Effects of educational campaigns on mathematical models to control the spread of rotavirus infection

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Abstract. This research is to develop and evaluate the stability of a mathematical model for controlling the spread of rotavirus infection. The model is analyzed using standard methods including the equilibrium point and the stability of the equilibrium points. The education campaign rate in the model, the basic reproductive number and numerical solutions are studied. We found that the education campaign rate is the factor affecting the model. If the infection's population is educated and follows the hypothesis of this model, then the spread of rotavirus infection will decrease and there will be no epidemic. It concluded that when the value of the education campaign rate decreases, the number of infected human increases. Therefore, the basic reproductive number is greater than one, meaning the Rotavirus infection will occur in the community. On the other hand, when the value of the education campaign increases, the number of infected human decreases. The basic reproductive number is less than one, meaning that the Rotavirus infection will have died out the community.

Keywords: Mathematical model, Rotavirus infection, Education Campaign

Introduction

Studying the mathematical models of epidemics makes it possible to know the epidemic and the results obtained from the model, help researchers understand the factors that can control the spread of the disease. Including having a correct understanding of the transmission of the disease. The study also identifies the strengths of a mathematical model capable of altering the characteristics of an epidemic. Analyzing the model, data shows the effectiveness of understanding the evolution of the epidemic and understanding disease control measures. Therefore, the results of this study are highly beneficial in reducing the risk of infection. Infection transmission and epidemic control. Diarrhoea is a disorder of the gastrointestinal tract. It would call liquid stools three times a day in each year. There are up to 1.7 billion diarrhoea patients worldwide. There will be distension, abdominal pain, nausea, vomiting and often taken. If it is longer than three weeks, diarrhoea will be called chronic. If it healed within three weeks, it is called acute diarrhoea, bacteria and viruses. Countries in the United Kingdom report 13,000 diarrhoea patients with Rotavirus a year. Australia has the number of infected people.It is as high as 32,000 people per year, and in Africa, the death rate of children are 15%. Thailand and Southeast Asia were found that 43-56% of younger children more than five years with diarrhoea who need to be hospitalized, are caused by a virus called Rotavirus,

which is a virus in RNA Group (Double-stranded RNA virus) in the family Reoviridae 7 species (A, B, C, D, E, F, G). When receiving the Rotavirus into the body, a short incubation period of fewer than 48 hours (duration from 1-7 days), When entering the digestive tract, the small intestine will destroy the small intestine wall, resulting in water absorption, reduced water and minerals and Enzyme for indigestion of carbohydrates causing diarrhoea no mucus or blood. Therefore, Rotavirus Is the cause of diarrhoea worldwide, resulting in approximately 527,000 deaths per year. Diarrhoea from Rotavirus is usually found in young children under five years, but in the past two years, it increased in adults. It may be infected by caring for a sick child or infected by contamination in the environment, and the Rotavirus is the most common in the winter. Rotavirus diarrhoea is caused by an infection with food and water directly through the mouth or indirectly after exposure to contaminated faeces or toys contaminated with faeces [3]. Diarrhoea from Rotavirus is usually found in groups with the symptoms within 1-3 days, and a patient can spread the infection for more than a week after the onset. The disease symptoms are fever, vomiting, diarrhoea, and diarrhoea in patients with severe symptoms. They need to be hospitalized due to dehydration, and if the treatment is unsuitable, it may be dangerous. It can have recurrent infections, do many times later. Symptoms will be less. From the mathematical model, the spread of diarrhoea from Rotavirus is known. The model and the spread of disease help the researchers understand the factors that can control the spread of the disease and have a correct understanding of the transmission. In addition, the strengths of mathematical models can change the characteristics of the disease and the parameters related to the disease. The Mathematical study epidemics of Rotavirus, keeping in mind the consequences of the epidemic and helping researchers better understanding the factors that control the spread of the disease [2]. In addition, the strengths of the mathematical model can also modify the characteristics of the epidemic and various parameters associated with the disease [5]. So, the results of this study would be highly beneficial in reducing the risk of infection and Rotavirus infection control. This research aims to develop and evaluate the stability of mathematical modelling for controlling the spread of Rotavirus infection on the Education Campaign. The model is analyzed using standard methods, the equilibrium point, stability, and analytic solutions [6]. The effectiveness of the Education Campaign in mathematical modelling and numerical solutions is studied.

Model Formulation

In our model, we assume that the human population is one constant because the birth rates and the death rates of the human population are equal. Therefore, the total number of human people denote by. The human N population are divided into four classes; the susceptible human (S), the exposed human (E), the infected human (I) and the recovered human (R). The diagram of four classes of the human population and the crucial parameters are used, representing the Rotavirus infection dynamics model. That is shown in Figure 1.

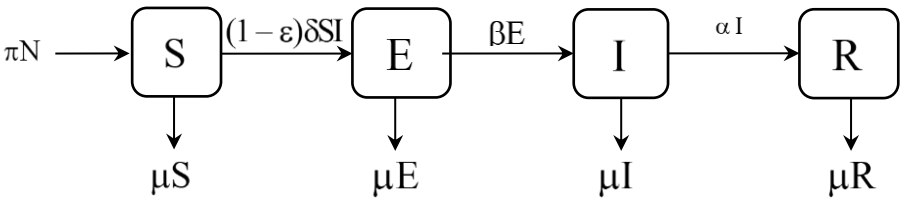

Figure 1. Flow chart of the dynamical transmission of Rotavirus infection.

The transitions between model classes can be now expressed by the following system of first order differential equations:

$$\frac{dS}{dt} = \pi N - (1-\varepsilon)\delta SI - \mu S \quad (1)$$

$$\frac{dE}{dt} = (1-\varepsilon)\delta SI - E(\beta+\mu) \quad (2)$$

$$\frac{dI}{dt} = \beta E - I(\mu+\alpha) \quad (3)$$

$$\frac{dR}{dt} = \alpha I - \mu R \quad (4)$$

with $N = S + E + I + R$

Where;

$S(t)$ is the susceptible human populations at time t

$E(t)$ is the exposed human populations at time t

$I(t)$ is the infected human populations at time t

$R(t)$ is the recovered human populations at time t

N is the total number of human populations

π is the birth rate of human populations

ε is the effectiveness of education campaign

δ is the probability that virus transmitted from infected human to susceptible human

β is the proportional rate for people exposed to the infected human populations

α is the recovery rate of infected human populations

μ is the natural death rate of human populations

Model Analysis

Since the model monitors human population, all the associated parameters and state variables are non-negative is $t \geq 0$. It is easy to show that the state variables of the model remain non-negative for all non-negative initial conditions [1]. The biological feasible region

$$\Psi = \left\{ (S, E, I, R) \in R_+^4 : N \to \frac{\pi}{\mu} \right\}$$

Lemma 1. The closed ψ is positively invariant and attracting.

Proof. Adding (1)-(4) give the rate of change of the total population.

$$\frac{dN}{dt} = \frac{dS}{dt} + \frac{dE}{dt} + \frac{dI}{dt} + \frac{dR}{dt}$$

$$\frac{dN}{dt} = \pi N - (1-\varepsilon)\delta SI - \mu S + (1-\varepsilon)\delta SI - E(\beta+\mu) + \beta E - I(\mu+\alpha) + \alpha I - \mu R$$

$$\frac{dN}{dt} = \pi N - \mu S - E\mu - I\mu - \mu R$$

$$\frac{dN}{dt} = \pi N - \mu(S + E + I + R)$$

$$\frac{dN}{dt} = \pi N - \mu N$$

$$\frac{1}{N}dN = (\pi - \mu)dt$$
$$\int \frac{1}{N}dN = \int (\pi - \mu)dt$$

$$\ln N = (\pi - \mu)t + c$$
$$N = e^{(\pi-\mu)t+c}$$
$$N(t) = N_0 e^{(\pi-\mu)t} \qquad \because N_0 = e^c$$

Thus, the total human population (N) are bounded by $\pi - \mu$, so that $\frac{dN}{dt} = 0$ whenever $\pi = \mu$. It can be shown that $N(t) = N_0 e^{(\pi-\mu)t}$. In particular $N(t) = N_0 e^{(\pi-\mu)t}$, if $N_0 e^{(\pi-\mu)t} > 0$. Hence, the region Ψ is positively invariant and attracts all solutions in R_+^4

Basic Reproductive Number

The basic reproductive number (R_0) is defined as the expected number of secondary cases produced by a single infection in a completely susceptible population, by using the next generation method and used spectral radius [8]. We have rewritten the system in matrix form

$$\frac{dx}{dt} = F(x) - V(x)$$

Here $F(x)$ gives the rate of appended of new infections in a compartment and $V(x)$ gives the transferring of individuals. We obtained,

$$F(X) = \begin{bmatrix} 0 \\ (1-\varepsilon)\delta SI \\ 0 \\ 0 \end{bmatrix} \quad \text{and} \quad V(X) = \begin{bmatrix} -\pi N + (1-\varepsilon)\delta SI + \mu S \\ \beta E + \mu E \\ -\beta E + \mu I + \alpha I \\ -\alpha I + \mu R \end{bmatrix}$$

where:

$$FV^{-1}(E_0) = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & \frac{(1-\varepsilon)\delta\beta N}{(\beta+\mu)(\mu+\alpha)} & \frac{(1-\varepsilon)\delta N}{\gamma+\varphi} & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$ and Spectral Radius from $FV^{-1}(E_0)$,

that is $\rho[FV^{-1}(E_0)] = \frac{(1-\varepsilon)\delta\beta N}{(\beta+\mu)(\mu+\alpha)}$. We have the basic reproductive number as shown,

$$R_0 = \frac{(1-\varepsilon)\delta\beta N}{(\beta+\mu)(\mu+\alpha)}$$

Stability Analysis

In this section, the stability of equilibrium can be analyzed by using the Jacobian matrix of the model at the disease free equilibrium. Referring to the results of Vanden Driessche and Watmough (2002), the stability of this system as shown in the follow theorem.

Theorem 1: The disease free equilibrium of the system about the equilibrium E_0, is local asymptotically stable if R_0>1 and unstable if R_0<1.

Proof. The Jacobian matrix of the model (Eqs. 1-4) evaluated a $E_0(S,E,I,R) = E_0(N,0,0,0)$ is obtained the local stability of equilibrium point is determined from the Jacobian matrix of the system of ordinary differential equation. The equation (1), (2), (3) and (4) evaluated at the equilibrium point. The Jacobian matrix is

$$J_0 = \begin{bmatrix} -\mu & 0 & -(1-\varepsilon)\delta N & 0 \\ 0 & -(\beta+\mu) & (1-\varepsilon)\delta N & 0 \\ 0 & \beta & -(\mu+\alpha) & 0 \\ 0 & 0 & \alpha & -\mu \end{bmatrix}$$

$$\det(J_0 - \lambda I) = \begin{vmatrix} -\mu-\lambda & 0 & -(1-\varepsilon)\delta N & 0 \\ 0 & -(\beta+\mu+\lambda) & (1-\varepsilon)\delta N & 0 \\ 0 & \beta & -(\mu+\alpha+\lambda) & 0 \\ 0 & 0 & \alpha & -\mu-\lambda \end{vmatrix}$$

$$\det(J_0 - \lambda I) = (\mu - \lambda)^2 [\lambda^2 + (\beta + 2\mu + \alpha)\lambda + (\beta + \mu)(\mu + \alpha) - (1 - \varepsilon)\beta\delta N]$$

The eigenvalues of the Jacobian matrix J_0 are obtained by solving $\det(J_0 - \lambda I) = 0$, then the characteristic equation as follows: $(\mu - \lambda)^2 [\lambda^2 + (\beta + 2\mu + \alpha)\lambda + (\beta + \mu)(\mu + \alpha) - (1 - \varepsilon)\beta\delta N] = 0$

where; $\lambda_{1,2} = -\mu < 0$ and $\lambda_{3,4} = \dfrac{-(\beta + 2\mu + \alpha) \pm \sqrt{(\beta+2\mu+\alpha)^2 - 4[(\beta+\mu)(\mu+\alpha) - (1-\varepsilon)\beta\delta N]}}{2}$

The two roots of $\lambda^2 + A\lambda + B = 0$ will be negative real part if they satisfy the Routh-Hurwitz criteria.

1) $A = \beta + 2\mu + \alpha$
2) $B = (\beta+\mu)(\mu+\alpha) - (1-\varepsilon)\beta\delta N$
3) A>0
4) B>0

Theorem 2: The endemic equilibrium of the system Eqs.(1)-(4) for the equilibrium

$$E_1(S^*, E^*, I^*, R^*) = \left(\frac{\pi N}{(1-\varepsilon)\delta I^* + \mu}, \frac{(1-\varepsilon)\delta S^* I^*}{\beta + \mu}, \frac{\beta E}{\mu + \alpha}, \frac{\alpha I^*}{\mu}\right),$$

is local asymptotically stable if $R_0 > 1$, and unstable if $R_0 < 1$.

Proof.

$$J_1 = \begin{bmatrix} -(1-\varepsilon)\delta I^* - \mu & 0 & -(1-\varepsilon)\delta S^* & 0 \\ (1-\varepsilon)\delta I^* & -(\beta+\mu) & (1-\varepsilon)\delta S^* & 0 \\ 0 & \beta & -(\mu+\alpha) & 0 \\ 0 & 0 & \alpha & -\mu \end{bmatrix}$$

$$\det(J_1 - \lambda I) = \begin{vmatrix} -(1-\varepsilon)\delta I^* - \mu - \lambda & 0 & -(1-\varepsilon)\delta S^* & 0 \\ (1-\varepsilon)\delta I^* & -(\beta+\mu+\lambda) & (1-\varepsilon)\delta S^* & 0 \\ 0 & \beta & -(\mu+\alpha+\lambda) & 0 \\ 0 & 0 & \alpha & -\mu-\lambda \end{vmatrix}$$

$$\begin{aligned} \det(J_1 - \lambda I) = (\mu+\lambda)[(\lambda^3 + ((1-\varepsilon)\delta I^* + \beta + \alpha + 3\mu)\lambda^2 + (((1-\varepsilon)\delta I^* + \mu)(\mu+\beta) \\ + ((1-\varepsilon)\delta I^* + \mu)(\mu+\alpha) + (\mu+\beta)(\mu+\alpha) - (1-\varepsilon)\beta\delta S^*)\lambda \\ + ((1-\varepsilon)\delta I^* + \mu)(\mu+\beta)(\mu+\alpha) + (1-\varepsilon)^2\beta\delta^2 S^2 I^* \\ - ((1-\varepsilon)\beta\delta S^*)((1-\varepsilon)\delta I^* + \mu)] \end{aligned}$$

The eigenvalues of the Jacobian matrix J_1 are obtained by solving $\det(J_1 - \lambda I) = 0$, we provided the characteristic equation as follows:

$$\begin{aligned} &(\mu+\lambda)[(\lambda^3 + ((1-\varepsilon)\delta I^* + \beta + \alpha + 3\mu)\lambda^2 + (((1-\varepsilon)\delta I^* + \mu)(\mu+\beta) + \\ &((1-\varepsilon)\delta I^* + \mu)(\mu+\alpha) + (\mu+\beta)(\mu+\alpha) - (1-\varepsilon)\beta\delta S^*)\lambda \\ &+ ((1-\varepsilon)\delta I^* + \mu)(\mu+\beta)(\mu+\alpha) + (1-\varepsilon)^2\beta\delta^2 S^2 I^* - ((1-\varepsilon)\beta\delta S^*)((1-\varepsilon)\delta I^* + \mu)] = 0 \end{aligned}$$

The three roots of $\lambda^3 + A\lambda^2 + B\lambda + C = 0$ will be negative real part if they satisfy the Routh-Hurwitz criteria.

1) $A = (1-\varepsilon)\delta I^* + \beta + \alpha + 3\mu$

2) $B = ((1-\varepsilon)\delta I^* + \mu)(\mu+\beta) + ((1-\varepsilon)\delta I^* + \mu)(\mu+\alpha) + (\mu+\beta)(\mu+\alpha) - (1-\varepsilon)\beta\delta S^*$

3) $C = ((1-\varepsilon)\delta I^* + \mu)(\mu+\beta)(\mu+\alpha) + (1-\varepsilon)^2\beta\delta^2 S^2 I^* - ((1-\varepsilon)\beta\delta S^*)((1-\varepsilon)\delta I^* + \mu)$

4) $AB > C$

Equilibrium Points

The model will be analyzed to investigate the equilibrium points by using the standard method for analyzing our model. The system has two possible equilibrium points. In the case of the absence of the disease, that is I=0. Given,

$$X = \begin{bmatrix} S \\ E \\ I \\ R \end{bmatrix}, \quad F(X) = \begin{bmatrix} 0 \\ (1-\varepsilon)\delta SI \\ 0 \\ 0 \end{bmatrix} \text{ and } \quad V(X) = \begin{bmatrix} -\pi N + (1-\varepsilon)\delta SI + \mu S \\ \beta E + \mu E \\ -\beta E + \mu I + \alpha I \\ -\alpha I + \mu R \end{bmatrix}$$

From equations (1) - (4) finding the Jacobian max of F(x) and V(x) evaluated at $E_*(S, E, I, R)$. We follow that,

$$J=\begin{bmatrix} -(1-\varepsilon)\delta I-\mu & 0 & -(1-\varepsilon)\delta S & 0 \\ (1-\varepsilon)\delta I & -(\beta+\mu) & (1-\varepsilon)\delta S & 0 \\ 0 & \beta & -(\mu+\alpha) & 0 \\ 0 & 0 & \alpha & -\mu \end{bmatrix}$$

The disease-free equilibrium point

We used the Jacobian max of F(x) and V(x) evaluated at $E_0(S,E,I,R)=E_0(N,0,0,0)$

We obtained $E_0(N,0,0,0)$, then

$$J_0=\begin{bmatrix} -\mu & 0 & -(1-\varepsilon)\delta N & 0 \\ 0 & -(\beta+\mu) & (1-\varepsilon)\delta N & 0 \\ 0 & \beta & -(\mu+\alpha) & 0 \\ 0 & 0 & \alpha & -\mu \end{bmatrix}$$

$$\det(J_0-\lambda I)=\begin{vmatrix} -\mu-\lambda & 0 & -(1-\varepsilon)\delta N & 0 \\ 0 & -(\beta+\mu+\lambda) & (1-\varepsilon)\delta N & 0 \\ 0 & \beta & -(\mu+\alpha+\lambda) & 0 \\ 0 & 0 & \alpha & -\mu-\lambda \end{vmatrix}$$

$$\det(J_0-\lambda I)=(\mu-\lambda)^2[\lambda^2+(\beta+2\mu+\alpha)\lambda+(\beta+\mu)(\mu+\alpha)-(1-\varepsilon)\beta\delta N]$$

where: $\det(J_0-\lambda I)=0$

$$(\mu-\lambda)^2[\lambda^2+(\beta+2\mu+\alpha)\lambda+(\beta+\mu)(\mu+\alpha)-(1-\varepsilon)\beta\delta N]=0$$

where; $\lambda_{1,2}=-\mu<0$ and

$$\lambda_{3,4}=\frac{-(\beta+2\mu+\alpha)\pm\sqrt{(\beta+2\mu+\alpha)^2-4[(\beta+\mu)(\mu+\alpha)-(1-\varepsilon)\beta\delta N]}}{2}$$

The endemic equilibrium point

In the case of the disease in present, that is $I^*>0$. Hence,

$$E_1(S^*,E^*,I^*,R^*)=\left(\frac{\pi N}{(1-\varepsilon)\delta I^*+\mu},\frac{(1-\varepsilon)\delta S^*I^*}{\beta+\mu},\frac{\beta E}{\mu+\alpha},\frac{\alpha I^*}{\mu}\right)$$

The Jacobian is defined as follows:

$$J_1=\begin{bmatrix} -(1-\varepsilon)\delta I^*-\mu & 0 & -(1-\varepsilon)\delta S^* & 0 \\ (1-\varepsilon)\delta I^* & -(\beta+\mu) & (1-\varepsilon)\delta S^* & 0 \\ 0 & \beta & -(\mu+\alpha) & 0 \\ 0 & 0 & \alpha & -\mu \end{bmatrix}$$

$$\det(J_1 - \lambda I) = \begin{vmatrix} -(1-\varepsilon)\delta I^* - \mu - \lambda & 0 & -(1-\varepsilon)\delta S^* & 0 \\ (1-\varepsilon)\delta I^* & -(\beta+\mu+\lambda) & (1-\varepsilon)\delta S^* & 0 \\ 0 & \beta & -(\mu+\alpha+\lambda) & 0 \\ 0 & 0 & \alpha & -\mu-\lambda \end{vmatrix}$$

$$\begin{aligned}\det(J_1 - \lambda I) = (\mu+\lambda)[&(\lambda^3 + ((1-\varepsilon)\delta I^* + \beta + \alpha + 3\mu)\lambda^2 + (((1-\varepsilon)\delta I^* + \mu)(\mu+\beta) \\ &+ ((1-\varepsilon)\delta I^* + \mu)(\mu+\alpha) + (\mu+\beta)(\mu+\alpha) - (1-\varepsilon)\beta\delta S^*)\lambda \\ &+ ((1-\varepsilon)\delta I^* + \mu)(\mu+\beta)(\mu+\alpha) + (1-\varepsilon)^2\beta\delta^2 S^2 I^* \\ &- ((1-\varepsilon)\beta\delta S^*)((1-\varepsilon)\delta I^* + \mu)]\end{aligned}$$

where: $\det(J_1 - \lambda I) = 0$

$$\begin{aligned}&(\mu+\lambda)[(\lambda^3 + ((1-\varepsilon)\delta I^* + \beta + \alpha + 3\mu)\lambda^2 + (((1-\varepsilon)\delta I^* + \mu)(\mu+\beta) + \\ &((1-\varepsilon)\delta I^* + \mu)(\mu+\alpha) + (\mu+\beta)(\mu+\alpha) - (1-\varepsilon)\beta\delta S^*)\lambda \\ &+ ((1-\varepsilon)\delta I^* + \mu)(\mu+\beta)(\mu+\alpha) + (1-\varepsilon)^2\beta\delta^2 S^2 I^* - ((1-\varepsilon)\beta\delta S^*)((1-\varepsilon)\delta I^* + \mu)] = 0\end{aligned}$$

where: $\lambda^3 + A\lambda^2 + B\lambda + C = 0$ and $AB > C$

1) $A = (1-\varepsilon)\delta I^* + \beta + \alpha + 3\mu$

2) $B = ((1-\varepsilon)\delta I^* + \mu)(\mu+\beta) + ((1-\varepsilon)\delta I^* + \mu)(\mu+\alpha) + (\mu+\beta)(\mu+\alpha) - (1-\varepsilon)\beta\delta S^*$

3) $C = ((1-\varepsilon)\delta I^* + \mu)(\mu+\beta)(\mu+\alpha) + (1-\varepsilon)^2\beta\delta^2 S^2 I^* - ((1-\varepsilon)\beta\delta S^*)((1-\varepsilon)\delta I^* + \mu)$

Numerical Analysis

In this section, we would like to present the numerical simulation of our model. The parameter values that we used in the numerical simulation are given in Table 1.

Table 1. Parameters values used in numerical simulation at disease free state

Description	Parameters	Values
The total number of human populations	N	1,500 persons
The birth rate of human populations	π	22 day^{-1}
The probability that virus transmitted from infected human to susceptible human	δ	1.59x 10^{-4} day^{-1}
the proportional rate for people exposed to the infected human populations	β	2.5 x 10^{-1} day^{-1}
The natural death rate of human populations	μ	1.2 x 10^{-2} day^{-1}
The recovery rate of infected human populations	α	1.4 x 10^{-1} day^{-1}
The effectiveness of education campaign	ε	0 – 1

By solving the system of differential equations. The numerical results showed the relationship between the parameters of education campaign rate and basic reproductive Number in Table 2.

Table 2. The relationship between the parameters of effectiveness of Education Campaign and Basic Reproductive Number

Education campaign rate (ε)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.85	1
Basic reproductive Number (R_0)	1.497	1.348	1.198	1.048	0.898	0.749	0.599	0.449	0.299	0.150	0

The analysis model was found that the stability of equilibrium points when the Education Campaign $\varepsilon = 0.4$, have basic reproductive number $R_0 = 0.8980$, and the Education Campaign $\varepsilon = 0$, the disease endemic equilibrium $R_0 = 1.4970$. The Education Campaign rate is the factor affecting to the mathematical modeling.

Stability of the endemic state

We changed the values of Education Campaign $\varepsilon = 0.999$, and the values of the other parameters are given in Table 1. We have obtained the eigenvalues, and basic reproductive numbers are: λ_1 =-0.01200000, λ_2 =-0.01200000, λ_3 = -0.304000181, λ_4 =-0.523999819 and R_0 = 0.002360<1. All of the eigenvalues are negative, and the basic reproductive is less than one, the endemic equilibrium point will be local asymptotically stable [4]. as shown in Figure 2.

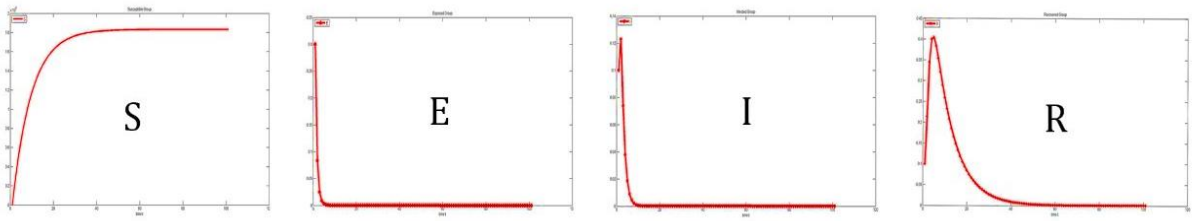

Figure 2. Time series (S) Susceptible human, (E) Exposed human, (I) Infected human, (R) recovered human. The solutions approach to the disease-free equilibrium state.

We changed the values of Education Campaign $\varepsilon = 0.4$, and kept the values of the other values of parameters to be those given in Table 1, we obtained the eigenvalues and basic reproductive numbers are: λ_1 =-0.01200000, λ_2 =-0.01200000, λ_3 =-0.15181961, λ_4 =-0.26218039 and $R_0 = 0.8980$ <1. Since all of eigenvalues have been negative and the basic reproductive has been less than one, the endemic equilibrium point will be local asymptotically stable. as shown in Figure 3.

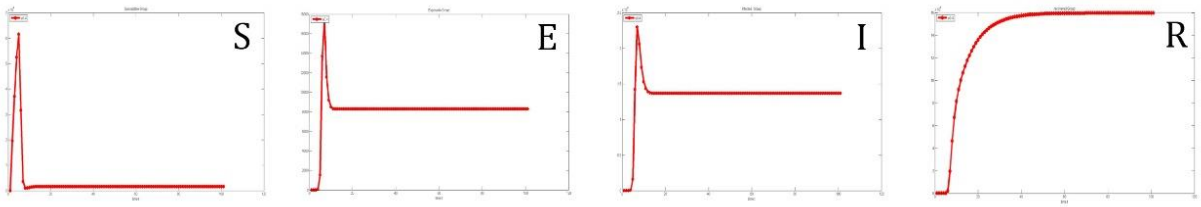

Figure 3. Time series (S) Susceptible human, (E) Exposed human, (I) Infected human, (R) recovered human. The solutions approach the endemic equilibrium state to the disease-free state.

We changed the values of Education Campaign ε =0.5, 0.6, 0.7, 0.8, and 0.85. Also, kept the values of the other values of parameters to be those given in Table 1, we have the eigenvalues and basic reproductive numbers are: $\lambda^4 + A\lambda^3 + B\lambda^2 + C\lambda + D = 0$,A=16.89534009, B=7.02090688, C=0.73721679, D=0.00786477, ABC>C^2+A^2D and R_0=0.898, 0.749, 0.599, 0.449, 0.299 and 0.150 (R_0 <1). Since all of eigenvalues have been negative and the basic reproductive has been less than one, the endemic equilibrium point will be local asymptotically stable [4] as shown in Figure 4-7.

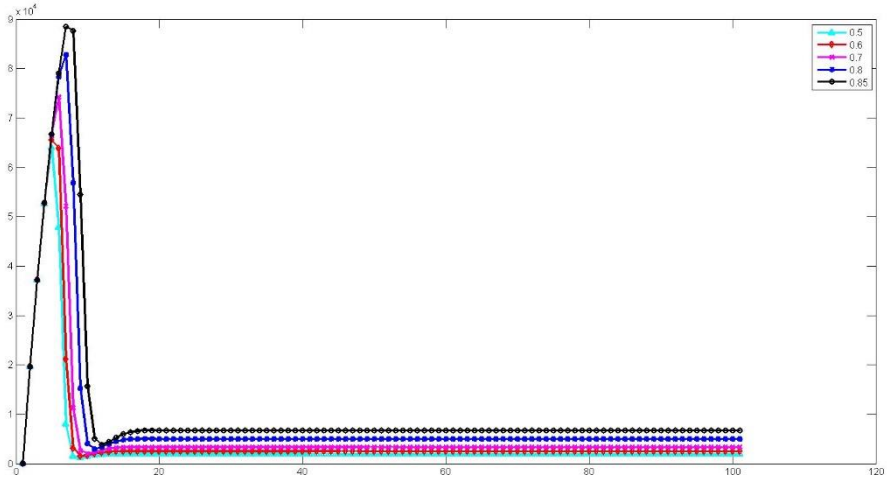

Figure 4. Time series of Susceptible human on Education Campaign rate ε =0.5, 0.6, 0.7, 0.8 and 0.85, respectively. The values of parameters are in the text. The solutions approach the endemic equilibrium state to the disease-free state.

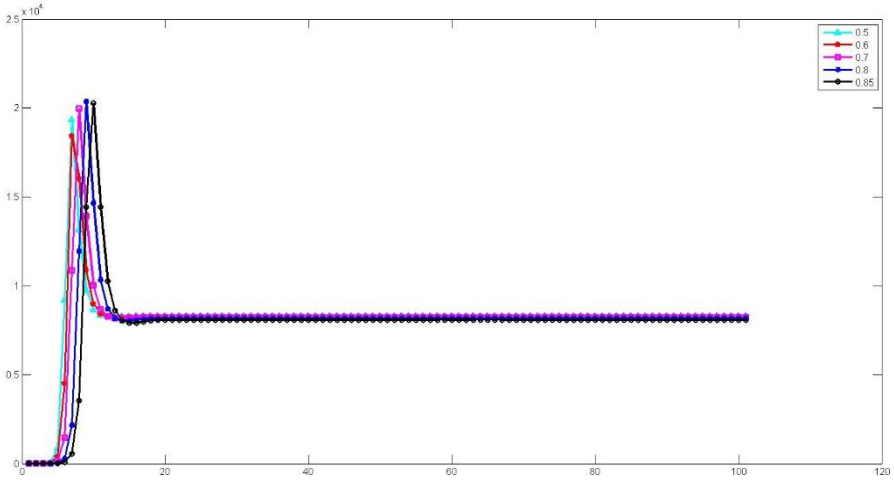

Figure 5. Time series of Exposed human on Education Campaign rate ε =0.5, 0.6, 0.7, 0.8 and 0.85, respectively. The values of parameters are in the text. The solutions approach the endemic equilibrium state to the disease-free state.

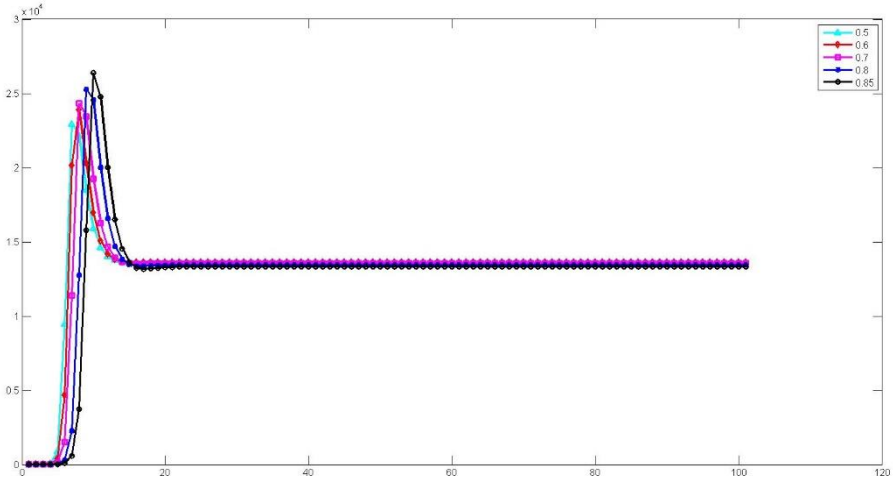

Figure 6. Time series of Infected human on Education Campaign rate ε =0.5, 0.6, 0.7, 0.8 and 0.85, respectively. The values of parameters are in the text. The solutions approach the endemic equilibrium state to the disease-free state.

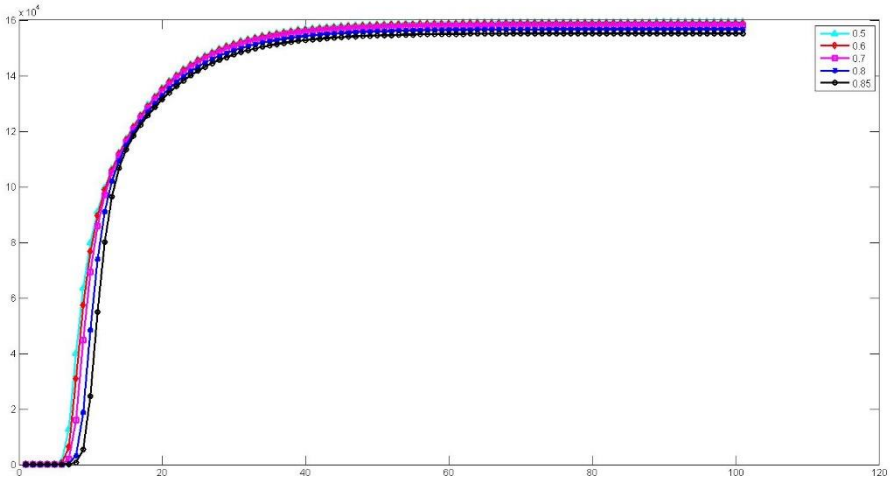

Figure 7. Time series of Recovery human on Education Campaign rate ε =0.5, 0.6, 0.7, 0.8 and 0.85, respectively. The values of parameters are in the text. The solutions approach the endemic equilibrium state to the disease-free state.

This study found that the Education Campaign rate is one of the factors affecting the dynamics of a mathematical model SEIR for controlling the spread of Rotavirus infection. It was explored that if the population at risk of infection with Rotavirus infection knows the prevention of Rotavirus infection less will contribute to the spread of the disease increases. If the most population at risk of infection with Rotavirus infection knows the prevention of Rotavirus infection, then it will contribute to the spread of the decreased disease until there is no further spread of Rotavirus infection. The population at risk of infection with knowledge about the prevention of Rotavirus infection, is not less than 40 percent of the total population, and will contribute to the spread of the disease until there is no further spread of infection.

Discussion

In this study, we proposed the dynamics model of Rotavirus infection by considering the education campaign. We analyzed the model by a standard method in which we determined equilibrium points and investigated the stability of the model. The basic reproductive number is obtained through the next generation method. The Education Campaign rate is the factor affecting the mathematical modelling. In epidemiology, the basic reproductive number is the number of secondary cases generated by a primary infectious cause for the mathematic model, the basic reproductive number is the threshold parameter for determining the stability of the model at each equilibrium point. The stability of the system is investigated using the Roth-Hurwitz criteria. The qualitative behaviours of this model are shown in Fig. 3. We found that when Education Campaign rate is 0.4, 0.5, 0.6, 0.7, 0.8 and 0.85, respectively. The population at risk of infection with knowledge about the prevention of Rotavirus infection is not less than 40 percent of the total population will contribute to the spread of the disease until there is no further spread of infection.

Conclusion

It concluded that when the value of the education campaign rate decreases, the number of infected human increase. The basic reproductive number is greater than one, meaning the Rotavirus infection will occur in the community. On the other hand, when the value of the education campaign increase, the number of infected human decrease. The basic reproductive number is less than one, meaning that the Rotavirus infection will have died out the community.

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