

ANALYSIS BY USING A SIMPLE MATHEMATICAL MODELING ON DENGUE IN ODISHA

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ABSTRACT. Dengue fever is a mosquito - borne viral disease. Warmer weather and rain bring excellent breeding ground for mosquitoes. Dengue is mainly spread by *Aedes Aegypti* mosquitoes. Early and accurate diagnosis is critical to reduce although dengue fever is usually self - limiting. Dengue infection has come up as a public health challenge in tropical nations. In Odisha, transmission of dengue disease has increased very rapidly, but it is still endemic in nature there. In this paper we described SIR model with the help of which we simulate and compare it with the given data. Since, dengue is a vector - borne disease, so SIR model is an approximation.

1. INTRODUCTION

Dengue fever is high on the list of mosquito - borne disease. Warmer weather and rain bring excellent breeding ground for mosquitoes, which transmitted the disease to humans. It transmitted by the bite of infected *Aedes Aegypti* mosquitoes and exists in two forms - Dengue Fever (DF) and the Dengue Hemorrhagic Fever (DHF) [1]. Dengue fever has the mortality rate of less than 1% when detected early but when left untreated, the mortality rate is as high as 20% [2]. It is possible to become infected by dengue multiple times because the Dengue virus (DENV) has four different serotypes known as DENV - 1, DENV - 2, DENV -3 and DENV - 4. A person infected by one of the four serotypes will never be infected again by the same serotype, but he loses immunity of the other three serotypes in about 12 weeks and then becomes more susceptible to developing dengue Hemorrhagic fever [3]. Dengue is the fastest spreading vector - borne viral disease now endemic in over 100 countries. At present half of the world population is living in areas at risk for dengue [4]. In India, the first outbreak of dengue was observed from Vellore in 1956 and first Dengue Hemorrhagic Fever outbreak was observed from Kolkata in 1963. In 2013, more than 75000 dengue cases were recorded from India with 193 deaths [6]. Dengue virus has also been recently detected in *Aedes albopictus* [7]. *Aedes aegypti* has a wide spread distribution in many towns and cities of India. Now this vector is spreading to rural areas also [8, 9]. Dengue has not been reported in Odisha, state in India and for the first time in 2010. In 2011

2010 *Mathematics Subject Classification.* 93A30, 92D30, 34A34.

Key words and phrases. SIR Model, Epidemic, Endemic, Basic reproduction number.

Submitted Jan. 27, 2020. Revised Feb. 13, 2020.

many more positive cases reported. Maximum numbers of cases were found in 2012. Majority (47.86%) of cases were detected in the month of September. The most common affected age group was 11 to 20 years. DENV - 1 and DENV - 2 were the detected serotypes [10]. Mathematical modeling has emerged as a powerful tool for understanding the dynamics of the spreading of disease and might be useful in controlling or eliminating disease[11].With even the simplest models, such as classical SIR(susceptible-infected-recovered) model can have significant implications for science and policy. In order to model this behavior, we will use Kermack and McKendrick's classical epidemic SIR model which use Ordinary Differential Equations as an appropriate modeling formation [12]. The purpose of our study is to describe SIR model in which we will compare and simulate it with actual data in 2013, when out of 1980 samples, 733 were positive for dengue [13].

2. STUDY SITE AND CLIMATE

Our study site is Odisha 20.9517°N, 85.0985°S is situated in northeastern part of India. The Climate of Odisha is tropical. It is warm almost throughout the year.(see Figure 1)



FIGURE 1. Map of Odisha

3. AVAILABLE DATA USED

For Research purpose, total reported cases data have been used in 2013, when out of 1980 samples, 733 were positive for dengue [13].

4. KERMACK AND MCKENDRICK'S CLASSICAL SIR MODEL

In order to understand the behaviour of infected by Dengue, we will use a classical SIR model which use Ordinary Differential Equations in which interaction happens in the variables(S, I and R) given below in a short period of time:-

S= number of susceptible individuals for Dengue

I= number of infected individuals for Dengue

R= number of recovered individuals for Dengue

In SIR model by Kermack and McKendrick (1927) assumes a fixed population $N(t) = S(t) + I(t) + R(t)$ derived three equations that can be used to simulate the deterministic spread of disease through this fixed population -

$$(i) \frac{dS}{dt} = -\beta SI$$

$$(ii) \frac{dI}{dt} = \beta SI - \gamma I$$

$$(iii) \frac{dR}{dt} = \gamma I$$

Where $\beta = \text{rate of infection}$ and $\gamma = \text{rate of recovery}$.

The initial value of the SIR model must satisfy the following conditions : -
 $S(0) = S_0 > 0, I(0) = I_0 > 0, R(0) = 0$.

In this types of model the population is closed, such that these three (S, I, R) make up the entire population and there are no births, deaths (for any cause other than Dengue), immigration and emigrations. It is assumed that the rate of infection and recovery is much faster than the time scale of birth and deaths and therefore, these factors are ignored in this model.

The compartment and transition of the SIR model is in the figure:-
 (see Figure 2)

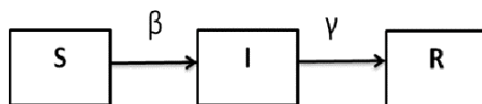


FIGURE 2. SIR Model

5. SIR MODEL GRAPH WITH ACTUAL DATA

For examine the actual behavior of dengue in Odisha, we have taken $\beta = 0.00015, \gamma = 0.4, S(0) = 1980, I(0) = 733, R(0) = 0$

From MATLAB code on equations (i) to (iii) the graph of SIR Model is created. (see Figure 3) The Basic reproduction number is taken as 1 (As here dengue is endemic in nature). The number of Susceptible, S decreases till 15 days as dengue comes into the system. After 15 days it becomes constant. The infectives, I decrease continuously because of the recovery, R. And R increases till 20 days then it becomes constant. As the inverse relation of S and R, R increases as S decreases. The graph also signifies that 'N' is always constant via a linear relation (equations (i) - (iii)).

$$\frac{dS}{dt} + \frac{dI}{dt} + \frac{dR}{dt} = (-\beta SI) + (\beta SI - \gamma I) + (\gamma I) = 0.$$

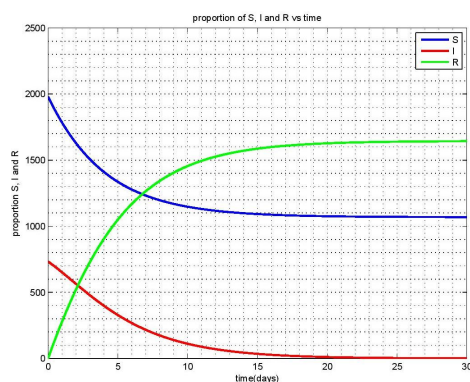


FIGURE 3.

6. SIMULATION OF SIR MODEL BY COMPARING WITH ACTUAL DATA

SIR modeling is a powerful tool to understand the dynamics of spreading of infectious disease with the maximum simplicity. In order to examine the behavior of dengue in Odisha, we have taken $\beta = 0.4, \gamma = 0.4, S(0) = 0.72, I(0) = 0.28, R(0) = 0$.

From MATLAB code on equations (i) to (iii) graph of SIR Model created.(See Figure 4). The Basic reproduction number is taken as 1 (As here dengue is endemic

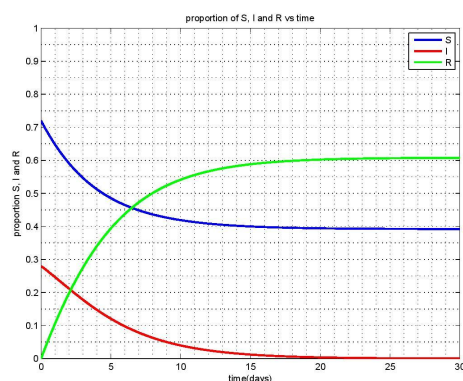


FIGURE 4.

in nature).

The number of Susceptible, S decreases till 15 days as dengue comes into the system. After 15 days it becomes constant. The infectives, I decrease continuously because of the recovery, R. And R increases till 20 days then it becomes constant. As the inverse relation of S and R, R increases as S decreases. The graph also

signifies that 'N' is always constant via a linear relation (equations (i) - (iii)).

$$\frac{dS}{dt} + \frac{dI}{dt} + \frac{dR}{dt} = (-\beta SI) + (\beta SI - \gamma I) + (\gamma I) = 0.$$

7. CONCLUSION

In this study, Kermack and McKendrick's classical SIR model has emerged as an important tool for understanding the dynamics of spreading of Dengue. It is noted that the population is constant in the SIR model. Because of no vaccination the susceptible never reaches to zero. On taking 72 % population as susceptible and 28 % as infected then model fits the actual data (using the goodness of fit method). The prepared model is very realistic to Dengue in Odisha.

REFERENCES

- [1] Singh, B., Jain, S., Khandelwal, R., Porwal, S. and Ujjainkar, G., Analysis of a dengue disease transmission model with vaccination,5(3),237-242,2014.
- [2] <https://www.medscape.com/answers/215840-43425/what-is-the-mortality-rate-for-dengue>.
- [3] Michael, B., Deen, J., Buchy, P., Gubler, D., Harris, E., Hombach, J., World Health Organization dengue guidelines for diagnosis, treatment, prevention, and control new,2009.
- [4] World Health Organization. <http://www.who.int/mediacentre/factsheets/fs104/en>. Geneva: WHO. Estimated incidence, prevalence and TB mortality ,2004.
- [5] Yadav a RL, Narsimham MVVL, Dengue/DHF and its control in India. Dengue News,17, 3-8, 1992.
- [6] National Vector borne Disease Control Programme, Dengue cases and deaths in the country since 2009, Delhi, India; NVBDCP - <http://nvbdc.gov.in/den-cd.html> .
- [7] Das, B. P., Kabilan, L., Sharma, S. N., Lal, S., Regu, K., Saxena, V. K., Detection of Dengue Virus in Wild Caught Aedesalbopictus (Skuse) around Kozhikode Airport, Malappuram District, Kerala, India,28, 210-220, 2004.
- [8] Sharma, S. N., Raina, V. K., Kumar, A., Dengue/DHF: an emerging disease in India. The Journal of communicable diseases, 32(3), 175-179,2000.
- [9] Kumar, A., Sharma, S. K., Padbidri, V. S., Thakare, J. P., Jain, D. C., Datta, K. K., An outbreak of dengue fever in rural areas of northern India. The Journal of communicable diseases, 33(4), 274-281,2001.
- [10] Padhi, S., Dash, M., Panda, P., Parida, B., Mohanty, I., Sahu, S., Narasimham, M. V., A three year retrospective study on the increasing trend in seroprevalence of dengue infection from southern Odisha, India. The Indian journal of medical research, 140(5), 660-664, 2014.
- [11] Braselton, J. P., Bakach, I., A survey of mathematical models of dengue fever. Journal of Computer Science Systems Biology, 8(5), 255,2015.
- [12] Kermack, W. O., McKendrick, A. G., A contribution to the mathematical theory of epidemics. Proceedings of the royal society of london. Series A, Containing papers of a mathematical and physical character, 115(772), 700-721,1927.
- [13] Rao, M. R. K., Padhy, R. N., Das, M. K., Episodes of the epidemiological factors correlated with prevailing viral infections with dengue virus and molecular characterization of serotype-specific dengue virus circulation in eastern India. Infection, Genetics and Evolution, 58, 40-49,2018.

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