A prediction model of Dengue Iincidence using climate variability in Denpasar city

Khadijah Azhar, Rina Marina, Athena Anwar

Research and Development Center for Public Health Efforts, National Institute of Health Research and Development, Ministry of Health, Jakarta, Indonesia

Corresponding address: Khadijah Azhar
Email: khadijah.azhar@gmail.com

Abstrak

Latar belakang: Kota Denpasar di Provinsi Bali merupakan salah satu kota dengan kejadian dengue tertinggi di Indonesia. Faktor lingkungan seperti variabilitas iklim merupakan salah satu faktor yang mempengaruhi timbulnya demam berdarah. Penelitian ini bertujuan untuk mendapatkan model prediksi kejadian dengue dengan menggunakan data sekunder iklim mingguan dan surveilans demam berdarah di Denpasar, Bali tahun 2010-2014.

Metode: Data iklim diperoleh dari Badan Meteorologi, Klimatologi, dan Geofisika Indonesia (BMKG), sedangkan data kasus klinis demam berdarah diperoleh dari Sistem Kewaspadaan Dini dan Respon (SKDR), Kementerian Kesehatan RI. Analisis data menggunakan regresi linier dengan berbagai kombinasi variabel iklim dan lag time.

Hasil: Hasil penelitian menunjukkan hubungan yang signifikan antara jumlah kasus demam berdarah, curah hujan, suhu, kelembaban dengan kejadian demam berdarah (p <0,05). Kejadian demam berdarah di kota Denpasar dipengaruhi oleh variabilitas iklim periode 4 minggu (at lag 4 weeks) lebih awal dan jumlah kasus demam berdarah terjadi dua minggu sebelumnya. Dengan demikian faktor iklim mempengaruhi kejadian demam berdarah secara tidak langsung.

Kesimpulan: Model prediksi dapat digunakan sebagai salah satu pertimbangan peringatan dini penyakit demam berdarah di kota Denpasar, disamping memberikan penyuluhan atau upaya edukasi kepada masyarakat tentang pencegahan demam berdarah dan eliminasi vektor. Selain itu memberikan kesempatan bagi sistem kesehatan dalam memahami dan merespon kasus dengue yang lebih baik. **(Health Science Journal of Indonesia 2017;8(2):68-73)**

Kata kunci: Denpasar, Dengue, Iklim, Regresi, Lag time.

Abstract

Background: Denpasar city in Bali province is one of cities with the highest dengue incidence in Indonesia. Environmental factors such as climate variability is one of the factors that influence the incidence of dengue. This study aimed to obtain a predictive dengue incidence models using secondary data of weekly climate and surveillance of dengue cases in Denpasar, Bali, 2010-2014.

Methods: Climate data was obtained from Indonesia Agency for Meteorological, Climatological, and Geophysical (BMKG), while dengue clinical cases were obtained from Primary Health Care as reporting unit in Early Warning Alerts Respons System (EWARS) Ministry of Health. Data analysis was using linear regression with various combinations of climate variables and *lag time.*

Results: The study showed significant relationship between the number of dengue cases, rainfall, temperature, humidity and the incidence of dengue (p<0.05). Incidence of dengue in Denpasar city was affected by climate variability of 4-week period (at lag 4 weeks) earlier and the number of dengue cases was from two weeks earlier. Thus climate factors affected the incidence of dengue indirectly.

Conclusion: The prediction model can be used as one of the considerations on the early warning of dengue disease in Denpasar city, while providing counseling or education efforts to the community about prevention of dengue and vector elimination. It also allows sufficient time for health systems to be prepared to respond and better understanding of dengue cases. **(Health Science Journal of Indonesia 2017;8(2):68-73)**

Keywords: Denpasar, Dengue, Climate, Regression, Lag time.

Climate change has become an international issue because of its major impact on human lives. In the context of environmental policy issues, the Intergovernmental Panel on Climate Change (IPCC) states that 90-95% of climate change caused by human activities and used the term of global warming.[1] Global warming is a condition of increasing the gases present in the atmosphere so that the heat energy trapped that the greenhouse effect occured. The main cause of global warming is the increased concentration of greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs) in the atmosphere due to fossil fuel burnings and decayed organic matters. This can be seen from the observed increase in temperature of the earth by $0.74 \pm 0.18\ {}^0C$ within the last century. [1,2]

Global warming could accelerate the climate change. Climate change is observed in the last few decades has contributed to changes in the physical, chemical, biological and social environments. The existence of extreme weather, heatwaves, changes in temperature and precipitation can affect the health, marked by the emergence of diseases related to air pollution, water and food, vector borne disease, diseases related to food and water scarcity, mental illness, and other infectious diseases. [3]

The impacts of climate change that have been felt in Indonesia are climate and season anomalies, changes in the frequency of El Nino and La Nina events, the increase of tornado and the extreme climate of flood and drought.[2] The impacts of climate change are changes in rain patterns, rising temperatures and rising sea levels. The impact will be more felt by the coastal areas.

The climate-disease relationships raises many important issues about the potential effects of global climate changes on the transmission of infectious diseases, particularly dengue. [4,5] It has been reported that dengue incidence associated with temperature, rainfall, and relative humidity.[6,7,8] Besides that, other important issues that potentially contribute to global changes in dengue incidence and distribution include population growth, urbanisation, lack of sanitation, increased human travel, ineffective mosquito control, and increased reporting capacity.[9] Climatic factors can influence dengue ecology both directly and indirectly by affecting mosquito growth dynamics, virus replication, and mosquito-human interactions.[10] The increase of air temperature could affect the behaviour of mosquitoes biting, the

average number of bites (biting rate), shorten of the maturity period of mosquito parasites and mosquito breeding period for the extrinsic incubation. [11,12] The incubation mosquitoes becomes shorter when the temperature and humidity rise.

Dengue virus is the agent of DHF, belongs to the flavivirus group. There are four serotypes of dengue virus i.e. Dengue 1, 2, 3 and 4. Dengue infection transmitted by Aedes mosquito vector. The primary vector of dengue virus is *Aedes aegypti*, distributed in tropical regions whereas *Aedes albopictus* as a secondary vector derived from tropical and subtropical regions of Asia which has now spread to America, Europe and Africa. The characteristic of both species is different, *Ae. aegypti* is suitable to the environment in the home, breed in and around houses in regular water containers or disposed water-holding vessels, so that its existence is increasing along with the rapid urbanization. Instead, *Ae. albopictus* is primarily forest species that has become adapted to rural, suburban and human environments. This species is more suited to live outdoors, especially areas that are still a lot of vegetation. The eggs can withstand very dry conditions and remain viable for many months in the absence of water.[13,14]

The first dengue cases was reported in Jakarta and Surabaya in 1968 and today has spread to all provinces in Indonesia. In 2013, the three provinces of highest Incidence Rate (IR per 100,000 population) were Bali (168,48), Jakarta (96,18) and East Kalimantan (92.73).[15] The incindence rate of dengue in Bali had increased and it reached 210.2 per 100,000 population in 2014, which was far exceeded the national target of less than 51 per 100,000 population. Total case fatality rate (CFR) since 2010 to 2014 did not decline significantly and it was still around 0.2 per 100,000 population. [16]

Denpasar was the city with highest dengue cases region in Bali Province, followed by Gianyar, Badung and Buleleng.[16] Most of Denpasar population are productive age group (20-44 years old) and toddlers, with similar proportion in men and women. Denpasar become one of tourist destination in Bali island which is popular among domestic or foreign tourists. Human movement has been identified as one of key factors in determining the transmission dynamics of dengue disease. [17] The number of tourist visits to Denpasar can be a potential risk of dengue outbreaks.

Denpasar city as a dengue endemic area and close to the coast, are more at risk of being affected by

climate change. Therefore, adaptation efforts are required to reduce the incidence of dengue through the understanding of the relationship of the climate variability and dengue cases. An early warning system is an essential tool for pre-epidemic preparedness and effectiveness of dengue control.[18] Thus, we develop a predictive tool for dengue risk factors, especially in terms of meteorological variables. This study aimed to determine the correlation between rainfall, temperature, humidity with dengue cases. Furthermore, we will attemp to forecast modelling incidence of dengue weekly using climate data and surveillance of DHF in the city of Denpasar so as to obtain a regression equation.

METHODS

This research was a cross sectional study. We analized the secondary data of climate conditions and dengue incidence of Denpasar, Bali. Weekly climate data were obtained from the Agency of Meteorology, Climatology and Geophysical (BMKG) and the dengue clinical cases were from Early Warning and Response System (EWARS), Directorate General of Disease Control and Prevention, Ministry of Health, Indonesia. Climate variables included rainfall (RF), rainyday (RD), temperature (T), and humidity (H) per week within a year. Observation periods were from the year 2010 - 2014, with the number of weeks in a year for 52 weeks except for 2014 was only available dengue incidence data up to week 46.

The relationship between the incidence of dengue with climate variability was calculated by looking at the coefficient correlation through a linear regression analysis. Incidence of dengue was used as the dependent variable, while independent variables were rainfall, rainyday, temperature, and humidity. There were various combinations of climate variables as follows:
1. Rainfall, rainydays, incidence of dengue 1 and 2 weeks earlier
2. Rainfall, rainydays, humidity, incidence of dengue 1 and 2 weeks earlier
3. Rainfall, temperature, humidity, incidence of dengue 1 and 2 weeks earlier
4. Rainfall, rainydays, temperature, humidity, incidence of dengue 1 and 2 weeks earlier

The lag time between climate variability with the emergence of the disease used statistical tests in combination with difference of time ranging from 0 to lag 6 weeks.

RESULTS

Based on EWARS weekly data, it has been known that the number of dengue cases in the city of Denpasar in 2010 reached 1213 cases. In following years there was a decline in the number of cases that were 331 cases in 2011, 113 cases in 2012 and 127 cases in 2013, while in 2014 increased to 381 cases. During the period 2010-2014 the average weekly temperature in Denpasar was 27.48 ^{0}C, while the average weekly rainfall was 39.17 mm. Rainfall tended to be high at the beginning of the year and started to decline after the 32nd week. The highest rainfall reached 335.5 mm and 286.6 mm, respectively at week 5 and the 15th in 2012. While in 2011 and 2013 were relatively low rainfall almost throughout the year. Throughout the five years average humidity in Denpasar was at 79.77%. The frequency distribution of each climatic variables were presented in the following Table 1.

Rainy period in 2010, the highest dengue cases was in late February to early March and rose again in the beginning of October to November. After that the number of cases gradually declined in December, but rose back in January 2011 and reached its peak in March 2011. In early 2012, ie the period from January to March the number of dengue cases was smaller than the previous two years. Dengue cases increased again in the rainy season in 2014, especially in February-March. The graph overlay incidence of dengue with rainfall throughout the 2010 to 2014 can be seen in Figure 1.

The R^2 value obtained from some combination of climate variables at different lag time based on weekly data from 2010 through 2014 in Denpasar (Figure 2). The results showed that the relationship was most closely marked correlation value among climate variability with the incidence of dengue was the model equations in lag 4 (R^2 = 0.687), that was a condition of the previous 4 weeks and incidence of dengue 1 and 2 weeks earlier. Based on the best coefficient determination (R^2 = 0.687), the regression equation for the dengue in the city of Denpasar is :

$$DHF_{(t)} = -30,087 - 0,006Rf_{(t-4)} + 0,646\ T_{(t-4)} + 0,173H_{(t-4)} + 0,460DHF_{(t-1)} + 0,387DHF_{(t-2)}$$

Table 1. Frequency Distribution of Weekly Climate Variables in Denpasar 2010-2014

Year	Variable	Average	Minimum	Maximum	SD
2010 (n = 52)	Temperature (^{0}C)	27.97	26.64	29.24	0.67
	Rainfall (mm)	53.16	0	198.5	50.67
	Humidity (%)	81.75	72.32	87.14	3.06
	Rainy day (day)	3.71	0	7	1.95
2011(n = 52)	Temperature (^{0}C)	27.16	25.57	29.02	0.87
	Rainfall (mm)	42.02	0	220.8	52.44
	Humidity (%)	80.62	73.18	89.32	3.39
	Rainy day (day)	3.29	0	7	2.28
2012 (n = 52)	Temperature (^{0}C)	27.31	25.54	29.16	1.02
	Rainfall (mm)	37.21	0	335.5	68.36
	Humidity (%)	80.28	65.50	92.39	5.87
	Rainy day (day)	2.46	0	7	2.31
2013 (n = 52)	Temperature (^{0}C)	27.60	25.81	29.31	0.89
	Rainfall (mm)	31.80	0	143.1	40.94
	Humidity (%)	78.22	72.36	85.71	3.45
	Rainy day (day)	2.96	0	7	2.28
2014 (n = 46)	Temperature (^{0}C)	27.46	25.34	29.37	0,93
	Rainfall (mm)	23.93	0	155.8	39.83
	Humidity (%)	76.76	66.86	89.00	4.01
	Rainy day (day)	1.67	0	7	1.84
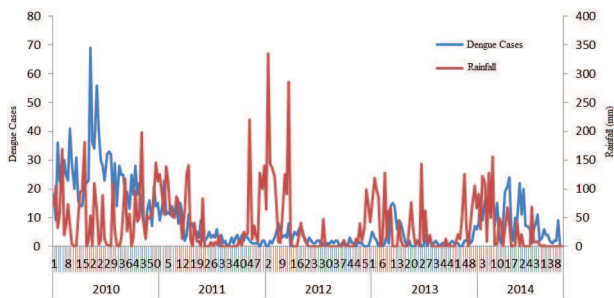
Figure 1. Weekly Rainfall and incidence of dengue in Denpasar 2010-2014
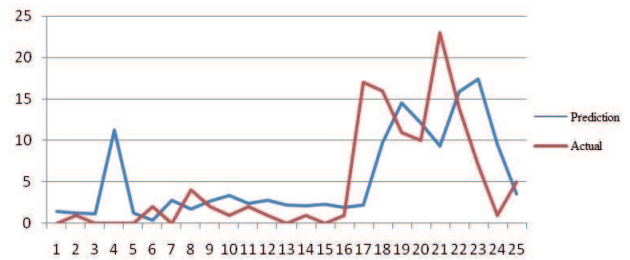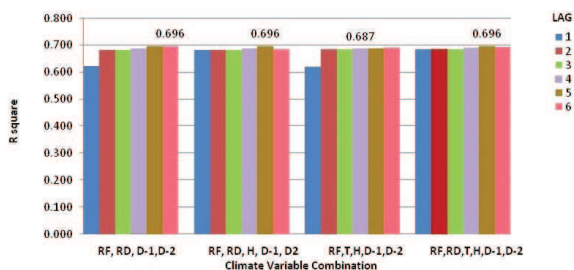

Figure 2. R² value of climatic variables and dengue combinations in Denpasar 2010-2014

Furthermore, the modelling used to predict dengue cases in Denpasar, 2015 and compared with the actual data in 2015 can be seen in Figure 3.

Figure 3. Dengue cases prediction in 2015

DISCUSSIONS

Average rainfall occurred in Denpasar City tended to decrease during the year of 2010-2014. Similarly, the parameters of temperature, humidity and number of rainy days have decreased as well. Generally, Bali has a monsoonal precipitation patterns, characterized by the peak of the rainy season which is between the months of December, January and February. Also, it has a clear distinction between the rainy season and dry season.[19] The monsoon season is considered begin to occur when the rainfall in three consecutive days has exceeded 100 mm per m², otherwise the high rainfall is considered as a transitional season. In contrast, monthly temperature pattern was increasing around 0.02^{0}C per year during 2004 to 2008. The average temperature in wet and dry in the period also rose.[19]

Associated with the incidence of dengue, high rainfall in 2010 was also followed by increasing number of dengue cases during in 2011-2014. High rainfall did not necessarily improve dengue cases but there was a lag time of several weeks. Rainfall, temperature, and humidity indirectly affected to the land cover and land-used that can enhance or inhibit the growth of vector populations.[10]

The temperature affect on the development, death, and the behavior of the vector, and the virus replication in the mosquito.[11,12,20] *Aedes aegypti* usually lay their eggs at temperatures of about 25 ^{0}C – 30^{0}C and it will hatch in 3-4 days in the water. Air humidity also affect the life of the mosquito. At 20^{0}C and relative humidity was 55% female mosquito lifespan could reach 88 days while the male mosquito was 50 days. At a relative humidity of less than 60%, the mosquitoes will be shorter-lived and therefore can not be a vector for the unavailability of sufficient time for the transfer of the virus from mid-gut to salivary glands of mosquitoes, because it needs 8-12 days for extrinsic incubation periode. [21] Thus the air humidity which is more than 60%, strongly caused the development of Aedes aegypti in transmitting the dengue virus.

Furthermore, in a temperature-controlled experiment, Yang *et al.* showed optimal ranges of mean temperature for survival of female adult mosquitoes, and for immature stages, to be 15^{0}C-30^{0}C and 15^{0}C-35^{0}C. [22] *Aedes aegypti* and *Ae. albopictus* has developed rapidly in the temperature ranging from 20^{0}C - 30^{0}C, while the increase in deaths occurred at 35^{0}C.[23] At 30^{0}C, conditions will affect the sex ratio in mosquitoes, where the number of females mosquito is higher than males (ratio is 4: 3).[11]

Rain water could wash away the mosquitoes during the highest rainfall, however the eggs still attach to the containers and may hatch later. Hence, peak incidence usually occurs in the months around the highest rainfall time period. The study in North Jakarta suggested that the peak incidence of DHF occurred in May, which actually was the lowest rainfall of the observed year and incidence remained quite low during the highest rainfall. [24]

The female Aedes will suck the human blood or animals to mature their eggs. When the ambient temperature is above 15^{0}C, the body size will tend to shrink, along with a shortened life cycle. [11] The smaller body size will increase the frequency of biting and automatically the spread of dengue virus will also increase. Increasing temperatures could also shorten gonotrophic development cycle in *Ae. aegypti.* [25] Thus, the temperature of the warm air will usually be followed by an increase in the mosquito population, the extrinsic incubation period of dengue virus will be shorten and then it make an extension of the time of infective mosquitoes spreading dengue virus.

In the rainy and transitional seasons, the breeding sites for Aedes mosquitoes will be widespread. Rainfall converts numerous artificial and natural sources into breeding habitats for mosquitoes. [22] The city of Denpasar and other areas will always face the same problems as the condensed waterways, increasing puddles and slums area. This condition can be a trigger for the increase of dengue cases. Capturing all aspects of the disease is a daunting task, but newer techniques may help overcome the difficulties.

Findings from this study showed limitations in term of short observation time period (five years) as well as possibility of under reported. The prediction model from this study reffered to a specific area which may be influenced by variety of conditions such as geographical factors, transmission dynamic of dengue cases, climate, population growth, risk behavior, lack of sanitation, ineffective or poor mosquito control, and weak surveillance system.

In conclusion, the results showed that both climatic variables and surveillance data can be used to predict the incidence of dengue. The prediction model is certainly needed to be developed using other techniques that are better suited to the local conditions of climate data and diseases. In the end, it can be obtained a model that truly 'rigid' so that it can be used for early warning of dengue disease is easier and cheaper. Effective policies and measures will be a key to prepared for and manage changes in the geographic range and incidence of the disease.

REFERENCES

1. Saxena H. Environmental ecology, biodiversity, and climate change – towards sustainable development. New Delhi: Rawat; 2015.

2. Wibowo S. Modul perubahan iklim. Jakarta: BMKG; 2013. Indonesian.

3. Patz JA, Githeko AK, McCarty JP, Hussein S, Confalonieri U, De Wet N. Climate change and infectious diseases. Climate change and human health: risks and responses [Internet]. Mc.Michael AJ, Campbell-Lendrum DH, Corvalan CF, Ebi KL, Githeko AK, Scheraga JD, et al., editors. World Health Organization. Geneva: World Health Organization; 2003. 1-306 p. Available from: http://www.who.int/globalchange/environment/en/ccSCREEN. pdf?ua=1%5Cnhttp://www .jstor .or g/stable/2137486?origin=crossref

4. Ramasamy R, Surendran SN. Global climate change and its potential impact on disease transmission by salinity-tolerant mosquito vectors in coastal zones. Front Physiol. 2012 June 3;1–14.

5. Sly PD. Health impacts of climate change and biosecurity in the Asian Pacific region. Rev Environ Health. 2011 Jan 1;26(1):7–12.

6. Jing Y, Wang X, Tang S, Wu J. Data informed analysis of 2014 dengue fever outbreak in Guangzhou: Impact of multiple environmental factors and vector control. J Theor Biol [Internet]. 2017;416(December 2016):161–79. Available from: http://dx.doi.org/10.1016/j.jtbi.2016.12.014

7. Gharbi M, Quenel P, Gustave J, Cassadou S, Ruche G La, Girdary L, et al. Time series analysis of dengue incidence in Guadeloupe, French West Indies: Forecasting models using climate variables as predictors. BMC Infect Dis [Internet]. 2011;11(1):166. Available from: http://bmcinfectdis.biomedcentral.com/articles/10.1186/1471-2334-11-166

8. Chen SC, Hsieh MH. Modeling the transmission dynamics of dengue fever: Implications of temperature effects. Sci Total Environ [Internet]. 2012;431:385–91. Available from: http://dx.doi. org/10.1016/j.scitotenv.2012.05.012

9. Struchiner CJ, Rocklöv J, Wilder-Smith A, Massad E. Increasing dengue incidence in Singapore over the past 40 years: Population growth, climate and mobility. Chowell G, editor. PLoS One [Internet]. 2015 Aug 31;10(8):1–14. Available from: http:// dx.plos.org/10.1371/journal.pone.0136286

10. Morin CW, Comrie AC, Ernst K. Climate and Dengue transmission: Evidence and implications. Environ Health Perspect [Internet]. 2013 Sep 20;121(11–12):1264–72. Available from: http://ehp.niehs.nih.gov/1306556/

11. Tun-Lin W, Burkot TR, Kay BH. Effects of temperature and larval diet on development rates and survival of the dengue vector Aedes aegypti in north Queensland, Australia. Med Vet Entomol [Internet]. 2000 Mar;14(1):31–7. Available from: http://doi.wiley. com/10.1046/ j.1365-2915.2000.00207.x

12. Rohani A, Wong YC, Zamre I, Lee HL, Zurainee MN. The effect of extrinsic incubation temperature on development of dengue serotype 2 and 4 viruses in Aedes aegypti (L.). Southeast Asian J Trop Med Public Health [Internet]. 2009 Sep;40(5):942–50. Available from: http://www. ncbi.nlm.nih.gov/pubmed/19842378

13. Murray NEA, Quam MB, Wilder-Smith A. Epidemiology of dengue: Past, present and future prospects. Clin Epidemiol. 2013;5(1):299–309.

14. CDC. Dengue and the Aedes albopictus mosquito. Centers Dis Control Prev Fact Sheet [Internet]. 2012; Available from: www.cdc.gov/dengue/resources/30Jan2012/albopictusfactsheet.pdf

15. Pusat Data dan Informasi. Situasi Demam Berdarah Dengue di Indonesia. Vol. 1, Infodatin. 2014. p. 1–2. Indonesian.

16. Dinkes Prov Bali. Provil kesehatan provinsi Bali tahun 2014. Dinas Kesehatan Provinsi Bali. Denpasar: Dinas Kesehatan Provinsi Bali; 2015.1-111 p. Indonesian.

17. Stoddard ST, Morrison AC, Vazquez-Prokopec GM, Soldan VP, Kochel TJ, Kitron U, et al. The role of human movement in the transmission of Vector-Borne Pathogens. PLoS Negl Trop Dis. 2009;3(7).

18. Hii YL, Zhu H, Ng N, Ng LC, Rocklöv J. Forecast of Dengue incidence using temperature and rainfall. Mutuku F, editor. PLoS Negl Trop Dis [Internet]. 2012 Nov 29;6(11):e1908. Available from: http://dx.plos. org/10.1371/journal. pntd.0001908

19. Setiawan O. Analisis variabilitas curah hujan dan suhu di Bali. J Anal Kebijak Kehutan. 2012;9(1):66–79.

20. Grech M, Sartor P, Almiron W, Luduena- Almeida F. Effect of temperature on life history traits during immature development of Aedes aegypti and Culex quinquefasciatus (Diptera: Culicidae) from Córd... - PubMed - NCBI. Acta Trop [Internet]. 2015;(146):1–6. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25733491

21. WHO. Dengue guidelines for diagnosis, treatment, prevention and control [Internet]. France: World Health Organization; 2009 [cited 2017 Oct 4]. Available from: www.who. int/neglected_diseases/en

22. Hii YL. Climate and dengue fever : Early warning based on temperature and rainfall. Sweden: The Dean of the Medical Faculty; 2013. 61 p.

23. Farjana T, Tuno N, Higa Y. Effects of temperature and diet on development and interspecies competition in Aedes aegypti and Aedes albopictus. Med Vet Entomol [Internet]. 2012 Jun [cited 2016 Aug 5];26(2):210–7. Available from: http://doi.wiley.com/10.1111/ j.1365-2915.2011.00971.x

24. Sungkar S, Fadli RS, Sukmaningsih A. Trend of Dengue Hemorrhagic fever in North Jakarta. J Indian Med Assoc. 2011;61(10):394–9.

25. Focks DA, Barrera R. Dengue transmission dynamics: Assessment and implications for control [Internet]. Geneva; 2006 [cited 2017 Oct 9]. Available from: http://www.who.int/tdr/ publications/publications/swg_dengue_2.htm