IOSR Journal of Mathematics (IOSR-JM)
e-ISSN: 2278-5728, p-ISSN: 2319-765X. Volume 17, Issue 3 Ser. III (May – June 2021), PP 05-12
www.iosrjournals.org

Forecasting COVID-19 Pandemic in Bangladesh by Using Homotopy Perturbation Method

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A B S T R A C T
In this paper, we have discussed the future condition of COVID-19 in Bangladesh with graphical trends by analyzing the present situation.It was an exertion to predict the final epidemic conditions by using the Susceptible-Infected-Recovered (SIR)model.And by applying the Homotopy perturbation method,we solved the SIR model according to the present data for Bangladesh.The results obtained can undoubtedly predict COVID-19 situations.
Keywords*: COVID-19,SIR model, WHO*

Date of Submission: 05-06-2021 Date of Acceptance: 18-06-2021

I. Introduction

COVID-19 has emerged in Wuhan, China, at the end of December 2019.It is an RNA-based virus.The virus that causes COVID 19 is in a family of viruses called Coronaviridae[1].COVID-19 is a nosogenic disease caused by the severe acute respiratory syndrome Coronavirus-2 (SARSCOV-2).Other viruses of this pattern-SARS virus and MERS virus have caused local outbreaks in the past [2].The common symptoms of COVID-19 are volatile, but often include fever,cough,bad headache,fatigue,breathing problems,and loss of smell and taste.[3][4][5].The world is now facing a drastic situation due to COVID-19.More than 216 countries have been affected by COVID-19.The WHO (World Health Organization) officially declared that COVID 19 is responsible for this ongoing pandemic.The first patient of COVID-19 was officially reported on March 8, 2020, in Bangladesh.After a few days, the number of infected people increased in a geometrical pattern,and still,this pattern in Bangladesh is going on.The government of Bangladesh has been exposed to lockdown to curb the COVID-19 and taken many steps(Fig-1).Bangladesh seems to be a highly risky country because of its high population density and confined infrastructure in healthcare systems[6].It is questionable whether to keep the appropriate distance and wear the mask in Bangladesh.As of April 26, 2021, ICDDR,B (International Centre for Diarrhoeal Disease Research,Bangladesh) had reported 748620(+0.44%) total cases where the death toll stood at 11150 (+0.88%).To face the second wave of COVID-19,The government of Bangladesh again declared a so-called "all-pervading"lockdown.The implementation of this so-called "all-pervading" lockdown, which prohibits travel by water, rail, and air.And the government shut the market down to combat the surge in coronavirus cases in the country,amidst demonstrations by small business owners against the move.Collectively, COVID-19 is a curse and a threat to global health, economics, subsistence, development, and a peaceful society.

II. Basic SIR Model

KerMach and McKendrick first disclosed the Susceptible, Infected, and Recovered (SIR) model in 1927.This model is considered the best model for estimating infectious diseases.In this model,it is assumed that the population size always remains constant.In other words, the population is considered to be closed and the sum of susceptible [7],[8].In this modeling process, first of all, we have to recognize the independent and dependent variables.The only independent variable in this model is time.And the dependent variables are S,I,R where they are in three different groups.
S(t) is the susceptible people at the time t
I(t) is the infected people at the time t
R(t) is the recovered people at the time t
For each time t,SIR model equations are described as follows,

$$\frac{dS(t)}{dt} = -BS(t)I(t)$$
$$\frac{dI(t)}{dt} = BS(t)I(t) - AI(t) \qquad (1)$$
$$\frac{dR(t)}{dt} = AI(t)$$

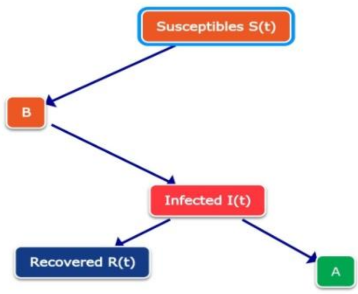
with initial conditions, $S(0) = S_0, I(0) = I_0, R(0) = R_0$ where,B is transmisson coefficient and A is recovery rate.Here,thepopulation,N= S(t)+I(t)+R(t) is a preserved quantity for every time settings.The ratio of transmission coefficient and recovery rate (B/A) is called the basic Reproduction Number R.It is a determinant factor for outbreaks that can detect the expected number of new cases.It depends on the duration of time.The value of R is the same for the same infectious diseases in different populations[9].

Date	Major activities against corona
21 January 2020	Thermal screening for passengers in all international airports, land ports, and sea ports receiving passengers from the COVID-19 affected countries. Quarantine of passengers with fevers, coughs, breathing difficulties, and sore throats.
10 March 2020	Quarantine of individuals without symptoms (with history of transport abroad and individuals having history of contact of foreign returnees or infected individuals Isolation of individuals (imported or local) with positive symptoms
17 March 2020	A ban on incoming flights from the European destinations.
26 March 2020	Closure of all public and private offices
31 March 2020	A ban on people's travel via water, rail, and domestic air routes and public transports.
5 April 2020	Announcement of a stimulus package amounting to some US$8bn to restrict the mass flow of garment workers.

Figure 1: Measures taken by the Government of the People's Republic of Bangladesh

III. Block Diagram of SIR Model

The primary purpose of the block diagram is to show how contagious diseases spread everywhere. People are in a susceptible group that acts to the infected group.And after getting infected,it works on the recovered group.In the final section, people will be healed or die from the disease.



IV. Homotopy Perturbation Method

To get the basic idea of the homotopy perturbation method[10],let's consider the following non -linear equation ,

$$A(u) - f(u) = 0 \quad (2)$$

where, $r \in \Omega$ with the boundary condition,

$$D\left(u, \frac{\partial u}{\partial n}\right) = 0 \quad (3)$$

where $r \in \Gamma$

Where A is general differential operation D is boundary operator.f(r) is known as analytic function,Γ is the boundary of the domain ω .The operator A(u) can be divided in two parts L and N .where L is linear and N is non-linear.Where A(u) is written as follows,

$$A(u) = L(u)+N(u) \tag{4}$$

Equation (4) can be written as,

$$L(u)+N(u)-f(r) = 0 \tag{5}$$

by homotopy technique,we construct a homotopyv[r, p]: $\omega\times[0,1] \in R$ which satisfies,

$$H(v, p) = (1-p)[L(v)-L(u_0)]+ p[A(v)-f(r)] = 0 \tag{6}$$

where $p \in (0,1)$ is an embedding parameter and u_0 is an initial approximation of equation (2),which satisfies the boundary conditions. from the equation (6) ,we have,

$$H(v,0) = L(v)-L(u_0) = 0$$

$$H(v,1) = A(v)-f(r) = 0 \tag{7}$$

The changing process of p from zero to unity is just that of v(r,p) from u_0 to u(r).In topology,this embedding process is called deformation and,$L(v)-L(u_0)$,$A(v)-f(r)$ are called homotopic.Hence,the solution of equation as a power series in p as the following,

$$v=v_0 +v_1p+v_2p^2+v_3p^3+\ldots=\sum_{n=0}^{\infty} p^n v_n \tag{8}$$

by the homotopy perturbation method,an acceptable approximation solution of equation (2)may be described as a series of the power of the p and settings p=1,

$$u = v_0+v_1+v_2+v_3+\ldots$$

$$u =\sum_{n=0}^{\infty} v_n \tag{9}$$

The series is convergent for most case [11],[12],[13],[14].

V. Mathematical Modeling for Bangladesh

This paper has discussed the different sections of Covid -19 disease and estimated that how many people got sick by the COVID-19 in Bangladesh.The data have been collected from the uplink by the WHO (World Health Organization) on 26 April 2021.Using this data,We have given a mathematical scheme in the light of the SIR model and created three couples of differential equations.We have solved those equations using the homotopy perturbation method and got the solutions.These solutions can estimate the current situation in Bangladesh.

Data List (Till 26 April,2021)		
Notations	Contents	sources/process
Total population	164.69 million	Worldometer
Total confirmed cases	745322	WHO
Death	11053	WHO
Recovered	657452	WHO
Active cases	70990	WHO
Susceptible	5345501	WHO

Table 01: Data table for estimating COVID-19 in Bangladesh (*According to WHO information, Recovery percentages is 88.2% in Bangladesh)

Consider a COVID-19 differential equation according to the data table of Bangladesh.so,we take that

$$S(0) = 53.45501$$
$$I(0) = 7.45322$$
$$R(0) =6.68505$$
$$B = \frac{70990}{5345501} = 0.01328$$
$$A = 0.882$$

$$\frac{dS(t)}{dt} = -BS(t)I(t) \tag{10}$$

$$\frac{dI(t)}{dt} = BS(t)I(t) - AI(t) \tag{11}$$

$$\frac{dR(t)}{dt} = AI(t) \tag{12}$$

Where, s = susceptible, I =infected, r = recovered, B = transmission coefficient, A = recovery coefficient, t =average time .

By applying the homotopy perturbation method in equation (10,11,12),we get,

$$(1-P)\frac{dS(t)}{dt}+p(\frac{dS(t)}{dt}+0.01328S(t)I(t))=0$$

$$\frac{dS(t)}{dt}=p(-0.01328S(t)I(t)) \quad (13)$$

$$(1-P)\frac{dI(t)}{dt}+p(-0.01328S(t)I(t)+0.882I(t))=0$$

$$\frac{dI(t)}{dt}=p(0.01328S(t)I(t)-0.882I(t)) \quad (14)$$

$$\frac{dR(t)}{dt}=P(0.882I(t)) \quad (15)$$

$$S(t)=S_0+p^1S_1+p^2S_2+...$$

$$I(t)=I_0+p^1I_1+p^2I_2+...$$

$$R(t)=R_0+p^1R_1+p^2R_2+...$$

Putting the values of S(t),I(t),R(t)in equation (13,14,15),we get,

$$\frac{dS(t)}{dt}=p(-0.01328(S_0+p^1S_1+p^2S_2+...)(I_0+p^1I_1+p^2I_2+...)) \quad (16)$$

$$\frac{dI(t)}{dt}=p(0.01328(S_0+p^1S_1+p^2S_2+...)+...)(I_0+p^1I_1+p^2I_2+...)-0.882(I_0+p^1I_1+p^2I_2+...)) \quad (17)$$

$$\frac{dR(t)}{dt}=p(0.882(I_0+p^1I_1+p^2I_2+...)) \quad (18)$$

Comparing the coefficient of identical degrees of p among the equation (16,17,18),

$$S_0=53.45501$$

$$I_0=7.45322$$

$$R_0=6.685$$

$$\frac{dS_1(t)}{dt}=(-0.01328)(53.45501)(7.45322)$$

$$S_1=-5.2909t$$

$$\frac{dI_1(t)}{dt}=(0.01328)(53.45501)((7.45322)-(0.442)(7.45322)$$

$$I_1=-1.282t$$

$$\frac{dR_1(t)}{dt}=(0.442)(7.45322)$$

$$R_1=6.5737t$$

$$\frac{dS_2(t)}{dt}=(-0.01328)(53.45501)(-1.282t)-(0.01328)(-5.2909t)(7.45322)$$

$$S_2=1.43\frac{t^2}{2}$$

$$\frac{dI_2(t)}{dt}=-(0.01328)(53.45501)(1.282t)+(0.01328)(-5.2909t)(7.45322)-(0.882)(-(1.282t))$$

$$I_2=-0.30298\frac{t^2}{2}$$

$$\frac{dR_2(t)}{dt}=-(0.882)(1.82t)$$

$$R_2=-1.130724\frac{t^2}{2}$$

So, we get the solution of equation (10,11,12),

$$S(t)=53.45501-5.2909t+1.43\frac{t^2}{2}+...$$

$$I(t)=7.45322-1.282t-0.30298\frac{t^2}{2}-...$$

$$R(t)=6.68505+6.5737t-1.130724\frac{t^2}{2}$$

VI. Results and Discussions

To get the clear concept of the estimation,we make a table from the solution of SIR model.

Estimation of COVID 19 in Bangladesh				
t	date	S(t)	I(t)	R(t)
0	26/04/2021	53.4501	7.45322	6.68505
1	27/04/2021	48.8790	6.0223	12.6932
2	28/04/2021	45.7331	4.2832	17.57095
3	29/04/2021	44.0171	3.5258	21.3178
4	30/04/2021	43.7310	-0.09862	23.9340
5	01/05/2021	44.8755	-2.7343	25.4123
6	02/05/2021	47.4496	-5.6920	25.7740
7	03/05/2021	51.4537	-8.9430	24.9901
8	04/05/2021	56.8878	-12.4981	23.0914
9	05/05/2021	63.75191	-16.3555	20.0529

From the above table,we can portend that most of the results from the solution are almost the same as the actual cases.A significant part of this paper is to find out the number of affected people due to COVID- 19 till March 05, 2021, in Bangladesh.The number of infections in Bangladesh about April 26, 2021, and since, then it has slowly decreased.The reduction occurs only when the number of susceptible people decreases.If the susceptible population is reduced,the infected population will be low for an extended period of time. In fig-3,We have got the variations in the population S(t).The susceptible population is varying with the values of I_0.So that,S(t) decreases concerning increase the average time.In our solution,the S(t) decreases till April 30,2021.After that,it slightly increases.Similarly,in fig-4,We have got the variations in the population I(t).The infected population is drastically varying with the values of I_0.So that,the I(t)decreases till March 05, 2021.In fig-5,we have got the variations in the population R(t).The recovered population is varying with the values of I_0.So that,the R(t) increases till April 29,2021.After that,it slightly decreases.

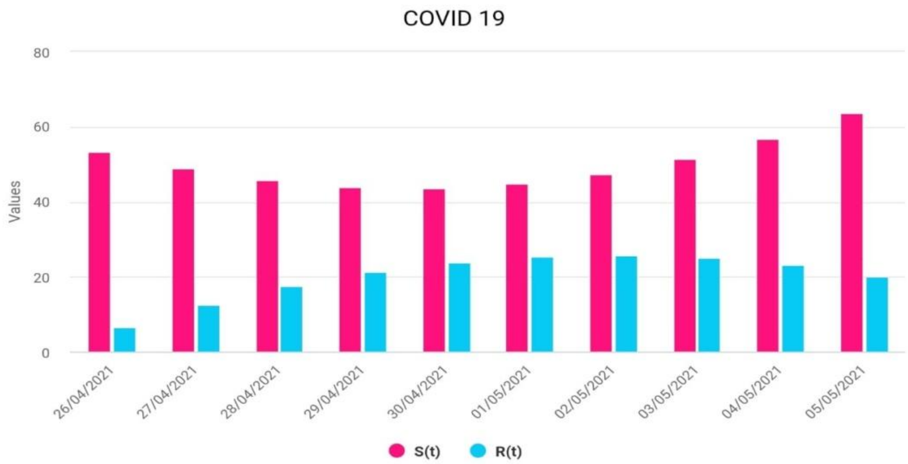


Figure 2: SIR bar diagram delineating the number of people susceptible and recovered

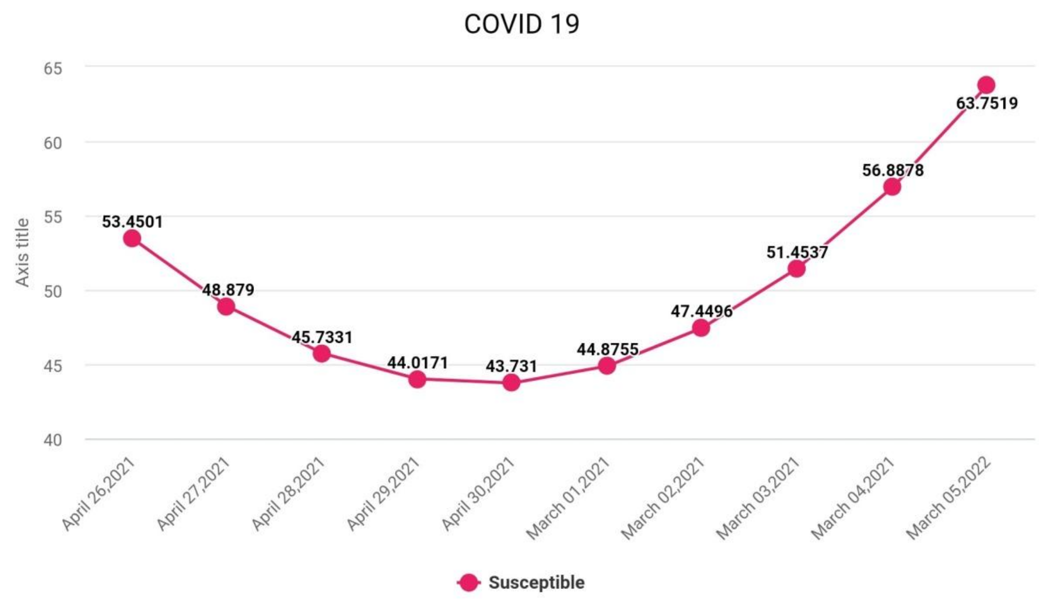


Figure 3: SIR line chart delineating the number of only susceptible people

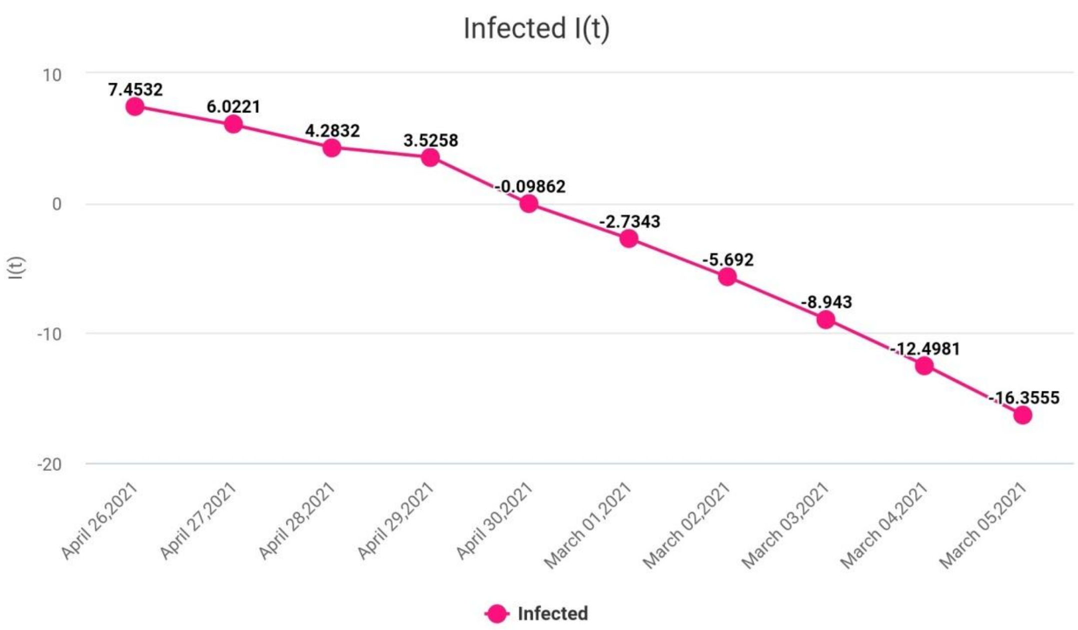


Figure 4: SIR line chart delineating the number of only infected people

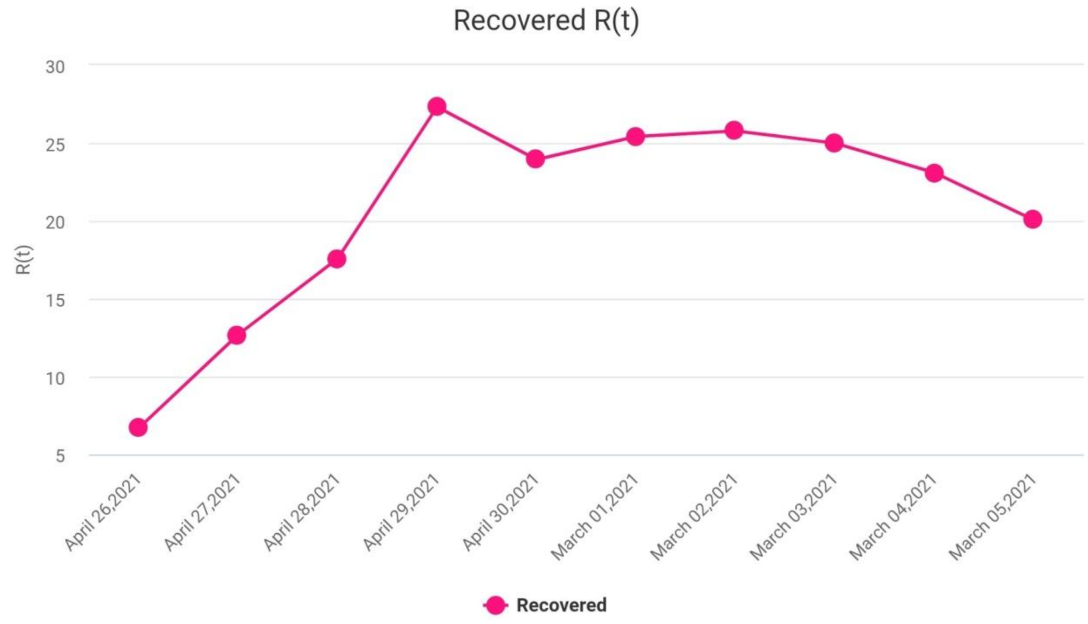


Figure 5: SIR line chart delineating the number of only recovered people

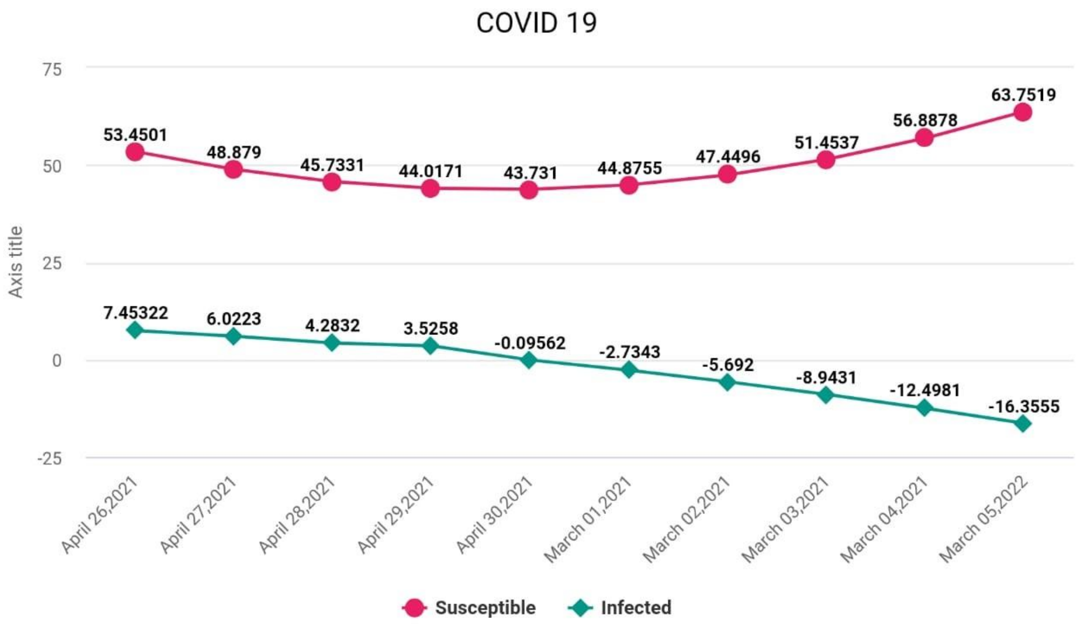


Figure 6: SIR line chart delineating the number of susceptible and infected people

VII. Conclusion

In this paper,Thehomotopy perturbation method has effectively been applied to estimate the COVID-19 case for Bangladesh.From the results and the graph,we can aver that Corona cases are decreasing and recovering in Bangladesh.Corona's positive rate is in the downcast.Also,the recovery rate is high.If we observe the following dates,it will be seen that our guess was correct.If people follow the proper regulations of COVID-19, we can hopefully say that the pandemic will end very soon in Bangladesh.

Acknowledgments

The author would like to thank Neloy Chandra Das for giving some instructions.

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OvijitChandrow. "Forecasting COVID-19 Pandemic in Bangladesh by Using Homotopy Perturbation Method." *IOSR Journal of Mathematics (IOSR-JM)*, 17(3), (2021): pp. 05-12.