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THE EFFECT OF LONG-LASTING INSECTICIDAL NETS ON THE DYNAMICS OF MALARIA SPREAD IN INDONESIA

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ABSTRACT

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Malaria is an infectious disease that can lead to death. Deaths from malaria globally have increased in 2020. So the spread of this disease is still a serious problem for society. The mathematical model used is the SIR-SI model, assuming that recovered individuals can be re-infected with malaria. Analysis was carried out on the effectiveness parameters of long-lasting insecticidal nets to determine their effect on the dynamics of the spread of malaria. The sensitivity analysis results showed that changes in the parameters of the effectiveness of long-lasting insecticidal nets had an inverse effect on the rate of spread of malaria. These results follow numerical simulations conducted using malaria case data in Indonesia (some assumptions). Thus, efforts can be made to suppress the spread of malaria by increasing the effectiveness of long-lasting insecticidal nets.

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1. INTRODUCTION

Malaria is an infectious disease caused by protozoa of the genus Plasmodium. Female Anopheles mosquitoes transmit this disease. When an Anopheles mosquito bites a human infected with malaria, the mosquito will suck Plasmodium along with blood. The malaria parasite then reproduces in the body of the Anopheles mosquito. When it bites another human not infected with malaria, the malaria parasite enters the victim's body along with the mosquito's saliva [1]. The initial symptoms resemble influenza [2], but if left untreated, complications can occur, leading to death [3]. WHO records that deaths from malaria in 2020 increased by 69 thousand from the previous year [4]. So that the spread of this disease needs to be a concern of the government, and malaria case-control programs need to be encouraged so that the number of malaria cases or deaths from malaria does not increase in the following years.

Malaria research has been studied in various scientific fields, one of which is in mathematics, namely by using a mathematical model. A mathematical model was constructed to see the dynamics of the spread of malaria. The article [5] examines a model of the spread of malaria, which consists of the SIR compartment for the human population and the SI compartment for the mosquito population. The model considers vector control as using long-lasting insecticide nets, namely insecticide-treated mosquito nets, which are effective for at least three years [6]. Long-lasting insecticidal nets not only prevent mosquitoes from biting humans but can also kill mosquitoes attached to mosquito nets because mosquito nets are equipped with insecticides that are harmless to humans [7]. However, this model assumes that recovered individuals get permanent immunity, so they cannot be re-infected. At the same time, recovered individuals can be re-infected with malaria [8].

Therefore in this article, the authors modified the model [5] by assuming that recovered individuals could be re-infected with malaria. Furthermore, the model will be simulated and interpreted to determine the effect of parameters of long-lasting insecticidal nets on population dynamics.

2. RESEARCH METHODS

In this section, the model is formed by modifying the model [5] with the additional assumption that recovered individuals can be re-infected with malaria. In the model, there are two populations, namely the human population and the mosquito population, with the human population divided into three, namely susceptible, infected, and recovered. The mosquito population is divided into two populations, susceptible and infected because the mosquito distribution period cycle ends in death (never recovering from infection).

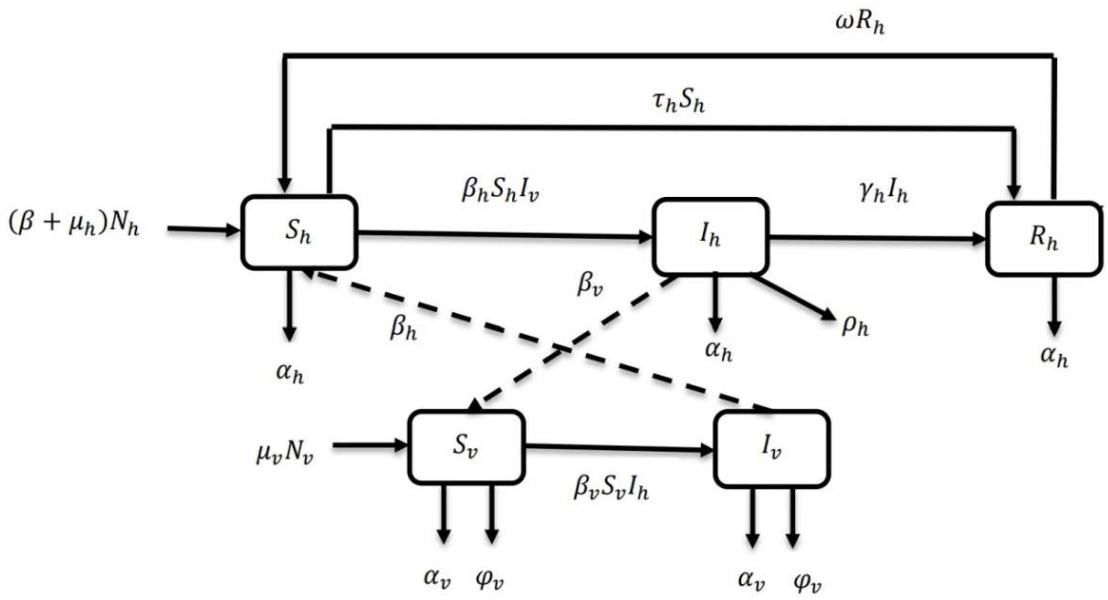

Figure 1. Compartment diagram of disease spread

Based on Figure 2, the mathematical model formed:

$$\frac{dS_h}{dt} = (\beta + \mu_h)N_h - \beta_h S_h I_v - \alpha_h S_h - \tau_h S_h + \omega R_h \quad (1)$$
$$\frac{dI_h}{dt} = \beta_h S_h I_v - \rho_h I_h - \gamma_h I_h - \alpha_h I_h \quad (2)$$
$$\frac{dR_h}{dt} = \gamma_h I_h - \alpha_h R_h + \tau_h S_h - \omega R_h \quad (3)$$
$$\frac{dS_v}{dt} = \mu_v N_v - \beta_v S_v I_h - \alpha_v S_v - \varphi_v S_v \quad (4)$$
$$\frac{dI_v}{dt} = \beta_v S_v I_h - \alpha_v I_v - \varphi_v I_v \quad (5)$$

with all parameters having positive values, and parameter definitions are presented in **Table 1**. For example, the total population of humans and mosquitoes is expressed by N_h and N_v, respectively, then $N_h = S_h + I_h + R_h$ and $N_v = S_v + I_v$.

Table 1. Description of Parameters

Parameter	Description	Dimension
μ_h	Human birth rate	1/time
β	Human migration rate	1/time
β_h	The ontact rate between susceptible humans and infected mosquitoes with a chance of being infected is 1	1/(mosquito × time)
γ_h	Human recovery rate	1/time
ω	The rate at which people recover from immunity	1/time
α_h	The natural death rate of human	1/time
τ_h	Effectiveness of the malaria vaccine	1/time
ρ_h	Death rate from disease in human	1/time
μ_v	Mosquito birth rate	1/time
β_v	The contact rate between susceptible mosquitoes and infected humans with a chance of being infected is 1	1/(humans × time)
α_v	The natural death rate of mosquito	1/time
φ_v	Effectiveness of the long-lasting insecticidal nets	1/time

Before the analysis, a simplification of the model with nondimensional will be carried out [9]. So that dimensionless variables are defined as follows:

$$s_h = \frac{S_h}{N_h}, i_h = \frac{I_h}{N_h}, r_h = \frac{R_h}{N_h}, s_v = \frac{S_v}{N_v}, i_v = \frac{I_v}{N_v}, t^* = t\,\mu_h.$$

If these variables are substituted into **Equation (1)** – **Equation (5)**, a mathematical model is obtained, which will then be used for analysis (the role of the notation t^* is replaced with t).

$$\frac{ds_h}{dt} = 1 + \xi - Bs_h i_v - (\alpha + \sigma)s_h + \eta(1 - s_h - i_h) \quad (6)$$
$$\frac{di_h}{dt} = Bs_h i_v - (\alpha + \gamma)i_h \quad (7)$$
$$\frac{di_v}{dt} = \frac{1}{\epsilon}(\nu(1 - i_v)i_h - \delta i_v - \theta i_v) \quad (8)$$

with the constants $\xi, B, \alpha, \sigma, \eta, \gamma, \epsilon, \nu, \delta, \theta$ having positive values which are expressed as follows:

$$\xi = \frac{\beta}{\mu_h}, B = \frac{\beta_h N_v}{\mu_h}, \alpha = \frac{\alpha_h}{\mu_h}, \sigma = \frac{\tau_h}{\mu_h}, \eta = \frac{\omega}{\mu_h}, \gamma = \frac{\rho_h + \gamma_h}{\mu_h}, \epsilon = \frac{\mu_v}{\mu_h}, \nu = \frac{\beta_v N_h}{\mu_v}, \delta = \frac{\alpha_v}{\mu_v}, \theta = \frac{\varphi_v}{\mu_v}.$$

3. RESULTS AND DISCUSSION

3.1 Fixed Point Stability Analysis

From **Equation (6)** – **Equation (8)**, two fixed points are obtained, namely the disease-free and endemic fixed points. The stability of the two points is determined based on the basic reproduction number. This number can indicate that a disease is spreading in the population or experiencing extinction **[10]**. The disease-free fixed point and endemic fixed point are respectively obtained as follows:

$$E_0(s_h, i_h, i_v) = \left(\frac{1+\eta+\xi}{\alpha+\eta+\sigma}, 0, 0\right),$$

and

$$E_1(s_h, i_h, i_v) = (s_h^*, i_h^*, i_v^*)$$

with

$$s_h^* = \frac{(\alpha+\gamma)(\delta\eta+\eta\theta+\alpha(\delta+\theta)+\gamma(\delta+\theta)+\nu+\eta\nu+\nu\xi)}{\nu(B(\alpha+\gamma+\eta)+(\alpha+\gamma)(\alpha+\eta+\sigma))},$$
$$i_h^* = -\frac{\alpha^2(\delta+\theta)-B\nu(1+\eta+\xi)+\gamma(\delta+\theta)(\eta+\sigma)+\alpha(\delta+\theta)(\gamma+\eta+\sigma)}{\nu(B(\alpha+\gamma+\eta)+(\alpha+\gamma)(\alpha+\eta+\sigma))},$$
$$i_v^* = -\frac{\alpha^2(\delta+\theta)-B\nu(1+\eta+\xi)+\gamma(\delta+\theta)(\eta+\sigma)+\alpha(\delta+\theta)(\gamma+\eta+\sigma)}{B(\delta\eta+\eta\theta+\alpha(\delta+\theta)+\gamma(\delta+\theta)+\nu+\eta\nu+\nu\xi)}.$$

Furthermore, the basic reproduction number can be determined using the next-generation matrix, namely FV^{-1} **[11]**. Based on **Equations (7)** – **Equation (8)**, it is obtained matrix

$$F = \begin{pmatrix} 0 & B\left(\frac{1+\eta+\xi}{\alpha+\eta+\sigma}\right) \\ \frac{\nu}{\epsilon} & 0 \end{pmatrix}, \qquad V = \begin{pmatrix} \alpha+\gamma & 0 \\ 0 & \frac{\delta+\theta}{\epsilon} \end{pmatrix}.$$

The largest non-negative eigenvalue of the next-generation matrix is called the basic reproduction number, so it is obtained

$$R_0 = \sqrt{\frac{B\nu(1+\eta+\xi)}{(\alpha+\gamma)(\delta+\theta)(\alpha+\eta+\sigma)}}.$$

The following section will prove the fixed point stability theorem for the two fixed points obtained from the model.

Theorem 1. The disease-free fixed point from **Equations (6)** – **Equation (8)** is locally asymptotically stable if $\boldsymbol{\mathcal{R}_0 < 1}$ and unstable if $\boldsymbol{\mathcal{R}_0 > 1}$.

Proof. Local stability analysis of point E_0 can be proven using the Jacobian matrix. Based on **Equation (6)** – **Equation (8)**, the Jacobian matrix at E_0 is:

$$J_0 = \begin{bmatrix} -\alpha-\eta-\sigma & -\eta & -\frac{B(1+\eta+\xi)}{\alpha+\eta+\sigma} \\ 0 & -\alpha-\gamma & \frac{B(1+\eta+\xi)}{\alpha+\eta+\sigma} \\ 0 & \frac{\nu}{\varepsilon} & \frac{-\delta-\theta}{\varepsilon} \end{bmatrix}.$$

The classification of fixed point stability is based on the eigenvalues (λ) typical of the Jacobian matrix. The eigenvalues of the Jacobian matrix J_0 are obtained from the characteristic equation $|\lambda \boldsymbol{I} - J_0| = 0$ so that

$$(\lambda+\alpha+\eta+\sigma)\left[\lambda^2+\left(k+\frac{\delta+\theta}{\varepsilon}\right)\lambda+\frac{k(\delta+\theta)}{\epsilon}(1-\mathcal{R}_0^2)\right]=0, \tag{9}$$

with $k=\alpha+\gamma$. Based on **Equation (9)**, three eigenvalues are obtained, namely:

$$\lambda_1=-\alpha-\eta-\sigma$$
$$\lambda_2=\frac{-\left(k+\frac{\delta+\theta}{\varepsilon}\right)-\sqrt{\left(k+\frac{\delta+\theta}{\varepsilon}\right)^2-4\frac{k(\delta+\theta)}{\epsilon}(1-\mathcal{R}_0^2)}}{2}$$
$$\lambda_3=\frac{-\left(k+\frac{\delta+\theta}{\epsilon}\right)+\sqrt{\left(k+\frac{\delta+\theta}{\varepsilon}\right)^2-4\frac{k(\delta+\theta)}{\epsilon}(1-\mathcal{R}_0^2)}}{2}.$$

The values of λ_1 and λ_2 are negative for all $\mathcal{R}_0$ values, while the value of λ_3 depends on $\mathcal{R}_0$. If $\mathcal{R}_0<1$, then λ_3 is negative so that point E_0 is locally asymptotically stable. Meanwhile, if $\mathcal{R}_0>1$, then λ_3 is positive; this shows that point E_0 is unstable because there is one positive eigenvalue. ■

Theorem 2. The endemic fixed point in **Equations (6)** – **Equation (8)** is locally asymptotically stable if and only if $\boldsymbol{\mathcal{R}_0>1}$.

Proof. The proof uses the Castillo-Chaves and Song Theorem **[12]**. Suppose B is chosen as the bifurcation parameter and $x_1=s_h; x_2=i_h; x_3=i_v$. When $\mathcal{R}_0=1$ is substituted for J_0, three eigenvalues are obtained, namely $\lambda_1=-\alpha-\eta-\sigma, \lambda_2=-\left(\alpha+\gamma+\frac{\delta+\theta}{\varepsilon}\right)$, and $\lambda_3=0$. Thus, the first assumption is fulfilled; namely, it has one simple zero eigenvalue, and the other is a negative real value.

Then, the J_0 matrix has one right eigenvector u and one left eigenvector v, corresponding to zero eigenvalues. The right eigenvector and left eigenvector are obtained as follows.

$$u=\begin{bmatrix}-\left(\frac{\eta(\delta+\theta)(\alpha+\eta+\sigma)+B\nu(1+\eta+\xi)}{\nu(\alpha+\eta+\sigma)^2}\right)u_3\\ \frac{\delta+\theta}{\nu}u_3\\ u_3>0\end{bmatrix},\quad v=\begin{bmatrix}0\\ \frac{\nu}{(\alpha+\gamma)\varepsilon}v_3\\ v_3>0\end{bmatrix}.$$

Furthermore, the values of a and b are obtained as follows.

$$\begin{aligned}a&=\sum_{k,i,j=1}^{3}v_k u_i u_j\frac{\partial^2 f_k(E_0,0)}{\partial x_i\partial x_j}\\ &=v_2u_1u_3\frac{\partial^2 f_2(E_0,0)}{\partial x_1\partial x_3}+v_3u_2u_3\frac{\partial^2 f_3(E_0,0)}{\partial x_2\partial x_3}\\ &=v_2u_1u_3B+v_3u_2u_3\left(-\frac{\nu}{\epsilon}\right)<0\end{aligned}$$

and

$$\begin{aligned}b&=\sum_{k,i,j=1}^{3}v_k u_i\frac{\partial^2 f_k(E_0,0)}{\partial x_i\partial B}\\ &=v_2u_3\frac{\partial^2 f_2(E_0,0)}{\partial x_3\partial B}\\ &=v_2u_3\left(\frac{1+\eta+\xi}{\alpha+\eta+\sigma}\right)>0.\end{aligned}$$

The values a and b obtained correspond to one Castillo-Chaves and Song Theorem case. Consequently, when $\mathcal{R}_0$ changes from $\mathcal{R}_0<1$ to $\mathcal{R}_0>1$, the unstable E_1 endemic fixed point changes from negative to positive and is locally asymptotically stable. So, it is proven that if $\mathcal{R}_0>1$, then the endemic fixed point E_1 is locally asymptotic. ■

Based on the two theorems above, the stability of the fixed point depends on the basic reproduction number. The basic reproduction number depends on several parameters, so changes in the value of specific parameters will affect the value of $\mathcal{R}_0$. However, each parameter has a different influence. The magnitude of the influence of parameters on changes in the value of $\mathcal{R}_0$ can be seen from the parameter sensitivity index values.

3.2 Sensitivity Analysis

The sensitivity analysis carried out in this study aims to see the effect of changes in the effectiveness parameters of long-lasting insecticidal nets on the basic reproduction number ($\mathcal{R}_0$). This analysis needs to be carried out because the basic reproduction number is a benchmark in predicting whether a disease will spread or not in a population. The sensitivity index measures sensitivity analysis [13]. The following is the sensitivity index for the effectiveness parameter of long-lasting insecticidal nets.

$$\Upsilon_\theta^{\mathcal{R}_0} = \frac{\partial \mathcal{R}_0}{\partial \theta} \times \frac{\theta}{\mathcal{R}_0} = -\frac{\theta}{2(\delta + \theta)} < 0$$

The above equation is negative, meaning that there will be a decrease in the value of $\mathcal{R}_0$ if the value of parameter θ is increased with the value of another parameter with a fixed value, and vice versa. This can be explained through the following simulation.

3.3 Numerical Simulation

In this section a numerical simulation will be carried out to determine the effect of the effectiveness of long-lasting insecticidal nets on the dynamics of the spread of malaria. A simulation will be carried out by changing the value of the parameter θ because this parameter depends on the parameter of the effectiveness of long-lasting insecticidal nets (φ_v). The simulation was carried out using Mathematica 11.0 software.

In this case, it will be shown that there will be a decrease in the value of $\mathcal{R}_0$ if the value of the parameter θ is increased by the value of another parameter having a fixed value. The simulation was carried out with the parameter values used, which are presented in **Table 2** assuming initial values, namely $s_{h0} = 0{,}9$; $i_{h0} = 0{,}1$; and $i_{v0} = 0{,}1$.

Table 2. Parameter Values in Numerical Simulation

Parameter	Value	Data Source
ξ	6,25	[14]
B	12	[15]
α	0,37	[16]
σ	16,9	[17]
η	1	Assumed
γ	2,34	[18], [19]
ϵ	0,7	[15]
ν	10	[15]
δ	1	Assumed
θ	10,71	[20]

Table 3. The Effect of Changing the Parameter Value θ on the $\mathcal{R}_0$ Value

Parameter Value θ	$\mathcal{R}_0$ Value
10,71	1,307
15	1,118
20	0,976

The following is a picture of the solution field, which describes the dynamics of each population due to changes in the value of θ, with changes in the value of θ shown in **Table 3**.

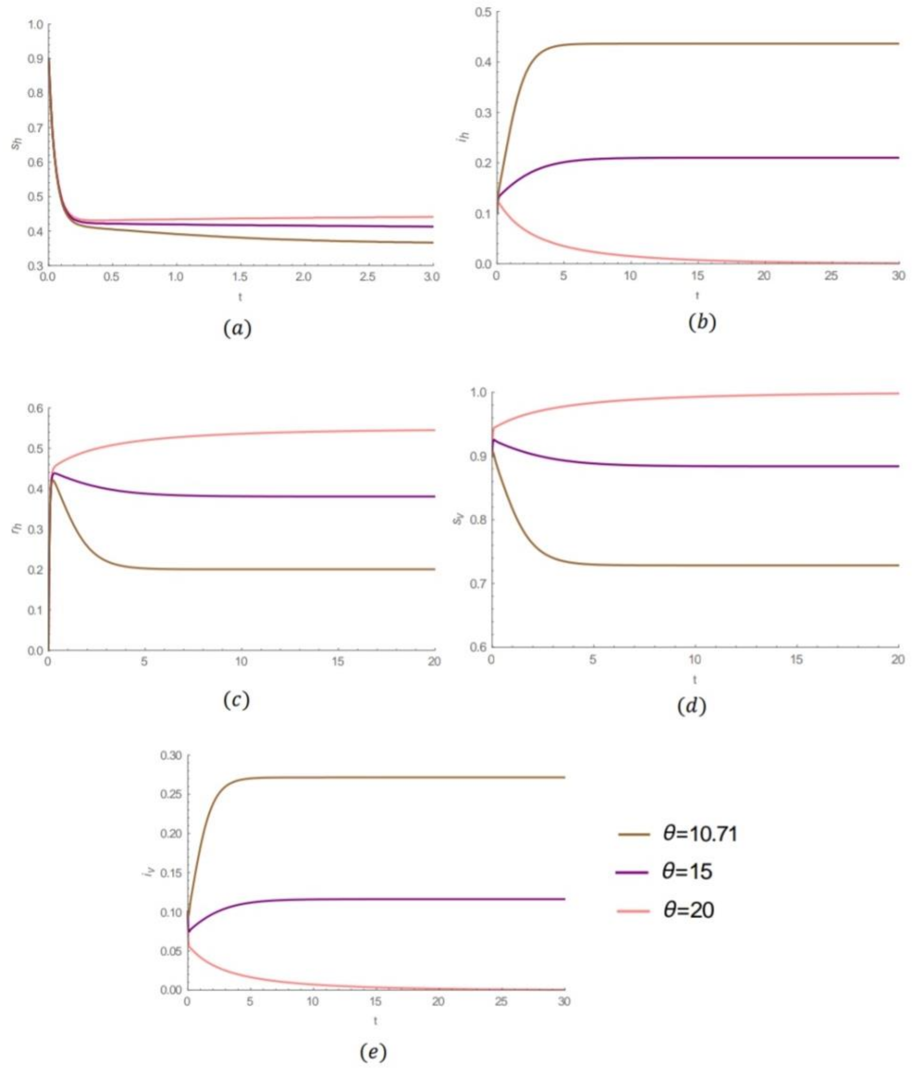

Figure 2. The dynamics of population proportions in (a) susceptible human, (b) infected human, (c) recovered human, (d) susceptible mosquito, and (e) infected mosquito

Figure 2 shows that changes in the value of θ affect the dynamics of each population. Figure 2e shows that there is a decrease in the proportion of the infected mosquito population because more and more mosquitoes die due to the use of long-lasting insecticidal nets and even experience extinction when $\theta = 20$ so that the remaining population of mosquitoes is susceptible, as can be seen from Figure 2d. The decrease in infected mosquitoes can affect interactions with humans, which can cause humans to become infected. As a result, the proportion of the infected human population decreases and even experiences extinction when $\theta = 20$, illustrated in Figure 2b, so the remaining susceptible and recovered humans in the population are shown in **Figures 2** (a) and **Equation 2** (c), respectively.

The numerical simulation results show that if the value of θ is enlarged, the proportion of infected human populations and infected mosquitoes decreases. Because the value of θ is directly proportional to the effectiveness of mosquito nets, an increase in the value of φ_v can reduce the proportion of infected human populations and infected mosquitoes and even become extinct.

4. CONCLUSIONS

a) Malaria still needs to be addressed in people's lives because deaths from malaria have increased globally in 2020. Research on malaria in the field of mathematics is by using a mathematical model. In this article, the model used is the SIR-SI model, with the possibility that recovered individuals could become infected again.

b) The analysis results show that in the model, there are two fixed points, namely the disease-free fixed point and the endemic fixed point, whose stability depends on the basic reproduction number. Numerical simulations show that the rate of spread of malaria will decrease or even become extinct within a certain period if the effectiveness of the long-lasting insecticidal net is increased. This is because the sensitivity index for the effectiveness parameter of long-lasting insecticidal nets is negative, which means that changes in this parameter have an inverse effect on changes in the basic reproduction number.

c) Therefore, efforts can be made to minimize malaria outbreaks caused by human populations and infected mosquitoes by increasing the effectiveness of long-lasting insecticidal nets, such as properly using and caring for mosquito nets.

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REFERENCES

[1] A. Sabiq and J. Fitriany, "Malaria," *J. Averrous*, vol. 4, no. 2, pp. 1–20, 2018, doi: 10.29103/averrous.v4i2.1039.
[2] N. Hamidah, Fatmawati, and U. D. Purwati, "Analisis model matematika penyebaran koinfeksi malaria-tifus," Surabaya: Universitas Airlangga, 2017, pp. 87–96.
[3] J. S. Sihite, L. Desi, F. A. Sihombing, S. J. Zebua, and S. Zai, "Pemanfaatan kelambu sebagai upaya pencegahan malaria pada ibu hamil tahun 2021," *Inst. Comput. Sci.*, vol. 4, no. 2, pp. 179–188, 2021.
[4] World Health Organization, *World Malaria Report 2021*. Geneva: World Health Organization, 2021.
[5] E. Aprianti, Jaharuddin, and E. H. Nugrahani, "The effect of susceptible immigrants in a system dynamic on the spread of malaria in Indonesia," *JTAM*, vol. 6, no. 3, pp. 777–788, 2022, doi: https://doi.org/10.31764/jtam.v6i3.8630.
[6] N. Rahayu, S. Sulasmi, and Y. Suryatinah, "Efektivitas Aplikasi Kelambu Berinsektisida (Long Lasting Insecticides Net) dalam Program Pengendalian Vektor Daerah Endemis Malaria di Kalimantan Selatan," Balai Litbang P2B2 Tanah Bumbu, Kalimantan Selatan, 2016.
[7] A. T. Saputra and Rizky, "Waspada! bahaya nyamuk Anopheles," *Provinsi Kepulauan Bangka Belitung*, 2014. https://serumpun.babelprov.go.id/waspada-bahaya-nyamuk-anopheles (accessed Sep. 05, 2022).
[8] F. H. Harsono, "Waspada serangan malaria yang timbulkan kekambuhan," *liputan6.com*, 2019. https://www.liputan6.com/health/read/3952046/waspada-serangan-malaria-yang-timbulkan-kekambuhan (accessed Nov. 27, 2022).
[9] S. H. Strogatz, *Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering*, 2nd ed. Boulder, CO: Westview Pr, 2015.
[10] J. Giesecke, *Modern infectious disease epidemiology*, 3rd ed. Boca Raton, FL: CRC Pr, 2017.
[11] P. van den Driessche and J. Watmough, "Reproduction numbers and sub-threshold endemic equilibria for compartmental models of disease transmission," *Math. Biosci.*, vol. 180, no. 1–2, pp. 29–48, Nov. 2002, doi: 10.1016/S0025-5564(02)00108-6.
[12] C. Castillo-Chavez and B. Song, "Dynamical models of tuberculosis and their applications," *Math. Biosci. Eng.*, vol. 1, no. 2, pp. 361–404, 2004, doi: 10.3934/mbe.2004.1.361.
[13] N. Chitnis, J. M. Hyman, and J. M. Cushing, "Determining Important Parameters in the Spread of Malaria Through the Sensitivity Analysis of a Mathematical Model," *Bull. Math. Biol.*, vol. 70, no. 5, pp. 1272–1296, Jul. 2008, doi: 10.1007/s11538-008-9299-0.
[14] Badan Pusat Statistik, *Profil Migran Hasil Survei Sosial Ekonomi Nasional 2019*. Jakarta: Badan Pusat Statistik, 2020.
[15] A. G. Wedajo, B. K. Bole, and P. R. Koya, "The impact of susceptible human immigrants on the spread and dynamics of malaria transmission," *Am. J. Appl. Math.*, vol. 6, no. 3, pp. 117–127, 2018, doi: 10.11648/j.ajam.20180603.13.
[16] World Bank, "Indonesia | Data," *World Bank*, 2019. https://data.worldbank.org/country/indonesia (accessed Nov. 28, 2022).
[17] M. H. Simanjuntak, "BRIN: Perlu uji klinis vaksin RTS,S ketahui efektivitas di Indonesia," *Antara News*, 2021. https://www.antaranews.com/berita/2458569/brin-perlu-uji-klinis-vaksin-rtss-ketahui-efektivitas-di-indonesia (accessed Nov. 28, 2022).
[18] KEMENKES RI, "Laporan Nasional RISKESDAS 2018," KEMENKES RI, Jakarta, 2018.
[19] KEMENKES RI, "Rencana Aksi Kegiatan (RAK) 2020-2024," KEMENKES RI, Jakarta, 2020.
[20] R. Nurmaliani, R. Oktarina, M. Arisanti, and D. Asyati, "Daya Bunuh Kelambu Berinsektisida Long Lasting Insecticidal Nets (LLINS) terhadap Nyamuk Anopheles maculatus," *ASPIRATOR - J. Vector-Borne Dis. Stud.*, vol. 8, no. 1, p. 8, 2016, doi: 10.22435/aspirator.v8i1.3931.1-8.