue fever in a central highlands Province, Vietnam Pham et al. (12)	To elucidate the linkage between climate factors, mosquito indices and dengue incidence	Province, Vietnam	Data on dengue cases, mosquito larval indices, temperature, sunshine, rainfall and humidity from 2004 to 2008	Poisson regression model	Temperature, sunshine, rainfall, humidity	Dengue cases associated with all variables but inversely associated with duration of sunshine
ID 4	Environmental factors can influence dengue reported cases Carneiro et al. (1)	To understand the consequences of temporal variability of air temperature in the occurrence of dengue	Greater Sao Paulo, Brazil	Data of dengue cases, climate & air pollutant concentration data between 2010 and 2013	Pearson correlation	Temperature, humidity and PM10	All the variables had statistical association with dengue cases except for temperature.

CONTINUE

Table I Characteristics of selected articles (CONT.)

Article ID	Title & Author(s)	Objective(s)	Location	Samples and study period	Type of analysis	Variables	Main results
1D 5	Lag effect of climatic variables on dengue burden in India Kakarla et al. (16)	To explore the relationship between El Nino Southern Oscillation (ENSO), and dengue cases	India	Report of dengue cases, data of temperature and rainfall from 2010 to 2017	Descriptive analysis, cross correlation	Temperature, rainfall	Both temperature and rainfall were positively associated with the number of dengue cases.
ID 6	Role of climatic factors in the incidence of dengue in Port Sudan City, Sudan Noureldin & Shaffer (14)	Describing the relationship between climatic factors and dengue fever incidence in Port Sudan City	Port Sudan City, Sudan	Secondary data of dengue fever cases and climatic factors from 2008 to 2013	The Wilcoxon rank sum test and multiple linear regression	Maximum and minimum temperature, relative humidity	All the variables correlated with dengue cases.
ID 7	Analysis of the effects of rainfall on dengue incidence in the City of Delhi, India Salam (17)	To assess the effects of seasonal rainfall on the incidence of dengue cases in Delhi	Delhi, India	Retrospective data of seasonal rainfall and dengue incidence from 2005 to 2015	Pearson's correlation	Annual rainfall	Positive and weak correlation between annual rainfall and dengue cases
ID 8	Correlational analysis of air pollution index levels on dengue surveillance data: A retrospective study in Melaka, Malaysia Mohammad et al. (7)	To elucidate the association between air pollution parameters on dengue vector density	Melaka, Malaysia	Entomological data and air pollution parameters data from 2013 to 2016	Correlation and Autoregressive Distributed Lag Models	O3, CO, SO2, PM10 and NO2	CO is the most air pollutant that contributed to the density of Aedes mosquitoes (r:0.310)
ID 9	Infection rates by dengue virus in mosquitoes and the influence of temperature related to different endemicity patterns in three Colombian cities Pena-Garcia et al. (15)	To assess the relationship between density, dengue cases and vector index	Riohacha, Bello and Villavicencio in Columbia	Data on dengue cases and climate between 2012 to 2013	Pearson's correlation	Temperature, precipitation and humidity	Weak associations between density of the mosquitoes
ID 10	Dengue fever outburst and its relationship with climatic factors Alshehri (13)	To address the effects of climatic factors on *Aedes aegypti* mosquito density	Saudi Arabia	Data for climatic factors, mosquito density and dengue fever cases for years 2004 to 2011	Descriptive and bivariate statistical analyses	Temperature, relative humidity and rainfall	Strong correlation between all variables with mosquito density
ID 11	Influence of environmental factors on dengue fever in Delhi. Bisht et al. (18)	To find correlations between incidence of dengue fever and environmental factors	Delhi, India	Dengue data and meteorological data from 2011 to 2016	Descriptive and correlation analysis	Rainfall, Humidity and temperature	All variables are associated with dengue cases
ID 12	The climatic factors affecting dengue fever outbreaks in southern Taiwan: an application of symbolic data analysis. Lai (19)	To elucidate the linkage between dengue fever incidence and climate factors	Kaohsiung city in Taiwan	Dengue fever and climatic data from 2005 to 2014	Symbolic data analysis	Temperature, rainfall, sunshine	All variables are significantly correlated with dengue fever incidence
ID 13	Climatic factors influencing dengue hemorrhagic fever in Kolaka District, Indonesia Tosepu et al. (22)	To understand dengue fever patterns	Kolaka District, Indonesia	Dengue fever and climate data for 2010 -2015	Multiple linear regression	Rainfall, humidity, average, min and max. temperature	All the variables are significantly correlated with dengue fever

CONTINUE

Table I Characteristics of selected articles (CONT.)

Article ID	Title & Author(s)	Objective(s)	Location	Samples and study period	Type of analysis	Variables	Main results
ID 14	Impact of climate and land use variability based on dengue epidemic outbreak in Subang Jaya Nazri et al. (20)	To identify correlation between climate and land use factor towards dengue cases	Subang Jaya, Malaysia	Secondary data of dengue cases, meteorological data and land use data from 2005 to 2010	SPSS correlation test	Rainfall, temperature, relative humidity and land use,	All the variables are positive correlated with dengue incidence
ID 15	Ecological environment and socioeconomic factors drive long-term transmission and extreme outbreak of dengue fever in epidemic region of China. Li et al. (24)	To investigate the long-term relationship between the ecological environment and socioeconomic drivers with DF transmission	City of Guangzhou, China	Data dengue cases, ecological environment and socioeconomic factors from 1998 - 2016	Principle components analysis	Population, population mobility, urbanization, vector habitat	All the variables are correlated with dengue cases
ID 16	Revealing two dynamic dengue epidemic clusters in Thailand. Lim et al. (25)	To study the patterns and biological reasons for dengue outbreaks	Thailand	Data of climate, human population, flight from 2007 to 2018	Bayesian regime switching models	Climate, urban population, urban land cover and flight passengers	All the variables are associated with the dengue outbreak
ID 17	Assessment of urban land surface temperature and vertical city associated with dengue incidences. Nakhapakorn et al. (27)	To study the association of urban land surface temperature with dengue incidence	Bangkok, Thailand	Data of dengue incidence and Digital map of Bangkok during 2009 to 2014	Pearson correlation and Bayesian hierarchical model	Land surface temperature, density of high buildings,	All the variables are associated with dengue incidence
ID 18	Land use changes and cluster identification of dengue hemorrhagic fever cases in Bandung, Indonesia Sari et al. (26)	To identify cluster areas and their correlation with land use	Bandung, Indonesia	Data dengue fever and normalized difference vegetation index (NDVI) from 2003 to 2013	Spearman correlation	Land use and vegetative index	NDVI had negative and positive correlation on 2008 and 2012 respectively
ID 19	Spatial density of Aedes distribution in urban areas: A case study of Breteau index in Kuala Lumpur (KL), Malaysia Aziz et al. (23)	To establish spatial density of mosquito population or breteau index (BI) in KL using GIS, RS and spatial statistic tools	Kuala Lumpur, Malaysia	Data of BI and meteorological for 2010	Pearson's correlation coefficient	Rainfall and hot spot localities	Strong correlation between hotspot localities with High BI and monthly rainfall data

climate, environmental factors and dengue cases.

Determination on the correlation between dengue cases, climatic and environmental variables are demonstrated in Table II. Nine articles were found to positively correlated with temperature and 2 articles were positively correlated with LST. Researchers also found 9 articles were positively correlated with rainfall amount or precipitation factor and 3 articles were positively correlated with sunshine or sunshine hours. Meanwhile, there is a number of articles that had a positive correlation with air quality parameters, land use, high density of buildings, population density and vegetative index (1- 4).

Based on the results, the variables used for the study were temperature, land surface temperature (LST), rainfall amount, total weekly rainfall, rainy days, wet days, humidity, daytime humidity, night time humidity, relative humidity, wind run, sunshine, sunshine hours, air quality parameters (PM_{10}, O_3, CO, SO_2, NO_2), land use, high density of buildings, population density and vegetative index. In addition, we also observed several factors that have no correlation with dengue cases such as wind run and rainy days.

Table II Determining the correlations of climatic and environmental variables with dengue cases

Factor	Significant correlation		Non- significant correlation	Additional explanation
	Positive	**Negative**		
Temperature Land surface temperature	2, 3, 5, 6, 7, 9, 10,11,12 13, 17		4	Increase in temperature tends to shorten the extrinsic incubation period within the mosquito vectors which increases the growth rate of Aedes mosquitos
Rainfall Total weekly rainfall Rainy days	2, 3, 5, 7, 9, 11,12,13, 19	1	6 2	On dry seasons, rainfall might become not significant and it is suggested to study intermediating variables such as water and sewage system at study area
Wet days	2			
Humidity Daytime humidity Nighttime humidity Relative humidity	3, 4, 9 2 2 2			The greater humidity, the higher the number of dengue cases
Wind run		2		
Sunshine Sunshine hours	3, 12 2			Increase in sunshine can lead to increase in temperature and in turn can increase the occurrence of dengue incidence
Air quality parameters PM_{10}, O_3, CO, SO_2, NO_2	8			The gap between air quality parameters and dengue cases are at scarce
Land use	14, 15, 16, 18			Change in land use results in process urbanization which results in increase case of dengue due to modern practice, water and sewage system
High density of buildings	17			High density of buildings results from change of land use and in turn increase the dengue variability and transmission of virus
Population density	15,16			
Vegetative index	15,17,18			

Note: The number in the table is referring to article ID

DISCUSSION

Prediction of the dengue outbreak can be investigated through the association of climate change, environmental factors and dengue incidence. This systematically review sought to investigate the main climatic and environmental factors influencing on dengue cases and how different types of these factors may influence the occurrence of dengue cases. Based on our findings, the following factors were positively correlated with dengue cases: temperature, land surface temperature (LST), rainfall amount, total weekly rainfall, wet days, humidity, daytime humidity, night time humidity, relative humidity, sunshine, sunshine hours, air quality parameters (PM_{10}, O_3, CO, SO_2, NO_2), land use, high density of buildings, population density and vegetative index.

Most of the studies showed that temperature has positive correlation towards dengue cases (11–20). This is because the rises in temperature could increase the biting rate of the vector, reduced the extrinsic incubation period of the dengue virus, shortened egg to adult development time (11,16,19,20). It was also found that elevated temperature could associate with the increase dengue cases as the development of rate of virus was accelerated and increased life stages of *Aedes aegypti* (12). Temperature was also described as one of the factors influence in Vector Borne Disease (VBD) of the dengue and this occurred when global temperature increased, it enhanced the transmission rate of mosquito-borne diseases and allowed expansion the vector into new geographic regions (16). In other study by Noureldin & Shaffer (14) temperature significantly affected the survival rate of the mosquito, number of blood meals and could increase the transmission of virus. However, study by Pena-Garcia et al. (15) showed that temperature could negatively affect the virus transmission when at 320C and its finding was supported by Alshehri (13) when the study mentioned that ideal temperature for Aedes growth was between 25°C to 27°C. Land surface temperature (LST) is different with the air temperature because it is calculated using thermal remote sensing images from Landsat which measures the emission of thermal radiance from the land surface (21). Studies by Alshehri (13) and Salam (17) showed positive correlation between LST and dengue cases. Hence, temperature factor is dynamically affecting the dengue cases and more research required to fill the gap between temperature and dengue incidence.

Most of the studies showed rainfall had a positive correlation towards dengue cases (11,12,15,16,18,23,24) except study by Goto et al. (22). This factor was further explained by Ehelepola et al. (11) as rainfall may increase breeding sites for the vector and deeper levels of water

allowing mosquitoes to complete their development of life cycles. This was similar in study by Pham et al. (12) increased in the amount of rainfall lead to increase in breeding site and increased in the number of adult female mosquitoes which eventually increased the probability of viral transmission in community. Meanwhile, Kakarla et al. (16) found that relative risk (RR) of dengue tends to increase as cumulative weekly rainfall increased from 40 to 60 mm then it decreased when rainfall exceeded 80 mm. However, rainfall could be seemed as negative correlation during dry seasons, with condition water and sewage system must be included as the intermediating variables because the assumption between rainfall and dengue has no correlation if only the study area has good system of water and sewage. Thus, researchers believe there is still a need to conduct study on rainfall and other intermediating variables which can interfere with the dengue cases.

According to Carneiro et al. (1) relative humidity is the ratio of the amount of water vapor in the air at a specific temperature and at higher temperature the air may contain more water vapor than the same volume of air at lower temperature. They also mentioned that mosquito needs humidity and temperature ranging between 15°C and 35°C and study showed mosquito life span can drop from 10 to 7 days when temperature increased from 27°C to 37°C. The findings were also similar with several studies (11,12,15). The association between temperature, relative humidity and dengue cases also could affect the infection rates (IR). Ehelepola et al. (11) found that when relative humidity and temperature was 25.1°C and 80% respectively, it was found to be positive correlation with dengue cases and this temperature range was supported by Carneiro et al. (1) when they found mosquito needs humidity and temperatures ranging between 15°C and 35°C for their life cycle.

Based on our findings, wind run (wind run = wind speed x duration) showed negative correlation with dengue cases (11). It was contradicted with the assumption that wind might increase the range of vector mosquitoes which could increase the effect of transmission. However, it was further explained in this study that high population may negate the effect of the wind as mosquitoes could find a human to feed on without the wind which make them fly farther. Sunshine was associated with dengue incidence (12,19). This finding was similar with study Ehelepola et al. (11) which found hours of sunshine showed correlations between dengue incidence. It was observed hours of sunshine could influence the dengue cases when more solar radiation on Earth which could increase the temperature and in turn can lead to the rise in dengue. The association between sunshine and temperature on dengue cases were also correlated well (11,19).

The increase trend in dengue cases was also influenced by land use changes (20,25–27). Land use changes were mainly due to the construction sites, commercial areas and industrial development which made that areas became exposed to the dengue virus (20). Change in land use did not only increase the resident's density but also affecting the water and vegetation system which making the places became favourable for breeding and feeding sites for mosquitoes (25). In Thailand, study by Lim et al. (26) found that urbanization is strongly associated with increased dengue incidence and this was further elaborated by urban practices such as storing water in plastic containers which can enhance the potential breeding of vectors and could result in increased the vector's viability at that particular area. These findings are homogeneous with a study performed in Bandung by Sari et al. (27). Association of land use change and land surface temperature (LST) had been studied (28) which found positive correlations between LST and high building density with dengue incidence.

Vegetation is one of the environmental factors including water receptacles and it becomes the main factor for vector habitat in study of dengue cases. Several studies also showed a positive correlation between vegetative and dengue cases (23,25,27). Finally, study by Muhammad et al. (7) showed that air pollution parameters were correlated with density of dengue vector. Air pollution parameters in this study were PM_{10}, O_3, CO, SO and NO_2. It was observed that CO was the most abundant air pollutant that contributed to the density of dengue vector.

The information is required for implementing dengue outbreak systems and mitigating harmful effects of dengue virus. Having such information about what and how environmental and climatic factors can have impact on dengue cases are essential. However, this study is exposed to some limitations such as we studied only articles in English and these criteria could create language bias in our results. This study also found that the review about correlation study on air quality parameters on dengue are at scarce. Therefore, more comprehensive review is suggested to assess the effect of air quality parameters on dengue cases.

CONCLUSION

The main findings of this review study are that following climatic and environmental factors are found to be positively correlated to dengue incidence: temperature, land surface temperature (LST), rainfall amount, relative humidity, sunshine, hours of sunshine, land use, high density buildings, high population, vegetative index and air quality parameters (PM_{10}, O_3, CO, SO and NO_2). Wind run had a negative correlation with dengue incidence. According to the study's findings, climatic and environmental factors play important roles in forecasting dengue outbreak, and further research is needed to improve the connection between climatic and

environmental factors and dengue cases. Researchers also suggest more study on factor that identified as negative correlation such as wind run and it is necessary to take consideration and emphasize the factor of air quality parameters as the review about it is at limited.

ACKNOWLEDGEMENTS

We thanked to the Faculty of Health Sciences, Universiti Teknologi MARA (UiTM) for the technical assistances rendered.

REFERENCES

1. Carneiro MAF, Alves BDCA, De Sousa Gehrke F, Domingues JN, Sб N, Paixгo S, et al. Environmental factors can influence dengue reported cases. Rev Assoc Med Bras. 2017;63(11):957–61.
2. Alto BW, Bettinardi D. Temperature and dengue virus infection in mosquitoes: Independent effects on the immature and adult stages. Am J Trop Med Hyg. 2013;88(3):497–505.
3. Tran A, L'Ambert G, Lacour G, Benoot R, Demarchi M, Cros M, et al. A rainfall- and temperature-driven abundance model for Aedes albopictus populations. Int J Environ Res Public Health. 2013;10(5):1698–719.
4. Liu-Helmersson J, Stenlund H, Wilder-Smith A, Rocklцv J. Vectorial capacity of Aedes aegypti: Effects of temperature and implications for global dengue epidemic potential. PLoS One. 2014;9(3).
5. WHO. Dengue and severe dengue [Internet]. 2020 [cited 2021 Mar 7]. Available from: https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue
6. Arboleda S, Jaramillo-O. N, Peterson AT. Mapping environmental dimensions of dengue fever transmission risk in the Aburrб Valley, Colombia. Int J Environ Res Public Health. 2009;6(12):3040–55.
7. Mohammad AKH, Dom NC, Camalxaman SN, Ismail SNS. Correlational analysis of air pollution index levels on dengue surveillance data: A retrospective study in Melaka, Malaysia. J Sustain Sci Manag. 2020;15(8):136–66.
8. Hii YL. Climate and Dengue Fever : Early Warning Based on Temperature and Rainfall. Umea University, Sweden; 2013.
9. Deng SQ, Yang X, Wei Y, Chen JT, Wang XJ, Peng HJ. A review on dengue vaccine development. Vaccines. 2020;8(1):1–13.
10. Alsolai H, Roper M. A systematic literature review of machine learning techniques for software maintainability prediction. Inf Softw Technol [Internet]. 2020;119:106214. Available from: https://doi.org/10.1016/j.infsof.2019.106214
11. Ehelepola NDB, Ariyaratne K, Buddhadasa WMNP, Ratnayake S, Wickramasinghe M. A study of the correlation between dengue and weather in Kandy City, Sri Lanka (2003 -2012) and lessons learned. Infect Dis Poverty [Internet]. 2015;4(1). Available from: http://dx.doi.org/10.1186/s40249-015-0075-8
12. Pham H V., Doan HTM, Phan TTT, Tran Minh NN. Ecological factors associated with dengue fever in a central highlands province, Vietnam. BMC Infect Dis. 2011;11:1–6.
13. Alshehri MSA. Dengue fever outburst and its relationship with climatic factors. World Appl Sci J. 2013;22(4):506–15.
14. Noureldin E, Shaffer L. Role of climatic factors in the incidence of dengue in port sudan city, sudan. East Mediterr Heal J. 2019;25(12):852–60.
15. Peca-Garcнa VH, Triana-Cнбvez O, Mejнa-Jaramillo AM, Dнaz FJ, Gymez-Palacio A, Arboleda-Sбnchez S. Infection rates by dengue virus in mosquitoes and the influence of temperature may be related to different endemicity patterns in three Colombian cities. Int J Environ Res Public Health. 2016;13(7):1–16.
16. Kakarla SG, Caminade C, Mutheneni SR, Morse AP, Upadhyayula SM, Kadiri MR, et al. Lag effect of climatic variables on dengue burden in India. Epidemiol Infect. 2019;147:1–10.
17. Salam N. Analysis of the Effects of Rainfall on Dengue Incidence in the City of Delhi, India. Int J Med Res Heal Sci [Internet]. 2018;7(12):149–55. Available from: www.ijmrhs.com
18. Bisht B, Kumari R, Nagpal BN, Singh H, Kumar S. Influence of environmental factors on dengue fever in Delhi. Int J Mosq Res. 2019;6(2):11–8.
19. Lai YH. The climatic factors affecting dengue fever outbreaks in southern Taiwan: An application of symbolic data analysis. Biomed Eng Online [Internet]. 2018;17(s2):1–14. Available from: https://doi.org/10.1186/s12938-018-0575-4
20. Nazri CD, Abu Hassan A, Abd Latif Z, Ismail R. Impact of climate and landuse variability based on dengue epidemic outbreak in Subang Jaya. 2011 IEEE Colloq Humanit Sci Eng CHUSER 2011. 2011;(May 2014):907–12.
21. Roslan NS, Latif ZA, Dom NC. Dengue cases distribution based on land surface temperature and elevation. 2016 7th IEEE Control Syst Grad Res Colloquium, ICSGRC 2016 - Proceeding. 2017;(December 2017):87–91.
22. Goto K, Kumarendran B, Mettananda S, Gunasekara D, Fujii Y, Kaneko S. Analysis of Effects of Meteorological Factors on Dengue Incidence in Sri Lanka Using Time Series Data. PLoS One. 2013;8(5):1–8.
23. Tosepu R, Tantrakarnapa K, Worakhunpiset S, Nakhapakorn K. Climatic factors influencing dengue hemorrhagic fever in Kolaka district, Indonesia. Environ Nat Resour J. 2018;16(2):1–10.
24. Aziz S, Aidil RM, Nisfariza MN, Ngui R, Lim YAL,

Wan Yusoff WS, et al. Spatial density of Aedes distribution in urban areas: A case study of breteau index in Kuala Lumpur, Malaysia. J Vector Borne Dis. 2014;51(2):91–6.
25. Li C, Wu X, Wang X, Yin J, Zheng A, Yang X. Ecological environment and socioeconomic factors drive long-term transmission and extreme outbreak of dengue fever in epidemic region of China. J Clean Prod [Internet]. 2020;279:123870. Available from: https://doi.org/10.1016/j.jclepro.2020.123870
26. Lim JT, Han Y, Dickens BSL, Choo ELW, Chew LZX, Cook AR. Revealing two dynamic dengue epidemic clusters in Thailand. BMC Infect Dis. 2020;20(1):1–11.
27. Sari SYI, Adelwin Y, Rinawan FR. Land use changes and cluster identification of dengue hemorrhagic fever cases in Bandung, Indonesia. Trop Med Infect Dis. 2020;5(2).
28. Nakhapakorn K, Sancharoen W, Mutchimwong A, Jirakajohnkool S, Onchang R, Rotejanaprasert C, et al. Assessment of urban land surface temperature and vertical city associated with dengue incidences. Remote Sens. 2020;12(22):1–21.