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A Study of a Nonlinear Model of COVID-19 Transmission with Vaccination

The coronavirus disease (COVID-19) was first observed in December 2019 in the Wuhan Province of China and then it spread throughout the world. It affected the whole world in the most devastating way possible. In this paper, a nonlinear differential equation-based mathematical model is proposed to describe the spread dynamics of COVID-19 with the consideration of some important factors like self-protection and vaccination. The basic reproduction number of the model, which is a critical signal of the dynamics of COVID-19 transmission, is calculated using the next-generation matrix method. The local stability of the steady states has been investigated. Moreover, global stability is demonstrated using the second method of Lyapunov and the LaSalle invariance principle. In addition, the effect of vaccination on the evolution of the disease spread has been studied. Further, an optimal control problem is formulated and solved to reduce the number of infected individuals and the cost of the controls by considering self-protection and vaccination as intervention options. It is found that the introduction of intervention affects the transmission dynamics of the COVID-19 pandemic. Finally, the theoretical aspects have been validated by extensive simulations conducted for various initial conditions and parameter values.

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