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SEIRS-SEI Model of Malaria Disease with Application of Vaccines and Anti-Malarial Drugs

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Abstract: *This article discusses the mathematical model of SEIRS-SEI type malaria disease. Modification of the model is done by giving the treatment in humans, in the form of vaccines and anti-malarial drugs treatment. In this model, the human population is divided into four classes, namely susceptible human, exposed human, infected human, and recovered human. The mosquito population is divided into three classes, namely susceptible mosquito, exposed mosquito and infected mosquito. Furthermore, the analysis of the model to show the effect of treatment given to disease transmission. At the end of this article is provided numerical simulations to show the effectiveness of vaccines and anti-malarial drugs in humans to suppress the rate of transmission of disease. The simulation results show that the increase of vaccines effectiveness and anti-malarial drugs in humans can reduce the reproduction numbers, so that within a certain time the disease will disappear from the population.*
Keywords: *Epidemic Model, Malaria, SEIRS-SEI model, Treatment, Vaccines*

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I. Introduction

Malaria is a disease caused by a parasitic infection of Anopheles mosquito that is very deadly for humans. Malaria can be transmitted through the bites of infected mosquitoes, blood transfusions, use of needles, and congenital. Therefore, it is necessary to take preventive measures to control both the infection rate and the extent of the spread of the disease. Based on several cases of malaria that have occurred, various studies have emerged that construct a mathematical model for malaria. Mathematical modeling can help understand and identify the relationship of malaria transmission with various epidemiological parameters, assist in future planning and consider appropriate control measures. In this study we discussed a malaria transmission model based on [1,2]. Modification of the model is done by addition of exposed classes in both populations with reference to [3]. This is necessary because the sporozoid produced from infected mosquito bites requires an incubation period of 9-14 days to actually cause the disease, as stated in [4]. During this incubation period, populations are grouped into exposed classes. Modification of the model is also done with the addition of parameters in the form of vaccines and anti-malarial drugs in humans. Vaccines given can make susceptible humans who have been bitten can directly move into humans recovered. In this case, it is assumed that humans in the susceptible class (S_h) may move into the recovered class (R_h) due to vaccines at the rate of θ as introduced in [5]. Stability analysis is then performed to reveal the effects of treatments on population dynamics. At the end of this article is provided numerical simulations to show the effectiveness of vaccines and anti-malarial drugs in humans to suppress the rate of transmission of malaria disease.

II. Mathematical Model

In constructing the model we employ the following assumptions.We assume that the human population is divided into four classes, namely susceptible human S_h, exposed human E_h, infected human I_h, and recovered human R_h, while the mosquito population is grouped into two classes, namely susceptible mosquito S_m, exposed mosquito E_m, and infected mosquito I_m. Individuals who are born and migrate to the susceptible class has a constant rate of λ_h. Humans in susceptible class can move into the exposed class due to an infected mosquito bite at a rate of $a\beta_1$ (with a is average number of infected mosquito bites on susceptible human per unit time and β_1 is the chances of disease transmission from infected mosquitoes to susceptible humans). Humans in susceptible class can move into the recovered class due to vaccination at a rate of θ. Humans in susceptible class (S_h) may die at a rate of μ_h. A newborn baby can be infected malaria due to congenital with a rate of γ. Human in exposed can move to the infected class after going through the incubation period at a rate of v_h. Human in exposed class (E_h) may die at a rate of μ_h. Humans in infected class can move to the recovered class due to the use of anti-malarial drugs with a rate of $k\psi$ (with k is the rate of human recovery and ψ is the effectiveness of anti-malarial drugs). Humans in infected class (I_h) can die at a rate of μ_h and death due to malaria at a rate of α. Human in recovered class can move to the susceptible class after immune lose at a rate of ω. Humans in recovered class (R_h) can die at a rate of μh.

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