Climate Variability and Dengau Hemorrhagic

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Submission date: 27-Jun-2022 03:48PM (UTC+0700)
Submission ID: 1863601863
File name: Jurnal_Climate_Variability_and_Dengau_Hemorrhagic.pdf (386.54K)
Word count: 4649
Character count: 25645

International Journal of Innovation, Creativity and Change. www.ijicc.net
Special Edition: Safe Communities, 2020

Climate Variability and Dengue Hemorrhagic Fever in Bandar Lampung, Lampung Province, Indonesia

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Climate impacts on health through ecosystem changes, namely the increased risk of vector-borne diseases through the distribution and abundance of vector organisms. The mean incidence of DHF (IR per 100,000 population) in Bandar Lampung from 2007 to 2018 was 104.20 (40.49-245.48), far exceeding the provincial (41.70) and national average (51.36). The study aims to determine the effect of climate, namely rainfall, temperature, and humidity of the number of dengue cases. Data sources are from the Bandar Lampung Health Office and the Geophysics Climatology and Geophysics Agency of Lampung Province. In data processing, daily climate data is converted into monthly and annual data, while the monthly DHF case data becomes annual. The analysis was carried out in stages to obtain a strong relationship between climate variables and the number of dengue cases. The analysis techniques used are mean, minimum-maximum, product-moment correlation, and multiple linear regression. The results showed that the average number of monthly dengue cases in 2007-2018 was 79.19 cases (8-552 cases), rainfall 6.68 mm (0.00-24.10 mm), temperature 28.120C (24.00- 29,300C), and humidity 79.71% (73.90-86.30%), while the climate factor associated with the incidence of DHF was rainfall (p-value = 0.022), with an effect of 19.0%. This research provides preliminary evidence about the influence of climate factors on dengue transmission.

Keywords: *Climate, DHF, Temperature, Humidity, Rainfall.*

Introduction

Dengue Hemorrhagic Fever (DHF) is an infectious disease that causes interference with the capillaries and blood clotting system, causing bleeding and can cause death. The cause of the disease is the dengue virus with the Aedes aegypti mosquito vector (Indonesia Ministry of Health, 2005). Today, dengue is a threat to more than half of the world's population and a significant cause of hospitalisation and death in endemic countries (Gubler, 2012, 2013; Thi Tuyet-Hanh et al., 2018). Thus, it places a physical and financial burden on infected individuals, families, and the national health system (Langkulsen, Promsakha Na Sakolnakhon, & James, 2019). Other studies estimate that 3.6 billion people are at risk, with more than 230 million infections, millions of cases with dengue, more than 2 million cases with severe illness, and 21,000 deaths (Gubler, 2012; Beatty, Letson and Margolis, 2009; Halasa, Shepard and Zeng, 2012). In Southeast Asia, there are an estimated 2.9 million cases of DHF and 5,906 deaths each year, and an economic burden of around $ 950 million per year (Langkulsen et al., 2019; Shepard, Undurraga, & Halasa, 2013).

DHF cases in Lampung Province from 2007 to 2017 (Incident per 100,000 population) amounted to 42.37 (16.37 - 68.44), this figure is still below the national figure of 54.21 (27.7 - 78.6). However, in Bandar Lampung, the incidence of DHF in the same period amounted to 103.97 (35.30-230.90), much more significant than at the provincial and national levels.

Four components significantly affect the spread and transmission of dengue disease, namely agents, vectors, hosts, and the environment (Lloyd, 2003; Word Health Organisation, 1997; World Health Organisation, 2011, 2014). Dengue disease agent is a dengue virus known as DEN-1, DEN-2, DEN-3, and DEN-4. The four viruses have been found in various regions in Indonesia (Indonesia Ministry of Health, 2005; Indonesia Ministry of Health, 2011). The virus is transmitted from person to person by mosquitoes Aedes subgenus Stegomyia, and Aedes aegypti are important epidemic vectors in causing dengue outbreaks (Indonesia Ministry of Health, 2005; Indonesia Ministry of Health, 2011; Lloyd, 2003; Word Health Organisation, 1997; World Health Organisation, 2011). Aedes aegypti is found in almost all regions of Indonesia, except areas with elevations above 1,000 meters above sea level (Indonesia Ministry of Health, 2005).

Host factors include age, sex, knowledge, mobility, and eradication behaviour of mosquito nets, and prevent mosquito bites (Lloyd, 2003; Word Health Organisation, 1997; World Health Organisation, 2011, 2014). Furthermore, environmental factors include house density, mosquito breeding places, mosquito resting places, mosquito density, House Index, and climate (Epstein, 2001; Hopp & Foley, 2001; Karyanti et al., 2014; Kraemer et al. ., 2015; Mondrow, 2016; Pascawati & Al, 2019; Tosepu, Tantrakarnapa, Nakhapakorn, & Worakhunpiset, 2018). Climate factors, especially temperature, rainfall, and humidity, cause an increase in the transmission of some infectious diseases (Brisbois & Ali, 2010). Climate factors play a role in the distribution and abundance of vector organisms (Hopp & Foley, 2001). Therefore, diseases that are spread through vectors (vector-borne disease) such as malaria and DHF need to be aware of because the transmission of such conditions will increase with climate change (Pascawati et al., 2019).

Geographically, the spread of Aedes aegypti is in the tropics and subtropics with an environment close to humans (Kraemer et al., 2015). In contrast, Aedes albopictus is more tolerant of cold temperatures so that its spread is more significant to the sub-tropical regions (Brady et al., 2014, 2013). Aedes aegypti lives optimally at temperatures of 26-30 ○C and the humidity of 70-80% (Lloyd, 2003; Mourya, Yadav, & Mishra, 2004; Word Health Organisation, 1997; World Health Organisation, 2011) together with the availability of breeding grounds (Espinosa et al., 2016; Lloyd, 2003) and food sources (Arrivillaga & Barrera, 2004).

Climate change is a global phenomenon that many countries are concerned about because it has an impact on humans and the environment. The increase in global temperatures during the decade 2006-2015 was 0.87 ^{0}C, and between 2030 and 2052, it was predicted to be 1.5 ^{0}C (Myles Allen, 2018). This increase in temperature will increase health risks. The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) concluded that indirect climate affects health through ecosystem changes, namely the increased risk of diseases caused by food, water and vector-borne conditions (Haryanto, 2009; Myles Allen, 2018). The challenges hampering the country's ability to control and eliminate vector-based diseases are resistant to insecticides and anomalous climate patterns (World Health Organisation, 2014).

Considering the relationship between climate and DHF, climate projections imply an increased risk of dengue outbreaks. In addition to strengthening surveillance and control systems, epidemic prediction capabilities are needed to enable timely mitigation and effective distribution of resources. To date, there is no early warning system for climate-based outbreaks. Lack of data and knowledge, as well as inadequate support from policymakers for the use of such systems, can hamper the development of technological innovations to control dengue fever.

Materials and Methods

Study Location

The study was conducted in Bandar Lampung, which has an area of 197.22 km2 consisting of 20 districts and 126 villages. It is geographically located at coordinates 5°20'-5°30' South Latitude and 105°28'- 105°37' East Longitude (Figure 1).

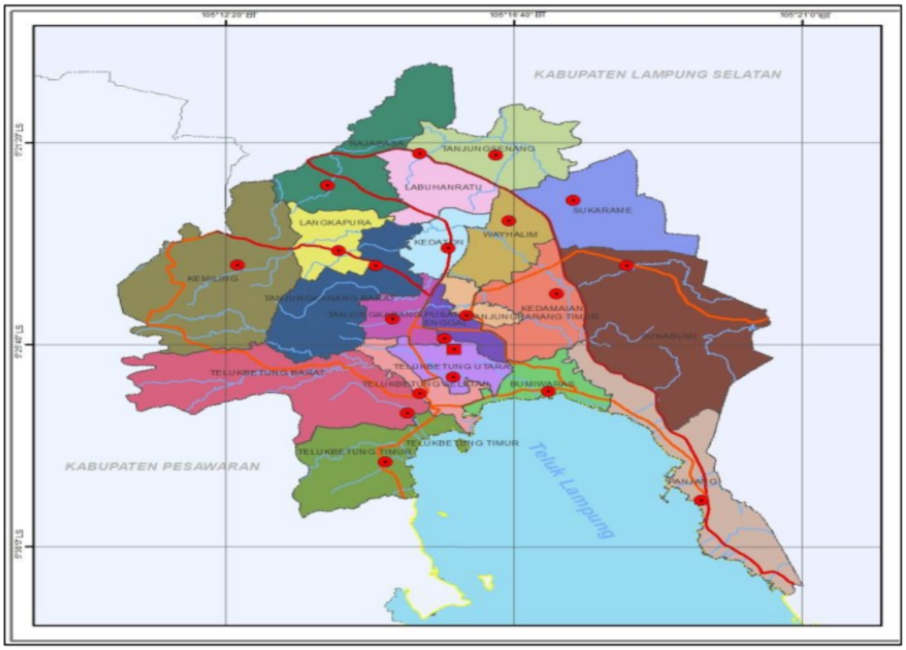


Figure 1. Bandar Lampung Administration Map (Statistics of Bandar Lampung Municipality, 2018)

Study Population

The population of Bandar Lampung is seen to increase every year with the position of the city as the capital of Lampung Province, as well as the centre of government, economy, and education (Figure 2).

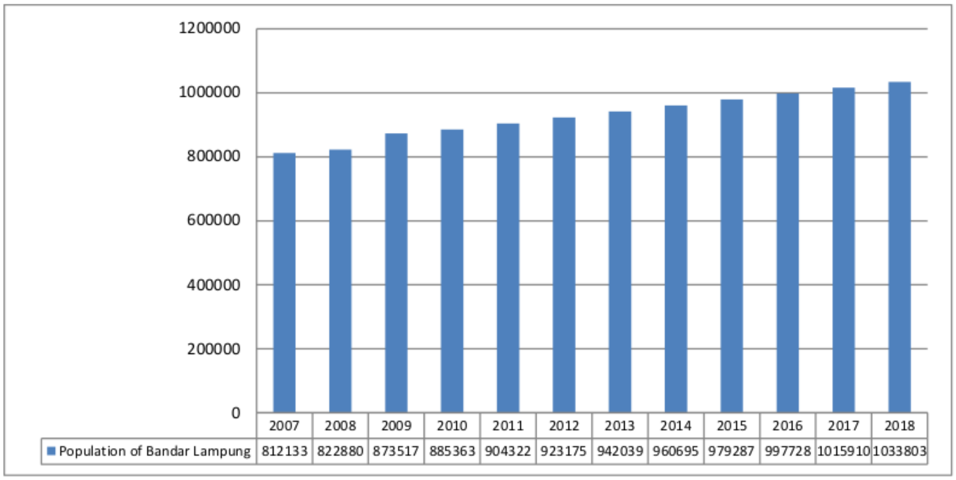


Figure 2. The population of Bandar Lampung in 2007-2018 (Statistics of Bandar Lampung Municipality, 2018)

Data collection

This study used secondary data for the period 2007-2018, which is sourced from data on the number of monthly DHF cases in the Bandar Lampung Health Office with a total of 11,404 cases. Climate data were obtained from the Lampung Province of Meteorology, Climatology, and Geophysics Agency of which consisted of rainfall, temperature, humidity.

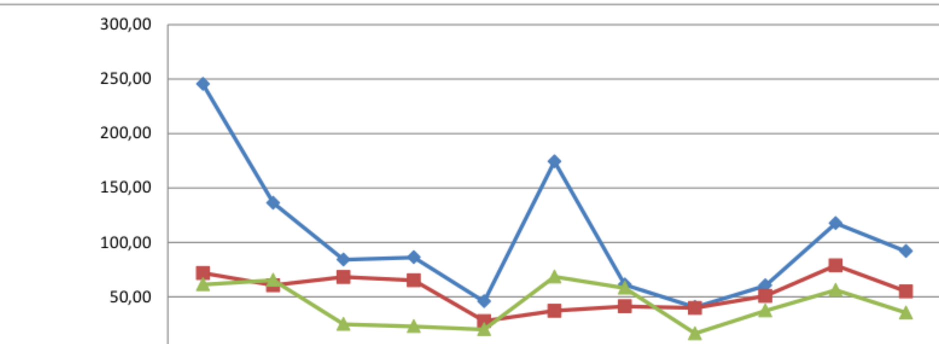
Processing and data analysis

Data from the Bandar Lampung Health Office and the Lampung Province of Meteorology, Climatology, and Geophysics Agency were processed and formatted using SPSS software version 20.0. Data processing performed on DHF case data is to convert monthly data into annual data. As for climate data, the conversion is made from daily data into monthly and yearly data.

Data analysis was carried out in stages, namely univariate, bivariate, and multivariate. Univariate analysis is to get an overview of each research variable using the mean and minimum-maximum. Bivariate uses product-moment correlation to examine the relationship between monthly DHF cases and climate variables. In contrast, multivariate uses multiple linear regression analysis techniques to determine the involvement of all independent variables to the dependent variable simultaneously. The steps taken at the analysis stage are a) Selecting the candidate variables to be included in the model, the variables which in the bivariate analysis have p <0.25; b) Determine valid variables in the multivariate model, i.e., variables that have a p-value <0.05. If in the multivariate model, it has a p value> 0.05, then the variable must be excluded in the model. Variable expenditure is done in stages one by one, starting from the most significant p-value; c) Assess the assumptions that must be met from the linear regression analysis, namely the assumption of existence, the assumption of independence with the Durbin Watson test, and linearity assumptions with ANOVA test. We assess the Assumption of Homoscedascity by making residual plots, normality assumptions by looking at the normal PP plot residual graph, and multicollinearity diagnostic by looking at the value of VIF (variance inflation factor); d) Conduct an interaction test to assess the estimated variables as variables that can strengthen or weaken the relationship between the independent variable and the dependent variable.

Results

The results showed that the average incidence of DHF (in Incident per 100,000 population) in Bandar Lampung in 2007-2018 was 104.20 (40.49 - 245.28). This figure is always greater than the incidence of Lampung Province (IR = 51.36; 20.10 - 78.86) and national (IR = 41.70; 16.37 - 68.44). In full, the incidence of DHF in Bandar Lampung Regency in 2007-2018 is presented in Figure 3.



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Bandar Lampung	245,28	136,11	84,03	86,18	45,67	174,18	61,14	40,49	60,35	117,47	91,74
Indonesia	71,80	60,60	68,20	65,10	27,70	37,20	41,25	39,80	50,75	78,86	55,00
Lampung Province	61,32	65,28	24,82	22,88	20,03	68,44	58,08	16,37	37,24	56,23	35,38

Figure 3. The incidence of DHF in Bandar Lampung, Lampung Province, and Indonesia in 2007-2018

Based on the distribution of DHF events each year (Figure 3), the lowest DHF events occurred in 2014, amounting to 40.49; and the highest occurred in 2007, amounting to 245.28. While the peak cases occurred in 2007 (IR = 245.28), 2012 (IR = 174.18), and in 2016 (IR = 117.47), this number shows a recurring trend with a five-year pattern.

Compared to Lampung Province, it is seen that the incidence does not show the same pattern. The highest incidence rate in 2016 (IR = 78.86) and the lowest in 2018 (20.10). The peak cases in the 2007-2018 period occurred in 2016, amounting to 78.86. However, when compared with the national incidence rate, the DHF trend in Bandar Lampung shows similarities with the widespread trend pattern. The similarity of trend patterns began from 2008 to 2018, although overall, it was below the incidence in Bandar Lampung. The highest impact in 2012 (IR = 68.44) and the lowest in 2014 (16.37).

Based on the number of monthly cases, the average number of DHF cases in Bandar Lampung in 2007-2018 was 79.19 cases (8-552 instances). The lowest cases were in June 2011, and the highest was in December 2007. While the peak cases occurred in December 2007 (552 cases), February 2012 (467 cases), and January 2017 (188 cases), these results indicate a shift in peak cases from the end of the year (November-December), to the beginning of the year (January-March). The peak months of trials in 2007-2018 are presented in Table 1.

Table 1. Peak Month of DHF Cases in Bandar Lampung in 2007-2018

Year	Month	Year	Month
2007	November - December	2013	January - February
2008	December - January	2014	January - February
2009	January - February	2015	February - March
2010	January - February	2016	February - March
2011	January - February	2017	February - March
2012	January - February	2018	February - March

The results of the calculation of the monthly average value of dengue cases in Bandar Lampung City in 2007-2018 were 79.19 cases (8-552 cases). While the average value of climate factors is rainfall 6.68 mm (0.00-24.10 mm); temperature of 28.12^{0}C (29.30-24.00^{0}C); humidity 79.71% (73.90-86.30%). Table 2 also shows the months without rain, namely September 2007, February and July 2008, August 2011, and September 2015.

Table 2. Univariate analysis results

Variables	Average	Highest		Lowest	
		Value	Year	Value	Year
DHF (case)	79.19	552.00	Dec 2007	8.00	June 2011
Rainfall (mm)	6.68	24,10.	Aug 2018	0.00	Sept 2007; Feb, July 2008; Aug 2011; Sept 2015
Temperature (Celcius)	28.12	29.30	June 2018	24.00	April 2008
Humidity (%)	79.71	86.30	April 2018	73.90	Sept 2012

The bivariate analysis aims to determine the relationship of each independent variable with the dependent variable using product-moment correlation analysis techniques and to determine the candidate variables to be included in multivariate analysis. The results of the analysis found that the variables related to the number of dengue cases were rainfall (R = 0.191; p-value = 0.002). The relationship shows a positive direction, so the higher the rainfall, the higher the case of DHF. The other two variables did not show a significant relationship with the number of cases, namely air temperature (R = -0.071; p-value = 0.395) and air humidity (R = -0.078; p-value = 0.352). Although it does not have a statistically significant relationship, the results of the analysis show a negative relationship between temperature and humidity with the number of DHF cases (Table 3).

Table 3. Bivariate analysis results

Variables	R	p-value
Rainfall	0,191	0,002
Temperature	-0,071	0,395
Humidity	-0,078	0,352

Regression analysis was performed to determine the relationship of all independent variables with the dependent variable. The analysis results got an R^2 value of 3.7%. The magnitude of the effect of rainfall on DHF cases was 19.0% (Table 4).

Table 4. Multivariate analysis results

	B	SE	t	Sig.	Beta	R^2
Constanta	55.55	12,20	4,55	0,000		0.037
Rainfall	3.49	1,50	2,32	0,022	0,19	

Discussion

Based on the distribution of rainfall every month, the incidence of DHF is in the month with high moisture. These results indicate a relationship between rainfall and the impact of DHF in Bandar Lampung in 2007-2018. The results of statistical analysis showed that rain had an effect of 19.0% on the incidence of DHF. Rainfall is a climate factor that directly influences the incidence of DHF (Yushananta & Ahyanti, 2014), and the most crucial variable in explaining DHF (Langkulsen et al., 2019). The impact of rainfall on DHF cases was also shown in several other cities in Indonesia. In Kendari and Kolaka, rain indicated high significance with the incidence of DHF (Tosepu, Tantrakarnapa, Nakhapakorn, et al., 2018; Tosepu, Tantrakarnapa, Worakhunpiset, et al., 2018). Rainfall contributed 13.5% - 27.4% in Sleman (Kesetyaningsih, Andarini, Sudarto, & Pramoedyo, 2018a), had a correlation value of 40.7% in Surabaya (Tang, Rusli, & Lestari, 2018), and showed a significant relationship in Denpasar(Azhar, Marina, & Anwar, 2017).

Rainfall plays an essential role in the breeding of Aedes aegypti. In the rainy season, the Aedes aegypti breeding ground is filled with water, and eggs that have not had time to hatch will hatch into larvae after being submerged in water for 1-2 days (Lloyd, 2003; Word Health Organisation, 1997; World Health Organisation, 2011). Therefore, in the rainy season, objects that can hold rainwater are potential breeding places (Gubler, 2013; Lloyd, 2003; World Health Organisation, 2011; Yushananta & Ahyanti, 2014).

In selecting breeding places, female mosquitoes will lay their eggs in areas that contain clear water and do not come in contact with the ground. These are every curved object that can hold water, such as empty cans, broken bottles, roof gutters, old tires, pieces of bamboo, holes in trees, and fronds (Lloyd, 2003; World Health Organisation, 2011, 2014; Yushananta & Ahyanti, 2014).

Directly, the relationship between high rainfall and dengue cases is through the increase in the potential of mosquito breeding sites, so that it will increase vector density and spread, and ultimately will increase the risk of dengue virus transmission (Gubler, 2013; Lloyd, 2003; Word Health Organisation, 1997; World Health Organisation, 2011).
Indirectly, rainfall affects the temperature and humidity of the air which further affect the breeding cycle, survival, and frequency of blood-sucking, and reduce the period of extrinsic incubation (Brady et al., 2014, 2013; Lloyd, 2003; Mourya et al. , 2004; Negev et al., 2015; Word Health Organisation, 1997; World Health Organisation, 2011). High rainfall triggers a drop in temperature and high humidity. In this condition, the vector population increases while extending the vector's life. Large temperature fluctuations at low average temperatures accelerate the extrinsic incubation period (EIP), thereby increasing the likelihood of virus transmission (Brady et al., 2014, 2013; Kesetyaningsih, Andarini, Sudarto, & Pramoedyo, 2018b; Mourya et al. ., 2004; Tang et al., 2018).

Given the rainfall as a variable that can not be controlled, then the effort that can be done to reduce the incidence of DHF is by controlling the Aedes aegypti larvae density through environmental management. As long as drugs and vaccines have not been found, the only way to tackle DHF is through environmental management (Lloyd, 2003; World Health Organisation, 2011).

There are two methods of environmental management (World Health Organisation, 2011), including modifying the environment and manipulating the environment. Environmental modification is to make changes in the environment that are settled in the vector breeding place. These efforts include 1) Improving the distribution of clean water to households with quality right quantity and continuity; 2) Using an anti-mosquito underground water tank; 3) Drying calm water; 4) Disposing of solid waste; 5) Perforated plants must be cut at the segments. Meanwhile, environmental manipulation is to make environmental changes that are not settled in vector breeding places, which include 1) Cleaning and closing the water reservoir; 2) Inserting sand or soil in a flower vase filled with water; 3) Cleaning the base of the pot drinking water tank and gutter; 4) Storing old tires under the roof, so they do not collect rainwater; 5) Cleaning and spreading fish larvae in ornamental ponds; 6) Punching a used bucket or a large can.

Environmental management through environmental modification and manipulation activities requires the participation of the whole community, which focuses on household roles and responsibilities.

Conclusion

Rainfall has an impact on increasing DHF cases by expanding the potential of mosquito breeding sites, thereby increasing vector density and spread. Indirectly, the rain affects the temperature and humidity of the air, which further affects the breeding cycle, survival, and frequency of blood sucking and reduce the extrinsic incubation period. Vector monitoring effort. Environmental modification and manipulation need to be encouraged in every household while the macro attempt is carried out by spatial planning and improvement of the slum environment.

Acknowledgments

The author would like to thank the Bandar Lampung City Health Office and the Meteorology, Climatology, and Geophysics Agency for providing secondary data.

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1	Prayudhy Yushananta. "Dengue Hemorrhagic Fever and Its Correlation with The Weather Factor In Bandar Lampung City: Study From 2009-2018", Jurnal Aisyah : Jurnal Ilmu Kesehatan, 2021 Publication	26%
2	Submitted to Universiti Malaysia Sabah Student Paper	3%
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4	Ramadhan Tosepu, Kraichat Tantrakarnapa, Kanchana Nakhapakorn, Suwalee Worakhunpiset. "Climate variability and dengue hemorrhagic fever in Southeast Sulawesi Province, Indonesia", Environmental Science and Pollution Research, 2018 Publication	1%
5	Naish, Suchithra, Pat Dale, John S Mackenzie, John McBride, Kerrie Mengersen, and Shilu Tong. "Climate change and dengue: a critical and systematic review of quantitative	1%

modelling approaches", BMC Infectious Diseases, 2014.
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8	Khadijah Maulindah, Sukri Palutturi, Syamsiar S. Russeng. "Related Factors to the Performance of Cadres of Larva Monitoring and Health Workers in the Control of Dengue High Fever (DHF) in Palopo", Proceedings of the International Conference on Healthcare Service Management 2018 - ICHSM '18, 2018 Publication	1%
9	Submitted to University of Bedfordshire Student Paper	1%
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11	Shahera Banu, Md Abu Choudhury, Shilu Tong. "Chapter 9 Dengue: Emergence, Determinants and Climate Change", Springer Science and Business Media LLC, 2016 Publication	<1%
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DENGUE INFECTION EPIDEMICS IN JAKARTA AND YOGYAKARTA", Cold Spring Harbor Laboratory, 2020
Publication

13	Dwi Sarwani Sri Rejeki, Nunung Nurhayati, Budi Aji. "A spatiotemporal analysis of dengue hemorrhagic fever in Banyumas, Indonesia", International Journal of Public Health Science (IJPHS), 2021 Publication	<1 %
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Journal of Environmental Research and Public Health, 2020
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21 Uma Langkulsen, Kamol Promsakha Na Sakolnakhon, Nigel James. "Climate change and dengue risk in central region of Thailand", International Journal of Environmental Health Research, 2019 <1%
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22 Jalil Nejati, Rubén Bueno-Marí, Francisco Collantes, Ahmad A. Hanafi-Bojd et al. "Potential Risk Areas of Aedes albopictus in South-Eastern Iran: A Vector of Dengue Fever, <1%

Zika, and Chikungunya", Frontiers in Microbiology, 2017
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27 Nazish Bostan, Sundus Javed, Nabgha-e-Amen, Syed Ali Musstjab Akber Shah Eqani, Faheem Tahir, Habib Bokhari. "Dengue fever virus in Pakistan: effects of seasonal pattern and temperature change on distribution of vector and virus", Reviews in Medical Virology, 2017
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