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Mathematical analysis of transmission dynamics in vector-borne diseases via a generalized SEIR model

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Abstract

Vector-borne diseases continue to impose a substantial burden on public health systems worldwide, largely due to the complex interaction between human hosts and mosquito vectors. In this paper, a generalized SEIR-type mathematical model is formulated to study the transmission dynamics of vector-borne diseases, with particular emphasis on mosquito-borne infections. The model incorporates four human compartments and five vector-related compartments, allowing for a detailed representation of disease transmission and vector population dynamics. Analytical results are obtained for the equilibrium points of the system and the basic reproduction number is derived to determine threshold conditions for disease persistence or elimination. Stability properties of the disease-free and endemic equilibria are investigated using standard methods from dynamical systems theory. Numerical simulations, performed using the fourth-order Runge–Kutta method and implemented in Wolfram Mathematica, illustrate the influence of personal protection, larvicidal, and adulticidal control measures on disease spread. The simulation results show qualitative agreement with previously reported data, supporting the relevance of the proposed model for understanding transmission patterns and evaluating vector control strategies.

Keywords SEIR model, Vector borne diseases, Equilibrium points, Basic reproduction number

Mathematics Subject Classification 92B05, 92C10, 92CXX, 92C35, 92C50, 46N60

1 Introduction

Vector-borne diseases are caused by pathogens (bacteria, viruses, or parasites) transmitted to humans or animals through infected vectors such as mosquitoes, ticks, and flies. These diseases have existed for centuries and continue to represent a significant global public health challenge, with more than 50% of the world's population at risk. According to the World Health Organization (WHO), vector-borne diseases account for nearly 17% of all infectious diseases worldwide [1]. On the occasion of World Health Day (April 7,



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