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ARTICLE

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A MATHEMATICAL STUDY ON FEW EARLY COVID 19 WAVES IN WEST BENGAL

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A comparative study of different COVID 19 waves has been presented with the help of a heterogeneous SIR (Susceptible- Infected-Recovered) model on West Bengal. The estimated parameters of the model also help us to study the nature of the infections in different waves. Our study shows that the 3rd wave is much infectious in comparison to other waves, as par the computed R_0 values and the fatality of the first wave is much higher in comparison to other waves. The study shows that the devastating nature of the disease has curved to some extent due to the weakening of the variants of SARS-CoV2 and the gradual development of immunity against the diseases.

Introduction

The first positive case of COVID 19 was confirmed in the Indian state of West Bengal on 17 March 2020 in Kolkata. Till 18th August, 2022, approximately 2103761 positive cases were reported with 21430 cases of death in West Bengal in four major waves of the pandemicin last two and half years. The major recorded fatality was observed in first two waves.

We know that Novel coronavirus (COVID 19) pneumonia is influenced by many factors, but here a time-phased approach has been considered to construct a suitable model to explain different time periods. The inexperience in the early phase of the epidemic made it difficult to make sound judgments on the unprecedented malignant epidemic COVID 19 [1]. The present study can be used to predict future infections by the disease. Zhao and others[1] presented three different models based on different phases / time zones during 23rd January to 16th May, 2020 of the pandemic in the Hubei province of China. Suneel Prajapati and Narasimha Kumar GV[2] have tried to throw some light on the concept of herd immunity amid COVID-19 crisis. A comparative study on fatality of the disease in four phases in West Bengal has also been included in the study. Our target is to formulate a model of the disease so that we can study the past infections.

The Mathematical Model

It has been observed that the epidemic situation is divided into different phases/ waves depending on different time points and arrival of different variants of SARS-CoV2**.** In the study a vaccinated - heterogeneous SIR model (Susceptible, Infected and Recovered individual) will be effectively applied in different time zones/ phases by incorporating birth / death rate of the population of the state. The daily number of active cases, deaths and the vaccinated population will be considered. In the model, following assumptions will be considered:

1. The population is evenly distributed.
2. The cured people will be permanently immune to the virus and will not be re-infected for a particular phase / wave.
3. The antibody created within the individuals is not permanent and decreases with time.

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4. The removal or recovery rate will include cure rates and the disease mortality.

5. The impact of population movement between states and districts will be ignored.

Fig. 1. Basic Diagram of SIR Model

Mathematically we will solve a system of first order ordinary differential equations with initial values of the parameters related to the transmission of the disease[3-6]

$$\frac{dS}{dt} = -\frac{\beta * S * I}{N} - p * S - \mu * S + \mu * N$$

$$\frac{dI}{dt} = \frac{\beta * S * I}{N} - \gamma * I - \mu * I \quad (1)$$

$$\frac{dR}{dt} = \gamma * I + p * S - \mu * R$$

Where β represents the effective transmission rate, γ represents the removal or recovery rate, μ is the birth / death rate (assumed to be equal for the model) and p is the vaccinated/ immuned population rate.The graphs (Figure 2, Figure 3 and Figure 4) represent a comparison between actual and our computed data with respect to the parameters as mentioned in the table (Table 1). Our computations agree with the actual data (https://www.wbhealth.gov.in/pages/corona/bulletin).infectious disease model on COVID-19, as presented in the study will have a wide range of operating prospect including prediction and control for future. Our study reveals that 3rd wave is much infectious in comparison to other waves, as par the computed R_0 values.

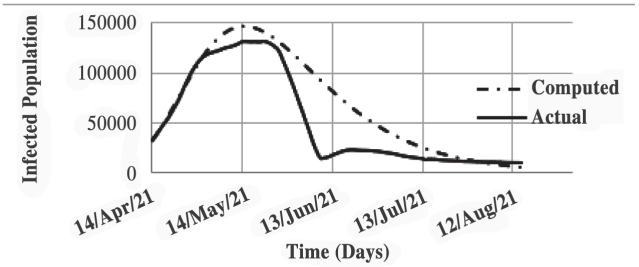

Fig. 2. Computed and Actual Daily Active Cases in 2nd Wave of COVID 19 in West Bengal

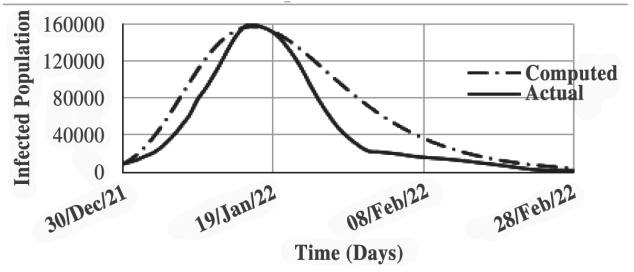

Fig. 3. Computed and Actual Daily Active Cases in 3rd Wave of COVID 19 in West Bengal

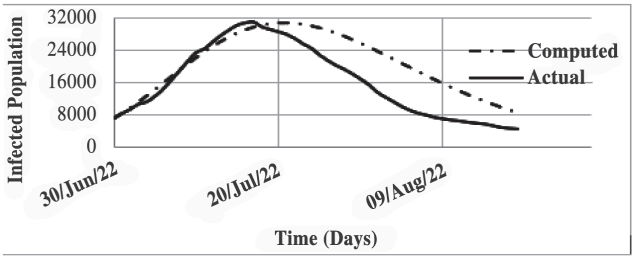

Fig. 4. Computed and Actual Daily Active Cases in 4th Wave of COVID 19 in West Bengal

Discussion

The COVID-19 pandemic was first confirmed in the Indian state of West Bengal on 17 March 2020 in Kolkata.

Table 1. Model Parameters

COVID 19 Waves	Transmission rate (β)	Recovery rate (γ)	Basic reproduction ratio $R_0 = \frac{\beta}{\gamma}$	Average death / birth rate per 1000 people in West Bengal*	Population of West Bengal (Census 2011)
2nd wave	0.21	$\frac{1}{14}$	2.94		
3rd wave	0.46	$\frac{1}{7}$	3.22	6.3	91276115
4th wave	0.33	$\frac{1}{7}$	2.31		

*State Statistical Handbook 2014, Government of West Bengal

The exponential nature of growth pattern of the disease was observed among the infected peoples. The people of West Bengal faced severe problems along with other states during the onset of the pandemic. But with the medical and other supportive help, they fought against the disease. The concepts of social distancing, hot spot, containment zones were introduced to control the rapid spread of the disease. In the first phase/ wave of the disease fatality rate was high and the people of our state fought the battle without vaccine. In this wave seniors were affected more and among the male and female COVID positive individuals, men (58 %) were affected than women (42%) (The Times of India, Dec 18, 2021).The average fatality rate was highest in this wave (Table 2). The deaths caused in this wave[7]was also highest among all the waves (Figure5). The number is very close to the 2nd wave which falls next to the first wave.

The devastating nature of the disease was curved to some extent in the 2nd wave. The total positive cases in this wave[7] of COVID 19 in West Bengal was also much higher in comparison to other waves (Figure 6) and also the occupancy of COVID Beds in the hospitals on the day of highest active cases was highest in this wave. The process of vaccination was introduced before the onset of the wave. The infection rate as well as number of infections was found to be comparatively larger in the South Bengal districts, especially in Kolkata, North 24 Parganas and Howrah. This may be due to high density of the population, major Railway Stations and International/ National Airport etc. Among North Bengal districts, it was observed that infections were greater in the districts of Malda and Darjeeling, especially in and around Siliguri. This may be due to cosmopolitan in nature and the migrant people. In this wave, more people were died with no known Co-morbidities in West Bengal and delta variant of SARS-CoV2 (COVID 19) dominated the wave. The genomes sequencing revealed that in the months of April 2021 and June 2021, among positive samples 59% and 89% respectively were the delta variants (The times of India, Sept. 22, 2021). It has also been observed that mostly COVID deaths were found in the age group 60-75 years and among co-morbidities, hyper tension and diabetes remained the primary.

The third wave of the disease in West Bengal was triggered by the new variant Omicron along with previous delta variant. The astronomical rise in the number of cases in short duration of time was observed. The positivity rate was also much higher during the onset of the wave.

Table 2. Comparative Study of Different Waves with Virus/ Variant Characteristics.

COVID 19 Waves	Virus / Variant of COVID 19 dominated	Symptoms of the COVID patients/Specialty of the variant	Age group of patients mostly affected	Average fatality rate[7] (%)
1st wave	SARS-CoV2	Fever, Cough, tiredness, loss of taste or smell, rash on skin and shortness of breath.	Aged Male patients.	1.20
2nd wave	Delta variant	1. Almost all symptoms as observed in 1st wave. 2. Delta variant has the immune-escape property. 3. Hypertension and diabetes remain the primary co-morbidities in COVID deaths across all age groups.	Youth and women were affected more.	1.19
3rd wave	Omicron variant and Delta variant.	1. Few symptoms as observed in 1st wave. 2. The Omicron variant causes less severe infection and large number of peoples were being affected despite taking two doses of COVID 19 vaccines. 3. Omicron has the ability to bypass the immunity imparted by vaccines administered so far.	Children were affected at a large extent.	1.06
4th wave	BA.4 and BA.5, subvariants of Omicron.	1. Mostly mild symptoms as observed in 1st wave. 2. Variants are highly infectious and not that of life threatening as that of earlier variants. 3. Diseases caused by the variants is mild like BA.2.	People of all age groups.	1.02

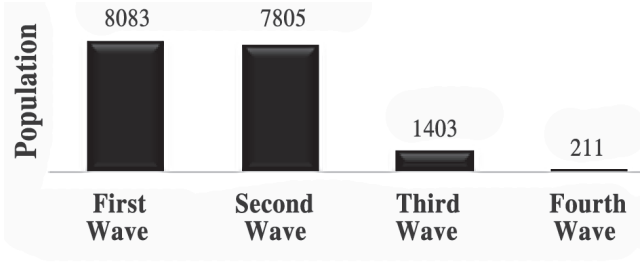

Fig. 5. Comparative study of deaths in different waves of COVID 19 in West Bengal

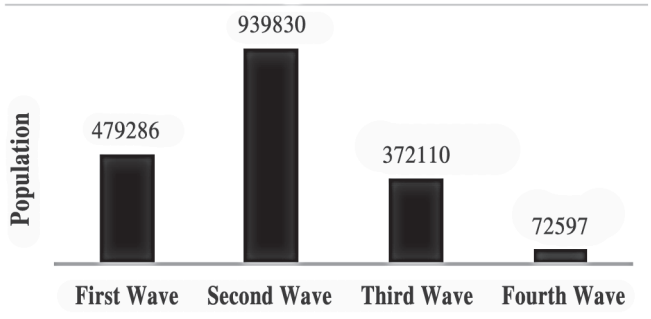

Fig. 6. Comparative study of total positive cases in different waves of COVID 19 in West Bengal

The sub-variants of Omicron, mostly the BA.4 and BA.5, were dominated the fourth wave. They were highly infectious but not that of threatening as compared to the previous waves. Nearly 65732 positive cases and 165 deaths were recorded in this phase which is comparatively lowest as compared to other waves.

The comparative study of different waves as presented in the table (Table 2) shows that the devastating nature of the disease has curved to some extent due to the weakening of the variants of SARS-CoV2 and at the same time vaccination has reduced the fatality of the diseases to some extent.Finally, it has been observed that, in one side the immunity of the people against COVID variants has improved and on other side fatality power of the new variants has also reduced considerably. Naturally, one may say that we are gradually moving back towards normal life and also approaching towards herd immunity against the COVID 19 pandemic in our state.

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