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MATHEMATICAL INSIGHTS INTO DENGUE DISEASE TRANSMISSION IN THAILAND: BRIDGING THE GAP

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Abstract: Dengue virus, endemic in tropical and subtropical regions like South-East Asia, the Western Pacific, and Latin and Central America, poses a significant public health threat. Transmitted to humans via Aedes mosquitoes, the virus comprises four distinct serotypes: DEN1, DEN2, DEN3, and DEN4. These mosquitoes can thrive in any environment with stagnant water, making them ubiquitous and challenging to control. Mosquitoes, despite their small size, are the most lethal animals on Earth, responsible for a staggering number of human fatalities each year. Mosquito-borne diseases, including malaria, yellow fever, encephalitis, and dengue fever, contribute to this alarming mortality rate.

Dengue fever, in particular, is a global concern, as there is no specific treatment available, and existing medical care primarily focuses on managing patients' symptoms and supporting their recovery. The absence of an effective vaccine further complicates the situation. Consequently, the primary approach to combat dengue revolves around controlling the mosquito vectors responsible for its transmission.

Mathematical modeling plays a pivotal role in understanding the dynamics of dengue transmission and the development of strategies for its control. This tool enables a comprehensive analysis of the spread of infectious diseases, shedding light on the mechanisms underlying dengue epidemics. By exploring mathematical models, researchers and public health officials can gain valuable insights into the spread and control of dengue, ultimately helping to mitigate the impact of this devastating disease.

Keywords: Dengue virus, Aedes mosquitoes, Mosquito-borne diseases, Mathematical modeling
Disease control

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INTRODUCTION

Dengue virus is found in tropical and subtropical region around the world such as South-East Asia, the Western Pacific and Latin and Central America [1]. Dengue virus is transmitted to human by biting of Aedes mosquitoes. There is four serotypes: DEN1, DEN2, DEN3, and DEN4. The mosquitoes can be growth in any places that have stagnant water which can be found anywhere and anytime in home. Mosquito is the most dangerous animal on earth because of the number of people killed by mosquito per year. The Washington Post, April 29, 2014, stated that mosquito is the animal that can kill most of people. Mosquitoes can carry devastating diseases, which are included malaria, yellow fever, encephalitis and dengue fever. Dengue disease is an international public health concern that is no specific treatment. There is no vaccine available that the appropriate medical care frequently survives the lives of patients. The way to control dengue disease is focused on mosquitoes spreading. Therefore, the mathematical model is an important tool in order to analyze the spread and control of infectious disease that can provide the dengue epidemic in order to better understand the mechanisms.

Dengue disease is a fastest emerging arboviral infection spread by Aedes mosquitos with major public health consequences in over 100 tropical and sub-tropical countries in SouthEast Asia, the Western Pacific and Latin and Central America which around 2.5 billion people globally live under the threat of dengue fever (WHO, 2013). The rising level of dengue infections around the world has become seriously an international concern that has increased with increasing geographic expansion distribution [1].

DENGUE DISEASE IN THAILAND

The first case of dengue disease in Thailand observed in 1949 and continued throughout 1950 and the first major outbreak of dengue disease was appeared in Bangkok in 1958 [2]. The historical reported case and death of dengue disease in Thailand during 1958-2014 are shown in Figure 1.

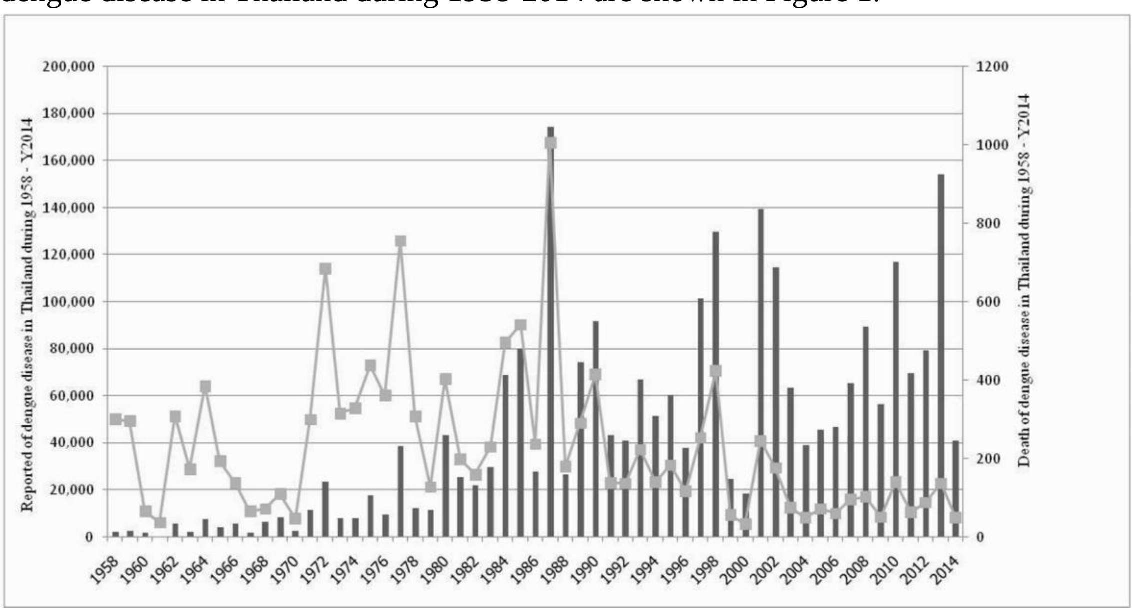

Figure 1: Historical reported and death of dengue disease in Thailand

Source: The Bureau of vector born disease, Thai ministry of public health [3]

The reported of deaths, reported rates, deaths rates, reported fatality rates (%), and population of dengue disease are presented [3]. The reported case and death due to dengue disease by regional in Thailand during

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2003-2014 are shown in Figure 2 and Figure 3 respectively. The regional are divided by geographical areas which include Bangkok, central (excluding Bangkok), north, north east, and south area. The detail of each regional consist of central (excluding Bangkok) 24 provinces, north 18 provinces, north east 20 provinces, and south 14 provinces.

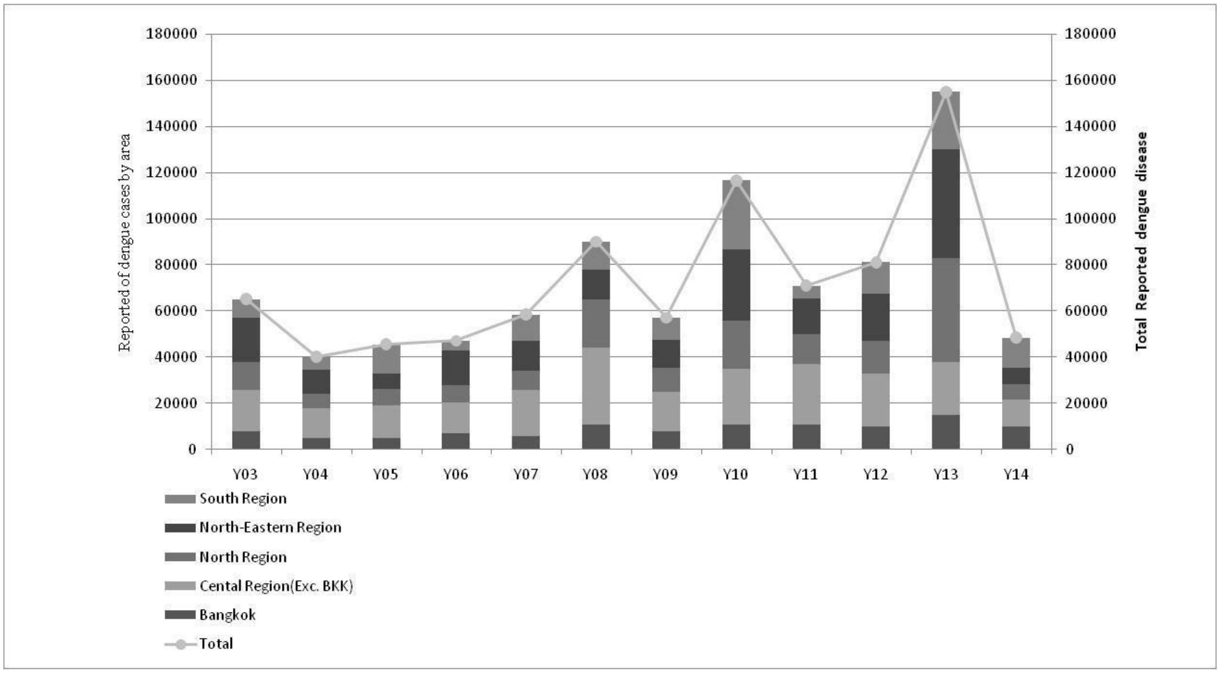

Figure 2: The reported of dengue disease in Thailand by regional during 2003-2014 Source: The Bureau of Epidemiology, Thai ministry of public health [4]

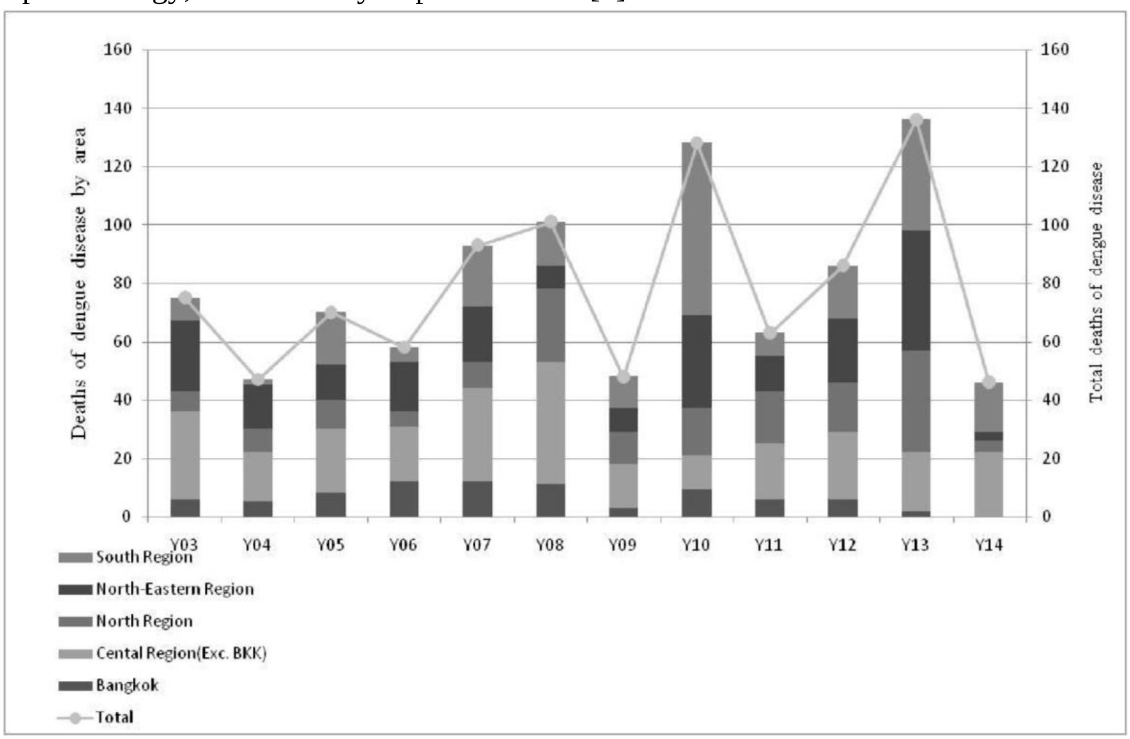

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Figure 3: The death of dengue disease in Thailand by regional during 2003-2014 Source: The Bureau of Epidemiology, Thai ministry of public health [4]

The reported case and death due to dengue disease by month in Thailand during 2003-2014 are shown in Figure 4 and Figure 5 respectively. The peak period for dengue reported is around rainy season in Thailand from May to September of each year which is the same pattern for death of dengue case. The dengue disease situation in Thailand has mad badly because of the unseasonably wet and warm weather which is allowing mosquitoes to reproduce at a rapid rate. Mosquitoes can breed in clear water which is usually found around housing development in urban area that is most active in daytime. As the results, seasonal is effected with mosquitoes breading and also reported and deaths of dengue disease in Thailand.

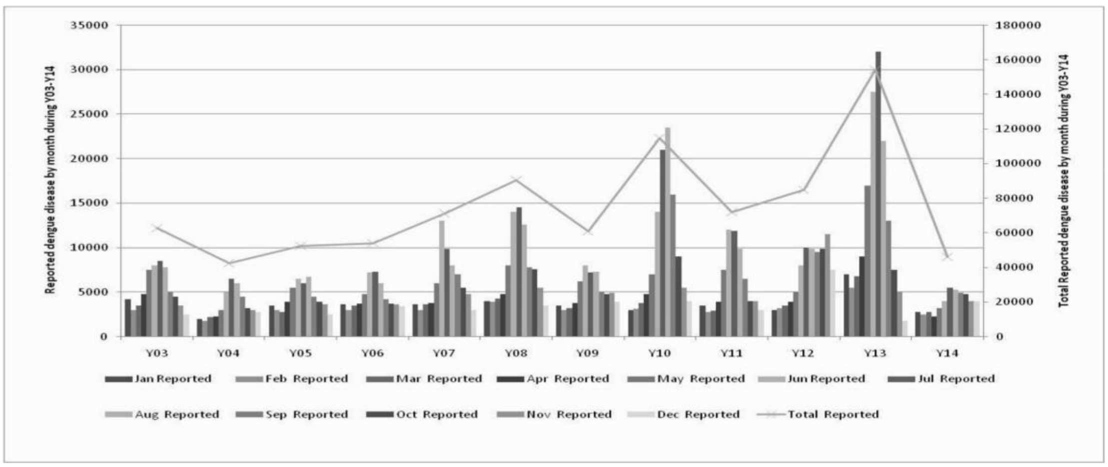

Figure 4: The reported cases of dengue disease in Thailand by month during 2003-2014 Source: The Bureau of Epidemiology, Thai ministry of public health [4]

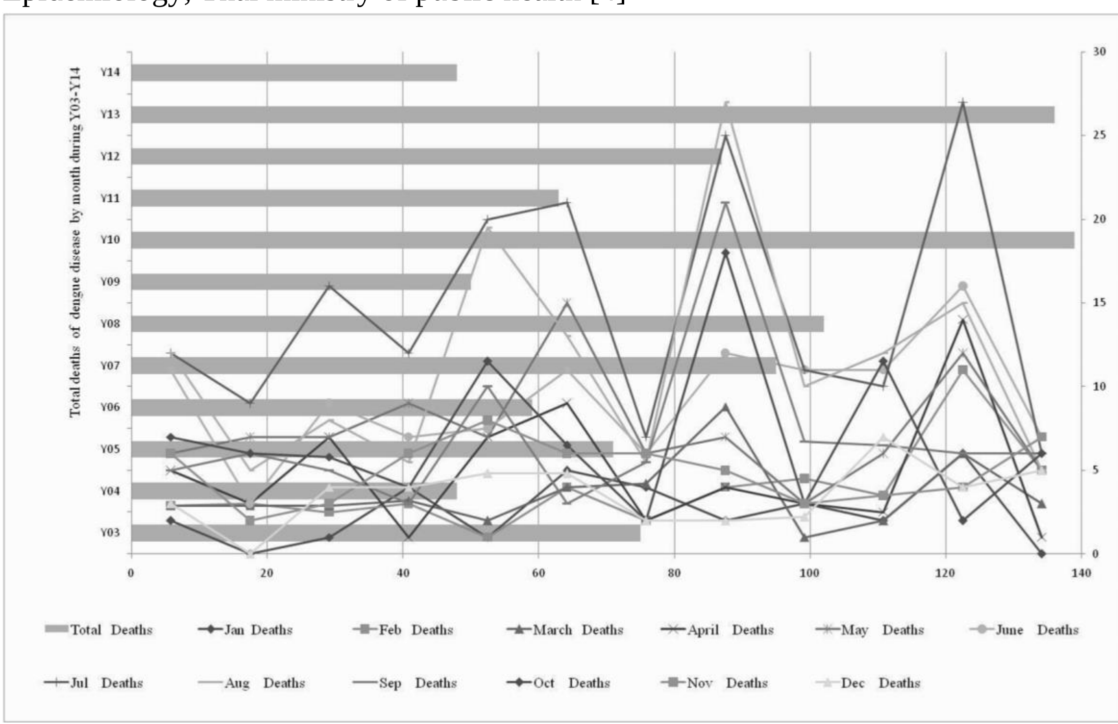

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Figure 5. The death of dengue disease in Thailand by month during 2003-2014 Source: The Bureau of Epidemiology, Thai ministry of public health [4]

The reported dengue disease by age in Thailand during 2004-2014 is shown in Figure 6. The high reported of dengue disease remains in age group 10-14 and 15-24. The highest reported changed from the age 10-14 years to 15-24 years in 2009.

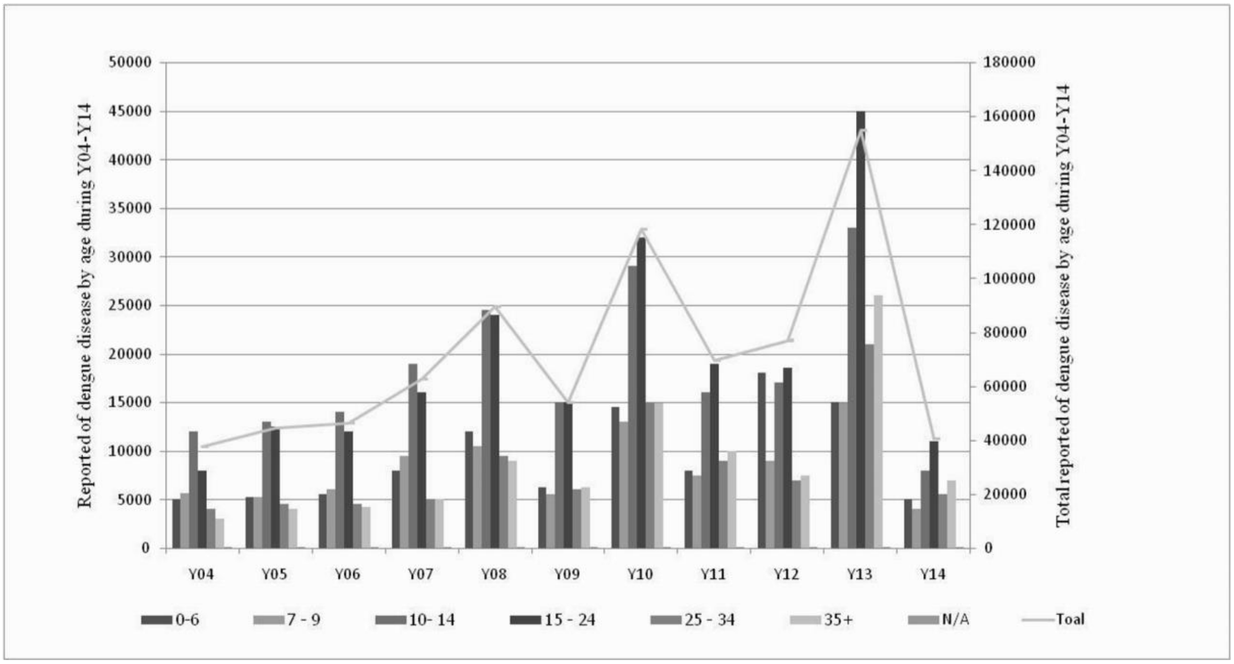

Figure 6: The reported of dengue disease in Thailand by age during 2004-2014 Source: The Bureau of Epidemiology, Thai ministry of public health [13]

The reported dengue disease by occupation in Thailand during 2006-2014 is shown in Figure 7. The highest reported of dengue disease remains in student occupation. The second and the third main reported of dengue disease are in employee and agriculturist occupation.

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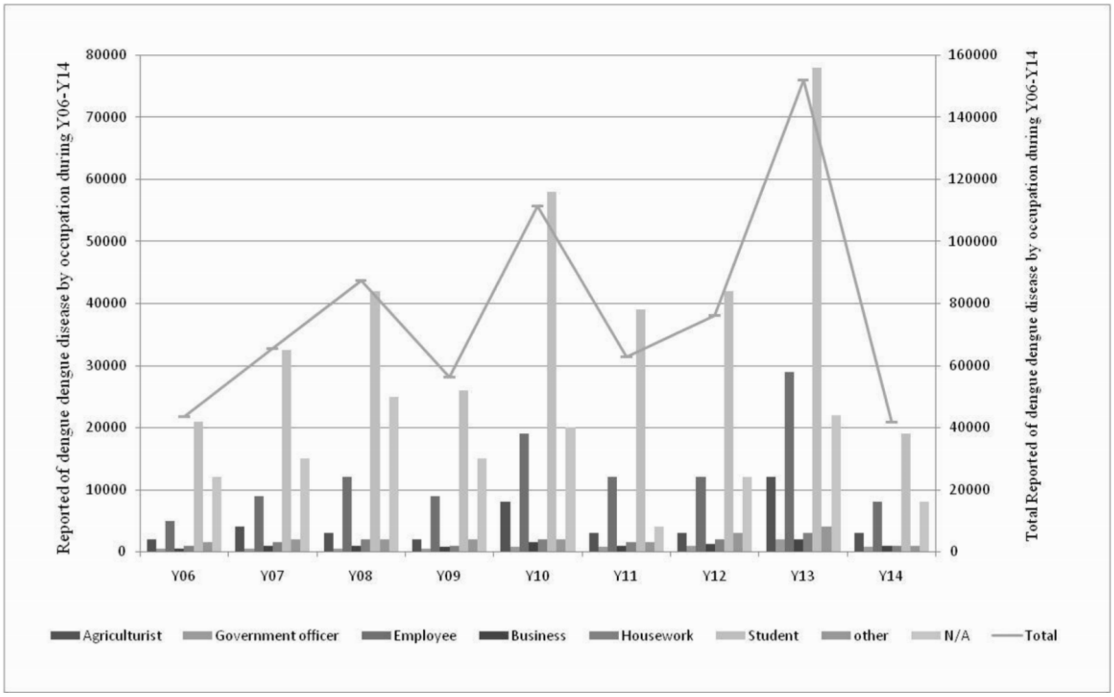

Figure 7: The reported of dengue disease in Thailand by occupation during 2004-2014 Source: The Bureau of Epidemiology, Thai ministry of public health [4]

In 2015, the reported of dengue disease as of 7 May was total 5837 reported cases and 0 deaths from 77 provinces which dengue disease situation is shown in the Figure 10. The morbidity rate was 9.06 per 100,000 populations. The reported proportions of dengue disease by age group were 15-24 years old 27.17%, 10-14 years old 20.56%, and 25-34 years olds 13.83%.

Dengue disease is an important mosquito-borne viral infection found in tropical and suptropical climates around the world especially urban and semi urban area. The widespread of dengue disease is throughout the tropic which local variation in risk is influenced by rainfall, temperature, and unplanned rapid urbanization. The current decade dengue disease situation in Thailand is shown in Figure 1 – 7. The highest reported and deaths were 154,444 cases in 2013 and 139 cases in 2010 which the morbidity and mortality rate per 100,000 populations were 241.03 in 2013 and 0.22 in 2010 respectively. In regional level, north-eastern region was reported the highest cases in 2013 while the highest deaths was south region in 2010. The highest reported by age group was aged 15-24 years in 2013 and main reported of occupation was student. The peak period reported each year was appeared during rainy season in May through September. The total reported, total death, trend of total reported, and trend of total death during 2003 - 2014 are shown in Figure 8.

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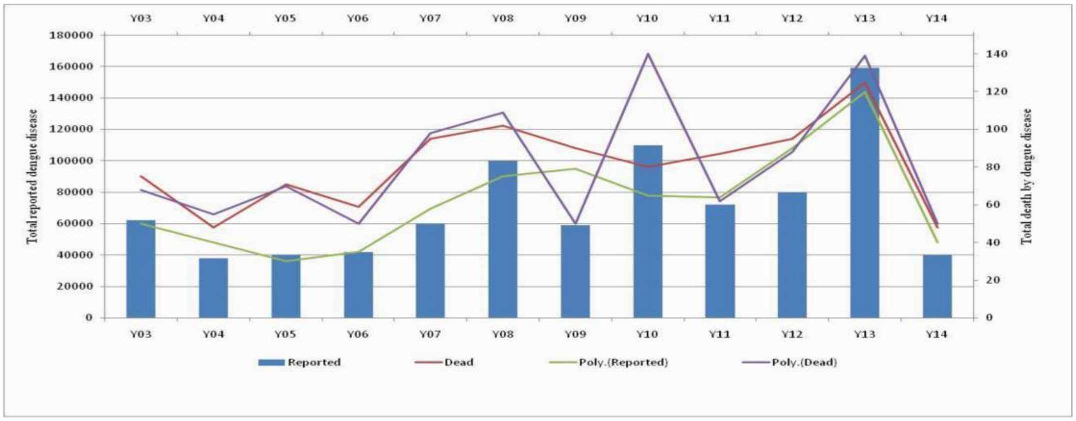

Figure 8: Dengue disease in Thailand during 2003 - 2014

MATHEMATICAL MODEL FOR TRANSMISSION OF DENGUE DISEASE

Aedes mosquito is vector of dengue disease. It can transmit dengue virus to human through biting of infected female mosquitoes. Incubation of dengue virus is around 4-10 days that infected mosquito is able to transmit dengue virus for the whole life. When human got dengue virus from infected mosquitoes, an infected human is the source of dengue virus for uninfected mosquito. The patients who got dengue virus from infected mosquito can transmit dengue virus to mosquitoes for 4-12 days after the first symptoms occur. The transmission cycle is completed when uninfected mosquitoes feed on a human with dengue infection.

There are several mathematical models to develop the transmission mechanism of dengue disease, the appropriated models can provide a qualitative risk assessment of the spread of dengue disease. Esteva and Vargas [5] proposed a model for the transmission of dengue fever in a constant human population and variable vector population. The global analysis was present to establish the global stability of the endemic equilibrium. Naowarat, S. et al. [6] proposed the dynamical model for determining human susceptibility to dengue fever. The standard method was proposed to analyze the dynamic of dengue disease system. They have proposed and analyzed the dynamical transmission model of Dengue fever by taking into account the role played without immunity in human population. They found that there are two equilibrium states, a disease-free state and endemic state. When the reproductive number is lower than one, the disease-free state is locally asymptotically stable. If reproductive number is more than one, the endemic equilibrium state is locally asymptotically stable. As the results, if the basic reproductive number decreases below one, it can reduce the human susceptibility to the disease and can reduce the outbreak of the disease.

Pongsumpun P. [7, 8, 9, and 10] proposed the mathematical models for dengue disease. The dynamical transmission model with the effect of extrinsic incubation period was present and the standard dynamical analysis to a modified Susceptible-Infected-Recovered (SIR) model included an annual variation in the length of the extrinsic incubation period was investigated [7]. They found that the dynamic behavior of the endemic state changes as influence of the seasonal variation of the incubation period. If the influence is increased, the trajectory exhibits sustained oscillations. The dynamic transmission model for dengue disease with and without the effect of extrinsic incubation period was compared [8]. The found that the dynamic behaviors of the endemic state changes while the influence of the seasonal variation of the incubation period become stronger. The modified mathematical model of dengue disease with effect of incubation period of virus was considered [9] that were formulated by separating the human population into susceptible, infected, infectious and recovered classes. The vector population was divided into susceptible, infected and infectious classes. She found that the infected class reduces the periods of the oscillations in the population. The seasonal transmission model of dengue virus infection in Thailand was presented [10]. She found that the basic reproductive number in high endemic season is higher than the normalized susceptible classes decrease. The basic reproductive number in lower endemic season is higher than normalized infected human classes increase. This behavior occurs because there is enough susceptible human to be infected from infectious mosquitoes.

Chanprasopchai P. and Pongsumpun P. [11] proposed the transmission dynamic of SIR model for dengue fever with vector-born infection. The infected vectors caused by both biting of infected human and vector-born infection are proposed. We apply standard dynamic modeling method to analysis our mathematical model and the stability of the model is analyzed by Routh – Hurwitz criteria. The numerical solutions show that the dynamical behaviors converge to the endemic equilibrium state and the relation between each individual variable with the biting rate of mosquito are presented. We found that if the mosquito biting is increased, the values basic reproductive number and susceptible human will increase while infected human and infected vector will increase.

Pongsumpun, P. and Kongnuy, R. [12, 13] presented the mathematical model to describe the transmission of dengue disease for pregnant and non-pregnant. In case of the basic reproductive is higher, the period of oscillation is shorter. The endemic equilibrium points for proportion of susceptible pregnant and non-pregnant decrease and proportion of infective pregnant and non-pregnant and infective vector decrease. These behaviors occur when there is enough of susceptible pregnant and non-pregnant to be infected from infectious vector. Application of an ultra-low volume amount of insecticide could reduce the basic reproductive number lower than one and the basic reproductive number would return to above one once the application is stopped. Since the endemic state is local stable, the dengue disease would return. So, the eradication program would have to be a continued one which can increase the outbreak of dengue disease.

Mathematical model is used to analyze and investigate the dengue disease. The basic reproductive number from mathematical analysis is applied to control the outbreak of dengue disease. The outbreak will spread when the basic reproductive number value is lower than one. On another hand, when the basic reproductive number is lower than one, it can control the outbreak. As the current, there is no specific treatment and vaccination for dengue disease. The best way to control the outbreak is to control spreading of infected mosquitoes.

CONCLUSION AND DISCUSSION

Dengue disease is an international concern disease affecting human around the world especially tropical and sup-tropical area. Dengue disease is caused by mosquito which is more dangerous. Global incidence of dengue disease has increased dramatically in the current decade and around half of world' population is living at risk area which has reported of dengue disease. It is not only the numbers of reported cases are increasing but also the dengue disease spreads to new area that the dengue disease is endemic in more than 100 countries. Thailand had reported of dengue disease since 1950 and the first outbreak in 1958. The historical reported of dengue disease in Thailand are shown in Figure 1. Figure 2 and 3 show the reported and death of dengue

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disease by regional. The report and death of dengue disease by month are presented in Figure 4 and Figure 5. The reported of dengue disease by age is shown in Figure 6 while Figure 7 presented the reported of dengue disease by occupation. The dengue disease situation in this year, 2015, is shown in figure 8 while the trend of reported and death of dengue disease is also proposed in Figure 5.

The mathematical model of dengue disease has developed for long time. The popular one was proposed by Esteva, L. and C. Vargus in 1999. Many researchers developed the mathematical model to find the way to control the outbreak. The reproductive number is used to control the outbreak. The reproductive number is lower than one will decrease the outbreak. At the present, the method to control the transmission of dengue disease is controlled the spreading of mosquitoes such as environmental management of egg laying, waste disposing, and water storage. The community participation and mobilization will improve the sustained mosquito control and the insecticides spraying during outbreak is the one of emergency vector control. The active monitoring of mosquitoes should be continued to control the outbreak [14].

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