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Mathematical Modelling of Spatial Distribution of Covid-19 Outbreak Using Diffusion Equation

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Abstract : The use of mathematical tools like Partial Differential Equations and Ordinary Differential Equations have become very important to predict the evolution of a viral disease in a population in order to take preventive and curative measures. In December 2019, a novel variety of Coronavirus (SARS-CoV-2) was identified in Wuhan, Hubei Province, China causing a severe and potentially fatal respiratory syndrome, i.e., COVID-19. Since then, it has become a pandemic declared by World Health Organization (WHO) on March 11, 2020 which has spread around the globe. A reaction-diffusion system is a mathematical model that describes the evolution of a phenomenon subjected to two processes: a reaction process in which different substances are transformed, and a diffusion process that causes a distribution in space. This article provides a mathematical study of the Susceptible, Exposed, Infected, Recovered, and Vaccinated population model of the COVID-19 pandemic by the bias of reaction-diffusion equations. Both local and global asymptotic stability conditions for disease-free and endemic equilibria are determined using the Lyapunov function are considered and the endemic equilibrium point exists and is stable if it satisfies Routh–Hurwitz criteria. Also, adequate conditions for the existence and uniqueness of the solution of the model have been proved. We showed the spatial distribution of the model compartments when the basic reproduction rate $\mathcal{R}_0 < 1$ and $\mathcal{R}_0 > 1$ and sensitivity analysis is performed in order to determine the most sensitive parameters in the proposed model. We demonstrate the model's effectiveness by performing numerical simulations. We investigate the impact of vaccination and the significance of spatial distribution parameters in the spread of COVID-19. The findings indicate that reducing contact with an infected person and increasing the proportion of susceptible people who receive high-efficacy vaccination will lessen the burden of COVID-19 in the population. To the public health policymakers, we offered a better understanding of the COVID-19 management.

Keywords : COVID-19, SEIRV epidemic model, reaction-diffusion equation, basic reproduction number, vaccination, spatial distribution
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