Mathematical Model of Repellent Effect in Dengue Transmission

Model Matematika Efek Repellent dalam Penularan Demam Berdarah

Tegar Arifin Prasetyo

Information Technology Department, Faculty of Informatics and Electrical Engineering
Institut Teknologi Del, Indonesia

tegar.prasetyo@del.ac.id

Abstract

Dengue is a disease that is a health problem in the tropics and subtropics. There are 4 serotypes of dengue virus, DEN1-DEN4 and all of these serotypes are transmitted through the bite of female *Aedes aegypti* mosquitoes. The big concern of the world health experts is the possibility of spreading dengue and becoming an uncontrolled epidemic. So this research is intended to be able to suppress dengue cases. We used is SIR-SI by adding all human classes do not or use repellent. The analysis conducted basic reproductive numbers R_0 which will be reviewed when $R_0 < 1$ and $R_0 > 1$. Furthermore, to illustrate the model was carried out simulation which resulted in the fact that the higher the level of repellent use in humans would reduce the spread of dengue.

Keywords: mathematical model, repellent effect, dengue

Abstrak

Demam berdarah merupakan penyakit yang merupakan masalah kesehatan di daerah tropis dan subtropis. Ada 4 serotipe virus dengue, DEN1-DEN4 dan semua serotipe tersebut ditularkan melalui gigitan nyamuk *Aedes aegypti* betina. Perhatian besar para ahli kesehatan dunia adalah kemungkinan penyebaran DBD dan menjadi epidemi yang tidak terkendali. Sehingga penelitian ini bertujuan untuk dapat menekan kasus DBD. Yang kami gunakan adalah SIR-SI dengan menambahkan semua kelas manusia jangan atau gunakan repellent. Analisis dilakukan terhadap bilangan reproduksi dasar R_0 yang akan ditinjau kembali pada saat $R_0 < 1$ dan $R_0 > 1$. Selanjutnya untuk menggambarkan model tersebut dilakukan simulasi yang menghasilkan fakta bahwa semakin tinggi tingkat penggunaan repellent pada manusia akan mengurangi penyebaran DBD.

Kata kunci: model matematika, efek repellent, demam berdarah

INTRODUCTION

Dengue is a disease that is a health problem in the tropics and subtropics. There are 4 serotypes of dengue virus, DEN1-DEN4, all of these serotypes are transmitted through the bite of female *Aedes aegypti* mosquitoes. Female mosquitoes live on average for about 1 week, but some female mosquitoes live for ≥ 2 weeks. Humans and monkeys are strongly influenced by this dengue virus (Balasubramani, et. al., 2018). Dengue is strongly influenced by rainfall, temperature, urbanization, and distribution of *Aedes aegypti* mosquitoes (Guzman, et. al., 2016). Indonesia is a tropical country and is classified as an endemic category of dengue virus infection in Southeast Asia. The spread of dengue in Indonesia experiences a peak during the rainy season, which is from October to March.

Aedes aegypti mosquitoes are very domestic species and can smell prey through carbon dioxide levels (Gordo, et. al., 2018). In general, female *Aedes aegypti* mosquitoes bite during the day (09.00 to 10.00) and in the afternoon (16.00 to 17.00). Dengue infection occurs when someone is bitten by an infected mosquito. Dengue can also be divided into three separate phases: acute phase (fever), critical phase (plasma leakage) and recovery or reabsorption phase (Guzman, et. al., 2016). During a period of fever, between 2-10 days, there is viremia (virus in the blood). If the uninfected *Aedes Aegypti* mosquito bites an infected person at this viremic stage, the mosquito will become infected. Mosquitoes remain infective for life and can infect everyone they bite (Guzman, et. al., 2016).

Many researchers have worked to produce drugs that are suitable for treating dengue (Balasubramani, et. al., 2018). For most mosquito-borne diseases, there is no vaccine or special care and therefore (Colucci and Muller, 2018). The most effective way to overcome the threat of mosquitoes is through personal protection measures, including the use of insect repellent. The use of repellent has become one of the most efficient ways to prevent transmission of diseases and discomfort due to mosquito bites.

Repellant is one type of household pesticide that is used to protect the body from mosquito bites that contain levels of DEET. DEET (N, N-diethyl-meta-toluamide) is a synthetic chemical that was first used by the United States Department of Agriculture in 1946 to protect workers from mosquito-borne diseases (Dennis, et. al., 2018). DEET is a protector of the most effective and long-lasting mosquito bites and is currently commercially available (Zhu, et. al., 2018). DEET can damage the central nervous system of insects such as mosquitoes (Pelley, 2016). At a distance of 1 meter, DEET can reduce the attractiveness of mosquitoes by 60% (Rodriguez et all, 2017). Types of Repellent in Indonesia vary among others in the form of lotion, fuel, spray, and electricity. DEET (> 25%) provides protection for up to 10 hours against mosquitoes (Lupi, Hatz, and Schlagenhauf, 2013). However, AAP (American Academy of Pediatrics) recommends the safety of DEET levels of 10% -30% for children, but it is not recommended for infants under 2 months. In repellents that contain levels of DEET around 10% -15%, humans will avoid mosquito bites for 2-2.5 hours, but at levels of DEET about more than 15% of humans will avoid mosquito bites for 6 hours (Colucci and Muller, 2018).

Several studies are currently trying to develop various mathematical models of dengue. Is there one that discusses optimal control on the use of repellents for the dengue model (Dipo, Thomas, and Edy, 2013). Based on this background, we discussed the topic of dengue transmission. The model used is SIR-SI by adding that all human classes do not or use repellent and provide various model simulations.

METHOD

The method used in this study is the determination of the problem, problem formulation, literature study, and conclusions. The steps to be taken in this study include: (a) collecting facts related to dengue epidemics from relevant writings, (b) compiling supporting and complementary assumptions in preparing mathematical models, (c) forming mathematical models (d) an analysis of the model begins with finding the equilibrium point of the model and then check the stability of the equilibrium point, (e) the numerical simulation of the results of the analysis to provide an overview of the analysis, geometric, and (f) conclusion.

RESULTS AND DISCUSSIONS

Result

The facts collected from various sources include (1) dengue divided into three separate phases: acute phase (fever), critical phase (plasma leakage) and recovery or reabsorption phase (Guzman, et. al., 2016). (2) *Aedes aegypti* mosquitoes females that transmit the dengue virus (Woke, Ally, and Rosemberger, 1959). (3) Female *Aedes aegypti* mosquitoes, these mosquitoes need proteins from the blood to ripen their eggs because they need human blood (Woke, Ally, and Rosemberger, 1959). (4) *Aedes aegypti* mosquitoes are very domestic species and can smell prey through carbon dioxide levels (Gordo, et. al., 2018). (6) Humans and monkeys are strongly

influenced by this dengue virus (Balasubramani, et. al., 2018). (7) Female mosquitoes will lay eggs on the surface of the water with approximately 100 eggs in one egg (Gubler and Clark, 1995). (8) Infected female mosquitoes require bites many times to meet their blood needs (Gubler and Clark, 1995). (9) Most of the dengue sufferers in hospitals that experience death are children (Dipo, Thomas, and Edy, 2013). (10) No vaccinations are suitable for treating dengue (Balasubramani, et. al., 2018). (11) Repellents containing DEET are a powerful protector in repelling mosquitoes compared to other ingredients (Woke, Ally, and Rosemberger, 1959). (12) DEET can damage the central nervous system of insects such as mosquitoes (Pelley, 2016). (13) At a distance of 1 meter, DEET can reduce the attractiveness of mosquitoes by 60% (Woke, Ally, and Rosemberger, 1959). (14) Mosquitoes remain infective for life and can infect everyone they bite (Guzman, et. al., 2016).

Assumptions added in the preparation of mathematical models include (1) In an area observed only there is a human population and *Aedes Aegypti* mosquitoes with the proportion of male mosquitoes: female mosquitoes = 50:50, but assume that will bite humans only *Aedes Aegypti* female mosquitoes. (2) Assume *Aedes Aegypti* female mosquitoes only bite humans, between vulnerable mosquitoes and infected mosquitoes do not bite each other so there is no chance of a successful bite on the mosquito. (3) In the human population, all ages are assumed to be uniformly distributed. (4) The population of humans who use mosquito repellent lotion will be separated in special compartments that will not have any contact with mosquitoes at all. (5) Birth and death occur. (6) Changes in the increase in human population and constant mosquitoes are not influenced by environmental factors (per unit time). (7) Assume the use of lotions containing uniform DEET levels which are > 25% -30% with only one day use. (8) The use of lotion is applied to parts of the body that are vulnerable to being bitten by mosquitoes and in accordance with the instructions for using the lotion. (9) Every individual human being has the same opportunity to contract the dengue virus. (10) There is no death due to dengue virus. (11) Assume there is only one DEN-3 virus, so that individuals who have recovered will be immune to the virus. (12) It is assumed that in the mosquito population only consists of vulnerable mosquito populations and infected mosquito populations, whereas the fact that mosquitoes have perfect metamorphosis is ignored. (13) It is assumed that there are no mosquito compartments that have been cured for mosquito populations due to the relatively short age expectation of mosquitoes, around 14-30 days. (14) The existence of the DEN virus in the mosquito's body does not provide a health effect on infected mosquitoes. (15) The average individual bite of mosquitoes in humans per day is constant. (16) Natural deaths occur in all classes. (17) Death to an infected mosquito is only affected by natural death.

The mosquito population is divided into 2 classes namely S_v , I_v (Susceptible vector, Infected vector) and the human population is divided into 6 classes namely S_{hn} , S_{hr} , I_{hn} , I_{hr} , R_{hn} , R_{hr} (Susceptible human non repellent, Susceptible human with repellent, Infected human non repellent, Infected human with repellent, Recovery human non repellent, and Recovery human with repellent). Based on these classes, mathematical models are formed with variables and parameters in the mathematical model. Can be see in Table 1 and Table 2.

Table 1. Description of Variables

No	Variable	Definition	Unit
1	$N_h(t)$	Size of human population at time t	Human
2	$N_v(t)$	<i>Aedes Aegypti</i> mosquito population size at time t	Vector
3	$S_v(t)$	The number of <i>Aedes Aegypti</i> mosquitoes that are vulnerable to dengue at time t	Vector
4	$I_v(t)$	The number of <i>Aedes Aegypti</i> mosquitoes infected with dengue at time t	Vector

5	$S_{hn}(t)$	The number of people susceptible without the use of repellent at time t	Human
6	$S_{hr}(t)$	The number of people susceptible to use repellent at time t	Human
7	$I_{hn}(t)$	The number of people infected without the use of repellent at time t	Human
8	$I_{hr}(t)$	The number of people infected to use repellent at time t	Human
9	$R_{hn}(t)$	The number of people recovery without the use of repellent at time t	Human
10	R_{hr}	The number of people recovery to use repellent at time t	Human

Table 2. Parameter Description

No	Parameter	Definition	Unit
1	μ_h	The proportion of births assumed by human expectation is 65 years	Time ⁻¹
2	μ_v	The assumed proportion of births is equal to the proportion of natural deaths in the mosquito population	Time ⁻¹
3	b	The average bite of a mosquito in humans per time t	Time ⁻¹
4	β_v	Proportion of dengue virus transmission from humans to mosquitoes	-
5	β_h	Proportion of dengue virus transmission from mosquitoes to humans	-
6	α	The human proportion uses repellent per time t	Time ⁻¹
7	ϵ	The proportion of loss of repellent effectiveness in humans per time t	Time ⁻¹
8	γ_h	The proportion of humans recovered per time t	Time ⁻¹

The mathematical model formed is given to the System (1)

$$\begin{aligned}
 \frac{dShn}{dt} &= \mu_h Nh + \alpha S_{hr} - \left(\mu_h + \frac{b\beta_h I_v}{Nh} + \epsilon \right) Shn \\
 \frac{dShr}{dt} &= \epsilon Shn - (\mu_h + \alpha) Shr \\
 \frac{dIhn}{dt} &= \frac{b\beta_h I_v Shn}{Nh} + \alpha I_{hr} - (\mu_h + \gamma_h + \epsilon) Ihn \\
 \frac{dIhr}{dt} &= \epsilon Ihn - (\mu_h + \gamma_h + \alpha) I_{hr} \\
 \frac{dRhn}{dt} &= (Ihn + I_{hr})\gamma_h + \alpha R_{hr} - (\mu_h + \epsilon) R_{hn} \\
 (1) \quad \frac{dRhr}{dt} &= \epsilon R_{hn} - (\mu_h + \alpha) R_{hr} \\
 \frac{dSv}{dt} &= \mu_v Nv - \left(\mu_v + \frac{b\beta_v Ihn}{Nh} \right) Sv \\
 \frac{dIv}{dt} &= \frac{b\beta_v Ihn Sv}{Nh} - \mu_v Iv
 \end{aligned}$$

The population of humans and vector is Nh and Nv , to simplify the system of equation (1) by normalizing where the proportion of the number of individuals in each group can be expressed as $s_{hn} = \frac{Shn}{Nh}$, $s_{hr} = \frac{Shr}{Nh}$, $ih = \frac{Ihn}{Nh}$, $i_{hr} = \frac{I_{hr}}{Nh}$, $r_{hn} = \frac{R_{hn}}{Nh}$, $r_{hr} = \frac{R_{hr}}{Nh}$, $sv = \frac{Sv}{Nv}$, $iv = \frac{Iv}{Nv}$ the population has been normalized meaning $s_{hn} + s_{hr} + ih + i_{hr} + r_{hn} + r_{hr} = 1$ and $sv + iv = 1$ so that the system of new equations is obtained as follows.

$$\begin{aligned}
 \frac{dshn}{dt} &= \mu_h + \alpha s_{hr} - (\mu_h + pb\beta_h iv + \epsilon) shn \\
 \frac{dshr}{dt} &= \epsilon shn - (\mu_h + \alpha) shr
 \end{aligned}$$

$$\begin{aligned}
\frac{dihn}{dt} &= pb\beta_h ivshn + \alpha i hr - (\mu_h + \gamma_h + \epsilon) i hn \\
\frac{dihr}{dt} &= \epsilon i hn - (\mu_h + \gamma_h + \alpha) i hr \\
\frac{drhn}{dt} &= (ihn + i hr) \gamma_h + \alpha r hr - (\mu_h + \epsilon) r hn \\
(2) \\
\frac{drhr}{dt} &= \epsilon r hn - (\mu_h + \alpha) r hr \\
\frac{dsv}{dt} &= \mu_v - (\mu_v + b\beta_v i hn) sv \\
\frac{div}{dt} &= b\beta_v i hns v - \mu_v iv
\end{aligned}$$

From System (2) the equilibrium point will be searched by making zero right segments so that the System (3) is obtained. Suppose $R_0 = \sqrt{\frac{N_v b^2 \beta_h \beta_v}{N_h \mu_v (\gamma_h + \mu_h)}}$, from System (2) based on the value of R_0 obtained:

- If $R_0 < 1$ then System (2) only has 1 disease free equilibrium point and asymptotic stable.
- If $R_0 > 1$ then System (2) has 1 endemic equilibrium point and asymptotic stable.

Discussions

The simulation is given to give a geometric picture related to the results of the analysis that has been done. The simulation is carried out by giving values for each parameter according to the conditions of R_0 with the theorem given above. Parameter values are given in Table 3.

Table 3. Parameter Value

No	Parameter	Value	Source
1	μ_h	$\frac{1}{65 \times 365} = 0.000042$	Prasetyo, Saragih, Handayani, 2020
2	μ_v	$\frac{1}{30} = 0.03$	Prasetyo, Saragih, Handayani, 2020
3	b	1	Prasetyo, Saragih, Handayani, 2020
4	β_v	$0 \leq \beta_v \leq 1$	Estimate
5	β_h	$0 \leq \beta_h \leq 1$	Estimate
6	α	0.01	Assumption
7	ϵ	0.001	Prasetyo, Saragih, Handayani, 2020
8	γ_h	0.3	Prasetyo, Saragih, Handayani, 2020

The value of $\mu_h = 0.000042$ means that on average there are 42 individuals who die without the influence of dengue after 1000000 days. The value of $\mu_v = 0.03$ means that on average there are 3 mosquitoes that die after 100 days. $b = 1$ means that the average mosquito bite is 1 time per day, $\beta_h = 0.1$ means that there is 1 individual human being infected with dengue fever if there are 10 infected mosquitoes bite human, $\beta_v = 0.1$ means that there is 1 vulnerable mosquito that becomes infected if biting 10 human beings infected with dengue fever, $\alpha = 0.01$ means that there is 1 individual human who loses repellent effectiveness from 100 people using repellent per day, $\epsilon = 0.001$ means that there is 1 individual human who uses 1000 people per day, and $\gamma_h = 0.3$ meaning that there are 3 human individuals who recover after 10 days.

This study analyzed the dynamics of the spread of dengue fever in two different conditions, namely when $R_0 < 1$ and when R_0 . To analyze the mathematical model of the spread of dengue fever is done by varying the values of β_v , and β_h . Suppose $R_0 = \frac{N_v b^2 \beta_h \beta_v}{N_h \mu_v (\gamma_h + \mu_h)}$, so you can find the limit values β_v and β_h . Assuming $R_0 = 1$ obtained a boundary value $\beta_v \beta_h = 0.0585$.

Simulation For $R_0 < 1$

Analysis of the mathematical model of the spread of dengue fever with the effect of using repellent on humans is done by varying the value of β_h, β_v so that $R_0 < 1$ which can be seen in Table 4.

Table 4. Value $R_0 < 1$ with variation of β_v and β_h

β_v	β_h	R_0
0.1	0.1	0.41348
0.2	0.15	0.71617
0.3	0.18	0.96085
0.08	0.05	0.2615

After analyzing the results presented in Figure 1.

Figure 1. Illustrated the population dynamics of disease-free dengue mathematical models. Pictures (a), (b), and (g) are positive and images (c), (d), (e), (f), (h) are worth 0 because they are disease free. Each picture above goes to each equilibrium point value which is done by substituting the parameter value in theorem 2.

In Figure 1 (a), (b), (c), (d), (e), (f), (g), and (h) by varying the parameter values β_v and β_h so that $R_0 < 1$ shows that the entire class towards one point, namely P_0 = disease free equilibrium points (0.09436; 0.9056; 0; 0; 0; 0; 1; 0) and P_0 stable local asymptotic.

From Figure 1 (a) it can be seen that the size of the population of non-repellent susceptible ($sh_n(t)$) has decreased, this is caused by humans using repellent. After that there is no change or constant at the point 0.09436 at certain t and $sh_n(t)$ local asymptotic stable. From Figure 1 (b) it can be seen that the population size of susceptible human with use repellent ($shr(t)$) has increased, this is caused by the addition of human populations that previously did not use repellent. After that there is no change or constant at 0.9056 at certain t and $shr(t)$ stabilizes local asymptotic. From Figure 1 (c) it can be seen that the size of infected human non-repellent population ($ihn(t)$) in the initial conditions has increased, this is due to the addition of human populations who become infected with dengue and drop out from humans infected with repellent. After that it decreases due to the reduction of infected human populations using repellent and healing, natural death, and then population dynamics do not change or are constant at point 0 at certain t and $ihn(t)$ asymptotically stable locally. From Figure 1 (d) it can be seen that the size of the population infected with human with use repellent ($ihr(t)$) in the initial conditions has increased, this is due to the addition of infected human populations using repellent. After that it decreases due to dropping out of repellent use and experiencing recovery, natural death, and then population dynamics do not change or are constant at point 0 at certain t and $ihn(t)$ stable local asymptotic. From Figure 1 (e) it can be seen that the size of the human non-repellent recovery population ($rhn(t)$) in the initial conditions has increased, this is due to the addition of populations of infected humans who recovered, and drop out of recovered humans using repellent. After that it decreases because humans use repellent, natural death, and then population dynamics do not change or are constant at point 0 at certain t and $rhn(t)$ stable local asymptotic. From Figure 1 (f) it can be seen that the size of the population recovery human with use repellent ($rhr(t)$) in the initial conditions has increased, this is due to the addition of a population of cured humans who use repellent. After that it decreases because humans use repellent to drop out using repellent, natural death and then population dynamics do not change or are constant at point 0 at certain t and $rhr(t)$ stable local asymptotic. From Figure 1 (g) it can be seen that the size of the susceptible vector population ($sv(t)$) in the initial conditions has increased, this is caused by birth in mosquitoes. After that there is no change or constant at point 1 at certain t and $sv(t)$ stable asymptotic locally. From Figure 1 (h) it can be seen that the size of the infected vector population ($iv(t)$) in the condition has

decreased, this is caused by natural deaths in mosquitoes. After that there is no change or constant at point 0 at certain t and $iv(t)$ stabilizes local asymptotic.

Simulation For $R_0 > 1$

Analysis of the mathematical model of the spread of dengue fever with the effect of using repellent on humans is done by varying the value of β_h, β_v so that $R_0 > 1$ which can be seen in Table 5.

Table 4. Value $R_0 > 1$ with variation of β_v and β_h

β_v	β_h	R_0
0.3	0.2	1.01283
0.4	0.3	1.43235
0.7	0.5	2.4462
0.6	0.3	1.75427

After analyzing the results presented in Figure 2.

Figure 2. Illustrated the population dynamics of the dengue mathematical model that is endemic. Figures (a), (b), (c), (d), (e), (f), (g), (h) are not worth 0 and all are positive. Each picture above goes to each equilibrium point value which is done by substituting the parameter value in theorem 2.

In Figure 2 (a), (b), (c), (d), (e), (f), (g), and (h) by varying the parameter values β_v and β_h so that $R_0 > 1$ shows that P1 stable local asymptotic.

From Figure 2 (a) it can be seen that the size of the population of non-repellent susceptible (shn (t)) has decreased, this is caused by humans using repellent. After that there is no change or constant at the point shn(t)=(0.0924;0.08259;0.07424;0.70663) at certain t and shn (t) local asymptotic stable. From Figure 2 (b) it can be seen that the population size of susceptible human with use repellent (shr (t)) has increased, this is caused by the addition of human populations that previously did not use repellent. After that there is no change or constant at shr(t)=(0.8871;0.7926;0.71253;0.67815) at certain t and shr (t) stabilizes local asymptotic. From Figure 2 (c) it can be seen that the size of infected human non-repellent population (ihn (t)) in the initial conditions has increased, this is due to the addition of human populations who become infected with dengue and drop out from humans infected with repellent. After that it decreases due to the reduction of infected human populations using repellent and healing, natural death, and then population dynamics do not change or are constant at point ihn (t) = (0.000107;0.0000655;0.000112;0.000132) at certain t and ihn (t) asymptotically stable locally. From Figure 2 (d) it can be seen that the size of the population infected with human with use repellent (ihr (t)) in the initial conditions has increased, this is due to the addition of infected human populations using repellent. After that it decreases due to dropping out of repellent use and experiencing recovery, natural death, and then population dynamics do not change or are constant at point ihr (t) = (0.000001508; 0.00000923;0.0000157;0.000185) at certain t and ihr (t) stable local asymptotic. From Figure 2 (e) it can be seen that the size of the human non-repellent recovery population (rh n (t)) in the initial conditions has increased, this is due to the addition of populations of infected humans who recovered, and drop out of recovered humans using repellent. After that it decreases because humans use repellent, natural death, and then population dynamics do not change or are constant at point rhn(t)=(0.00912;0.01176;0.020109;0.02368) at certain t and rhn (t) stable local asymptotic. From Figure 2 (f) it can be seen that the size of the population recovery human with use repellent (rhr (t)) in the initial conditions has increased, this is due to the addition of a population of cured humans who use repellent. After that it decreases because humans use repellent to drop out using repellent, natural death and then population dynamics do not change or are constant at point rhr(t)=(0.01845;0.112915;0.192985;0.22734) at certain t and rhr (t) stable local asymptotic. From Figure 2 (g) it can be seen that the size of the susceptible vector population (sv (t)) in the initial conditions has increased, this is caused by birth in mosquitoes. After that there is no change or constant at point sv(t)=(0.99969;0.99803;0.99646;0.9956) at certain t and sv (t) stable asymptotic locally. From Figure 2 (h) it can be seen that the size of the infected vector population (iv (t)) in the condition has decreased, this is caused by natural deaths in mosquitoes. After that there is no change or constant at point at iv(t)=(0.000303;0.001963;0.0035366;0.004377) certain t and iv (t) stabilizes local asymptotic.

To find out the repellent effect on dengue transmission, an image from a numerical simulation will be analyzed for variations in the value of ε at class infected human and vector shown in figure 3.

Figure 3. In Figure 3, it can be seen that the greater the value of epsilon, the population dynamics will reach the equilibrium point faster. This means that the higher the level of repellent use in humans will further suppress dengue cases in human infected and vector infected

CONCLUSION

Dengue is a disease that is a health problem in the tropics and subtropics. There are 4 serotypes of dengue virus, DEN1-DEN4 and all of these serotypes are transmitted through the bite of female *Aedes aegypti* mosquitoes. The big concern of the world health experts is the possibility of spreading dengue and becoming an uncontrolled epidemic. The analysis conducted basic reproductive numbers R_0 which will be reviewed when $R_0 < 1$ and $R_0 > 1$. Furthermore, to illustrate the model was carried out simulation which resulted in the fact that the higher the level of repellent use in humans would reduce the spread of dengue.

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