An Epidemic Dynamics Model with a Limited Capacity of Isolation for a Reinfectious Disease

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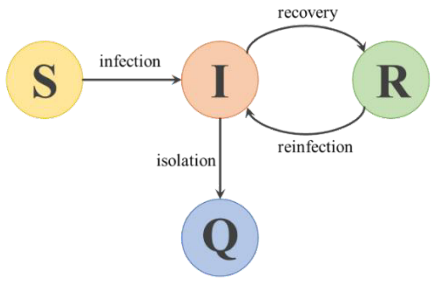
To reduce the risk of the epidemic spreading in the community, isolation can be considered as one of the important measures implemented after the outbreak of an epidemic. In this work, making use of a mathematical model for the epidemic dynamics with a reinfectious disease, we consider the relation of the limited isolation capacity to the final state of the epidemic dynamics. We assume that the recovered individuals could be reinfected since the nature of the pathogen with a number of variants could cause the infection again. Our model is the following SIRI model with the isolation state Q for which the isolated individuals cannot contact others or be discharged in the season:



$$\frac{dS}{dt} = -\beta\frac{I}{N-Q}S$$
$$\frac{dI}{dt} = \beta\frac{I}{N-Q}S + \varepsilon\beta\frac{I}{N-Q}R - \rho I - \Phi(Q,I)$$
$$\frac{dQ}{dt} = \Phi(Q,I)$$
$$\frac{dR}{dt} = \rho I - \varepsilon\beta\frac{I}{N-Q}R$$

with

$$\Phi(Q,I) = \begin{cases} \sigma I & \text{for } Q < Q_{\max} \\ 0 & \text{for } Q = Q_{\max} \end{cases}$$

and the initial condition $\big(S(0), I(0), Q(0), R(0)\big) = (S_0, I_0, 0, 0)$ where $I_0 > 0$ and $S_0 = N - I_0 > 0$. The variables S, I, Q and R are respectively the susceptible, infective, isolated, and recovered population densities. N is the total population density in the community. Parameter β is the infection coefficient, and $\varepsilon\beta$ is the reinfection coefficient smaller than β $(0 < \varepsilon < 1)$. The parameter ε can be regarded as an index for the likelihood of reinfection after the recovery. Parameter ρ is the natural recovery rate of the infective individual. The piecewise function $\Phi(Q,I)$ denotes the isolation rate of the infected individual, where the parameter $Q_{\max}$ is the capacity of isolation, and σ is the isolation rate at the isolation effective phase. Once the isolated subpopulation size reaches the capacity $Q_{\max}$, it will remain the capacity $Q_{\max}$ afterward, and then the system turns into the isolation incapable phase. Any demographic change due to birth, death or migration is assumed to be negligible in the epidemic season. In this presentation, we are going to show the results for the relation of the limited isolation capacity to the final epidemic or endemic size brought by the epidemic dynamics with a reinfection disease according to the above model.