Ann. of Appl. Math.
36:4(2020), 442-458

EFFECTS OF MEDIA COVERAGE AND TEMPORARY IMMUNITY TO A STOCHASTIC SEIR EPIDEMIC MODEL*†

Jing Zhang[1], Fengying Wei[1,2‡]

(1. *College of Mathematics and Computer Science, Fuzhou University, Fuzhou 350116, Fujian, PR China;*

2. *Key Laboratory of Operations Research and Control of Universities in Fujian, Fuzhou University, Fuzhou 350116, Fujian, PR China*)

Abstract

A type of SEIR epidemic model with media coverage and temporary immunity is investigated in this paper. The existence and uniqueness of the global positive solution with any positive initial value is proved. Under the condition $R_0^s > 1$, we prove that the disease is persistent in the mean for a long run. Furthermore, by constructing suitable Lyapunov functions, some sufficient conditions that guarantee the existence of stationary distribution are derived. We also obtain that, if the condition $R_0^e < 1$ is satisfied, then the disease is extinct with an exponential rate. As a consequence, some examples and numerical simulation are demonstrated to show the validity and feasibility of the theoretical results.

Keywords stochastic SEIR model; media coverage; temporary immunity; persistence; extinction; stationary distribution

2000 Mathematics Subject Classification 60H10; 34D20

1 Introduction

It is necessary and important to reveal the transmission mechanisms of the infectious diseases incorporating media coverage and temporary immunity when human life is threatened in modern society. When the infectious diseases attack healthy population, the total population usually is separated into three compartments: the susceptible (S), the infected (I), the recovered (R) as referenced in some epidemic models, in which the corresponding dynamical patterns were proposed and investigated well. For instance, the epidemic models with vaccination [1,2], media coverage

*This work was supported by NSFC under grant 61911530398, Natural Science Foundation of Fujian Province of China under grant 2016J01015.

†Manuscript received August 11, 2020; Revised October 10, 2020

‡Corresponding author. E-mail: weifengying@fzu.edu.cn

[1,3-8], temporary immunity [9-11], nonlinear incidence rate [5,10-12] have been considered in recent years.

Media coverage is one of the effective ways to control the spread of infectious diseases when infectious disease starts to invade the local population in a region [13,14]. Usually, media coverage in modern societies, including television and radio, network and APPs, have been adopted to awake the awareness of people and to slow down the spread of infectious diseases. For COVID-19 epidemic course, local people obtain the information regarding the spread of infectious diseases via media terminal devices to avoid visiting high risk spot. Wearing masks when outing, washing hands when appropriate, these strategies what people obeyed are much helpful for the public health. As a consequence, the impacts of media coverage for slowing down the spread of infectious diseases are active and effective, which could be checked in the literature [1,3-8].

The effective contact rate between the susceptible and the infected was often taken the nonlinear form of $\beta = \beta_1 - \beta_2 f(I)$ [1,3-8] (also referred as the nonlinear incidence rate [5,7,10-12]), where β_1 is the maximal effective contact rate, and β_2 is the maximum reduced contact rate due to the presence of protected individuals affected by the media coverage. Moreover, the decreasing exponential form $\beta = \mathrm{e}^{-aM(t)}$ in [13-18] is also governed to describe the tendency of the effective contact rate of media coverage. Here, function $f(I)$ satisfies the general assumptions: $f(0) = 0,\ \lim_{I\to\infty} f(I) = 1,\ 0 < f'(I) \le 1,\ f''(I) < 0$. In practice, the effective contact rate β is considered in the form of $\beta = \beta_1 - \frac{\beta_2 I(t)}{\alpha + I(t)}$ $(\beta_1 > \beta_2)$, and the term $\frac{\beta_2 I(t)}{\alpha + I(t)}$ reaches the maximum saturation when the number of the infected increases in media coverage environment.

Another effective way to stop the spread of the infectious diseases is the vaccine. Immune system for each individual works well when vaccinated until losing the vaccine. In most articles [1,2,19-21], the valid period of vaccination was denoted by τ_1, and the length of temporary immunity period was τ_2. Recent studies [2,9,22,23] investigated the epidemic models with vaccination term $S(t-\tau_1)\mathrm{e}^{-\mu\tau_1}$, in which the individuals kept being susceptible after vaccinating for a specific time τ_1. On the other hand, temporary immunity was built after a specific period of time τ_2 and the efficacy of the vaccine was less than one therewith being mentioned in the form of $I(t-\tau_2)\mathrm{e}^{-\mu\tau_2}$ in [9,19,21-26]. It means that the individuals lost their temporary immunities and return into the susceptible again. Recent related topics could be found in [18,27-31].

Motivated by the previous work, we propose an epidemic model incorporating vaccination and media coverage in this paper. We assume that epidemic model