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Mathematical Modelling of Transmission of Covid-19 in Indian Context: An Impact of Lockdown

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Abstract

Mathematical Modelling study has been carried out to model the out spread of Covid-19 in a localized society of India. Based on the transmission mechanism of Covid-19 authors established dynamics model of six chambers with population birth rate and mortality. Ordinary differential equations are used to model the system mathematically and solved numerically using ODE23 scheme. India imposes lockdown in very early stage of the Covid-19 transmission and impact of lockdown has been discussed through the mathematical model. Parameters are considered in view of the March scenario in India and the impact we got is quite similar with the present situation.

Keywords : *COVID-19, Disease Spreading, Lockdown, Mathematical Modelling.*

1.0 Introduction

Covid-19 was first observed in the December 2019 in China and named by World Health Organization (WHO). This new type of Corona virus has become pandemics and spread throughout the world in very short span of time. The countries with high population have to suffer most as it is an infectious virus and transmitted by contact. With a population of approximately one hundred and thirty cores people and with a high population density, India may stand in the border line situation and probably suffer most if it spreads in community. SIR-type models have been introduced earlier and transmission of different virus has been modelled using this method. The transmission dynamics of Ebola Virus mostly described through SI model[15], SIR model (Fisman et al. 2014), SEIR model (Chowell et al. (2004)) and SIRD model[1]. Where S stands for Susceptible, E for infected, I for infectious, R for recovered and D for dead or deceased. Cao et al. used SEIQDR model to predict the impact of epidemic and to suggest the prevention and control measures of COVID-19, where population birth rate and natural mortality rate has not been considered[2].

In this present model authors considered a specific town/ city and modelled with six chambers incorporated with population birth rate and mortality. Ordinary differential equations are used to model the system mathematically and solved numerically using ODE23 scheme. Present mathematical model will show us the impact of the full lockdown.

2.0 Mathematical Model

After the outbreak of the COVID-19 Central Government and State Governments of India has considered several measures as suggested by WHO. We divide the total population in five parts. Susceptible people are denoted by S (Susceptible). As the incubation period of the virus is 2 to 14 days and some of the people remains infected but not identified. Majority of the Indian population is young so the people with good immunity can recovered directly without showing the major symptoms. Authors considered this group of people as C (Unidentified

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Infected). Some people are infected and in hospital or quarantine centers, this group of people has been identified as I (Infected). Due to the infection some people will die and the people of this category has been considered as D (Dead/ Deceased) and majority people with good immunity will be survived and denoted by R (Recovered). In some of the different items like metal shit or plastic substances etc this virus may be alive for more than ten to twelve hours we mark this as P (pathogens).

Classes	Explanation of the classes
S	Susceptible
I	Infected
C	Unidentified Infected
R	Recovered
D	Dead/Deceased
P	Pathogens that can carry the virus.

Growth rate of normal human being is considered as π. Authors consider that susceptible persons can be infected mainly from four sources: (i) From Infected (ii) From Unidentified infected (iii) During the Funeral (iv) From Pathogens present in the society. Infected persons have two probabilities: (i) Recovered or (ii) Dead also they may be able to contribute for creating pathogens. Unidentified infected can be identified as infected or recovered or dead or contribute for creating pathogens. Susceptible, Infected, Recovered and Unidentified infected can die naturally at the rate μ. Dead human bodies handled carefully during their funeral at the rate b. Pathogens get their fuel from I, C and D with a constant rate and also get a source from the nature itself and it is denoted by σ. Where the destruction rate in the atmosphere is denoted by η. The transmission dynamics can be modelled pictorially and given in Fig.1:

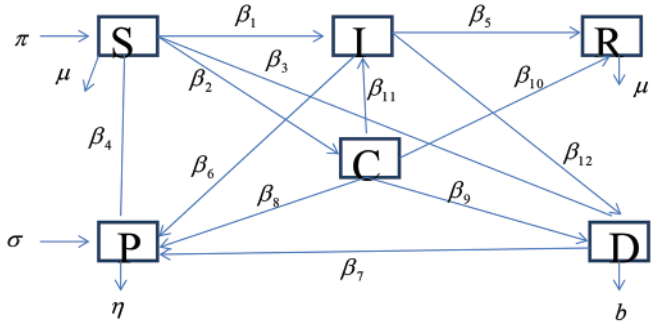


Figure 1.

Transmission of Covid-19 can be modelled using ordinary system of differential equations. Corresponding values of the variables are considered from the data available in Covid-19.org and world-o-meter. Mathematical Modelling of the transmission dynamics using this model is as follows:

$$\frac{dS}{dt} = \pi - (\beta_1 I + \beta_3 D + \beta_4 P + \beta_2 C)S - \mu S$$

$$\frac{dI}{dt} = (\beta_1 I + \beta_3 D + \beta_4 P)S + \beta_{11} C - (\beta_{12} + \mu + \beta_5)S$$

$$\frac{dC}{dt} = \beta_2 CS - (\beta_9 + \beta_{11} + \beta_{10} + \mu)\mathrm{C}$$

$$\frac{dR}{dt} = \beta_5 I + \beta_{10} C - \mu R$$

$$\frac{dD}{dt} = (\beta_{12} + \mu)\mathrm{I} + (\beta_9 + \mu)C - bD$$

$$\frac{dP}{dt} = (\sigma + \beta_6 I + \beta_7 D + \beta_8) - \eta P$$

Also the initial condition for the variables is well known to us and considered as:

$S(0) = c_1$; $C(0) = C_2$; $I(0) = c_3$;

$D(0) = 0$; $R(0) = 0$ and $P(0) = c_4$ where c_1, c_2, c_3 and c_4 are constant and that can vary for country to country. Where we considered t=0 when the first case is detected and we will consider the values for that time.

The present model is dynamically consistent and continuous model so the stable solution for the present system of equations are quite possible and can be proved using the methodology used by [1].

3.0 Numerical Solution and Discussion

The Euler method is a first-order numerical procedure. It often has a convergence problem so the error will become larger. To reduce the error in the numerical solution many methodologies have been proposed and implemented by the researchers and scientists. Solving this present problem third order Runge-Kutta method has been used. Whereas the inbuilt MATLAB function ODE23 estimates the errors automatically and interpolate to reduce the error significantly. The system of ordinary differential equation has been solved using ODE23 in MATLAB. ODE23 uses Runge-Kutta method of third order. In this present manuscript authors considered seventeen parameters to discuss the problem. Whereas most of the parameters (twelve) authors considered are depended upon the infection spread Modelling. Infection may be transmitted by the direct connection or by the indirect connections. The death rate due to Covid 19 has been varied depending upon the countries. Corresponding values of the variable are considered from the past scenario and the considered parameter values and their justifications are shown in Table 1:

Table 1

Variables	Range of the variables	Considered
β_1	Maximum 0.00435, min=0	0.005
β_2	We do not have clear conception but we can say 5% of the population. (will be affected in one month)	0.05
β_3	Chance is less but not equals to zero	0.0001
β_4	Chance is less but not equals to zero	0.0001
β_5	Recovered /Total cases ≈ 0.26	0.26
β_6	Shedding with less chances	0.0001
β_7	Shedding with less chances	0.0001
β_8	Good chance to contaminant.	0.06
β_9	Death rate must be same for unidentified Infected (β_{12}) ≈ 0.07	0.07
β_{10}	Recovered rate is again same for unidentified Infected (β_5) ≈ 0.26	0.26
β_{11}	Newly infected cases vary with different countries with different situations and different stages. So as an average we can consider 60% new cases in one month.	0.6
β_{12}	Dead/Total cases = 0.07	0.07
π	Birthrate in India per hundred people in month 0.115.	0.115
η	Not yet confirm but less	0.01
μ	Death rate in India per hundred people in month 0.062.	0.06
σ	Environmental contribution is less.	0.01
B	80% of the dead bodies handled carefully.	0.8

Data's are mostly taken from "world o meter"(www.worldometers.info/coronavirus) and covid19.org.

From Figure 2 it is clear that if we consider a close society of 100 people without any restriction then in between two months all the people of the society becomes affected. We consider that initially one infected people and three unidentified infected people are present. It is clear from the study that from zero to fifteen days the growth rate of the infected people is slow whereas the number of unidentified infected increases rapidly. In due course of time after one and half month there is a rapid decrease of unidentified infected people whereas the number of infected people increase rapidly and then after third month the number of infected people will be decreased slowly. The recovery of the people will enhance after one month. The number of death due to Covid-19 will not exceed 5 throughout the transmission of this virus.

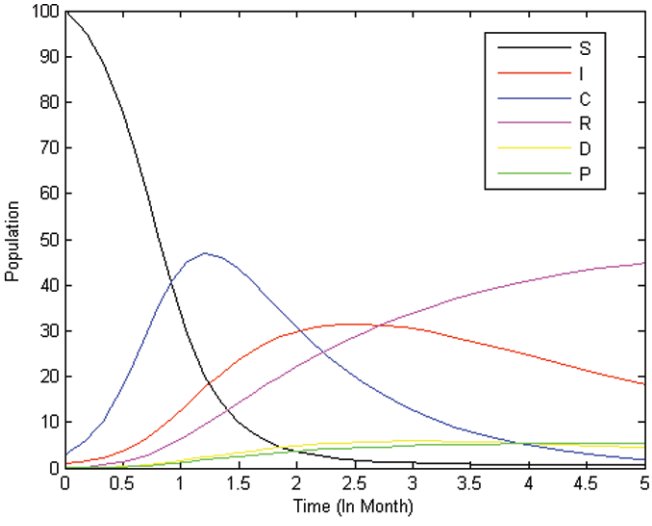


Figure 2: Impact of the Covid-19 in a close society of 100 people for five months

4.0 Impact of Lockdown in India

In very early stage of the transmission of the virus India imposes complete lockdown. In complete lockdown, transmission of the virus from unidentified people to the susceptible person becomes zero and unidentified infected people do not able to provide support to the pathogens. We can be able to show the impact of the lockdown by considering β_2 and β_8 as zero.

From Figure 3 it is clear that if the lockdown is followed strictly for five months then after five months seventy per cent people of the society remains uninfected. The growth of the infected person will be there but which is not that much impactful also the number of death reported due to Covid is

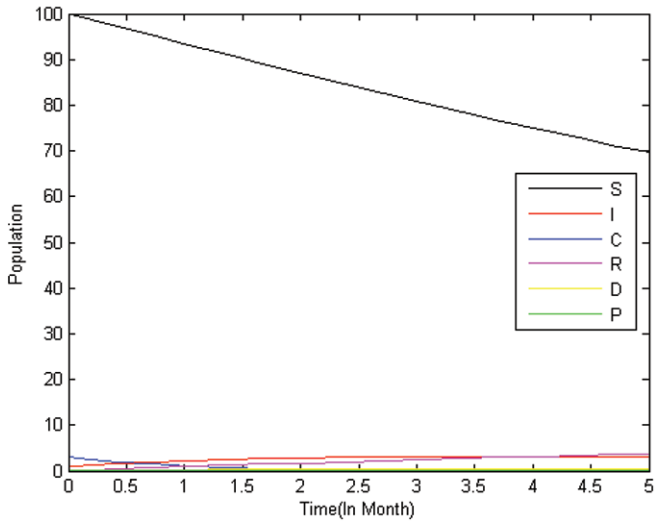


Figure 3: Impact of the Covid-19 in a close society of 100 people in five months with full lockdown

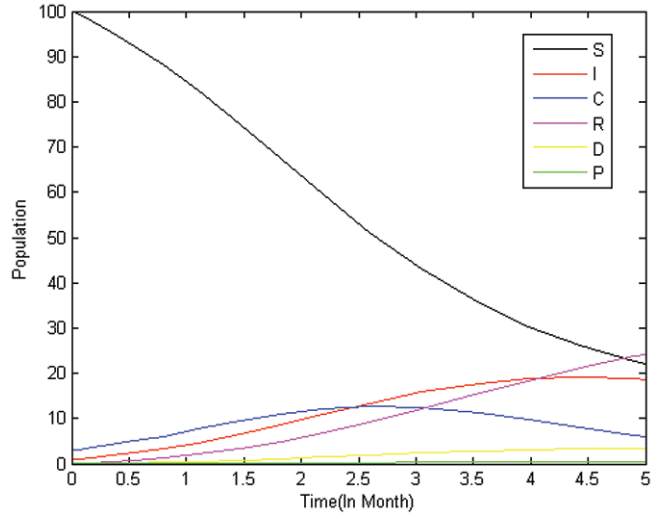


Figure 4: Impact of the Covid-19 in a close society of 100 people in five months with partial lockdown

very less. So we can say that complete lockdown was a good initiative to protect the common people.

The government imposes complete lockdown and tries to maintain it whole heartedly but due to some unfortunate events we can say that we are following partial lockdown. In Figure 4 impact of the partial lockdown has been shown. Eighty per cent of the susceptible people will be infected in five months so does not obeying the rules become costly for us. Number of infected people and unidentified infected will increase rapidly after twenty days. Number of death was also increase and we see a slow rate of recovery.

5.0 Impact of Lockdown withdrawal

Consider that lockdown has been followed strictly and after completion of the lockdown period of five month there is a relaxation. The system reopens in September then in next five months the number of healthy susceptible people will decrease rapidly from seventy to ten. The impact of the reopening is very much clear for the other variables too, all of them started to increase slowly and at fifteen months the number of recovered people will maximum in number and the death will becomes less than 2 per cent that matched with the scenario.

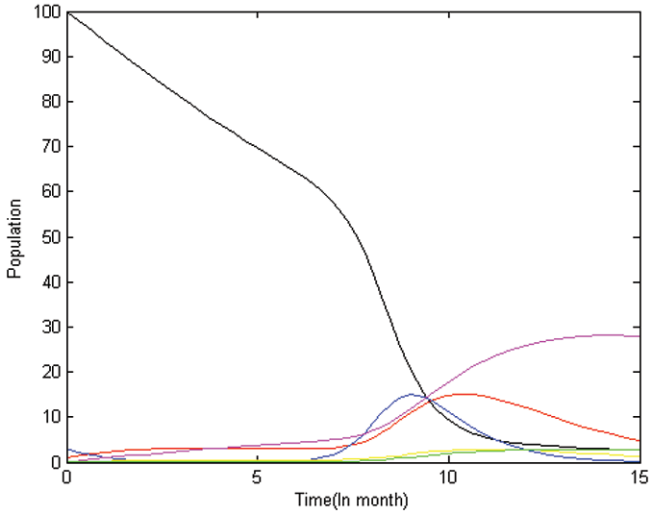


Figure 5: Reopen of lockdown after five months

6.0 Conclusions

Mathematical model with real life data provide us some major conclusions. Analyzing the different situations using this present mathematical model, we can conclude that:

1. If the virus spreads in a normal society without lockdown then it will contaminate the people of the society in one month with only one infected and three unidentified infected. So transmission of the virus was quite fast and must be stopped. So mathematically authors concluded the same well established result.
2. Impact of the Covid-19 virus can be reduced significantly using complete lockdown which is mathematically established again.
3. Partial lockdown was not that much effective to stop the Covid transmission, which is again established mathematically.

4. If lockdown is withheld after august then there is a rapid chance of infection between the people but due to hard immunity death rate will decrease significantly.
5. Withdrawal of lockdown may be helpful for majority of Indian people because they suffered most during the Lockdown.
4. Limitation Transmission of the virus from the unidentified infected may be a function depend on time and that may vary for different societies. In this present Modelling we consider the transmission of the virus in constant rate to simplify our mathematical model. Although the results hold good with the real life situation.

7.0 References

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