STUDY OF INFECTIOUS DISEASE COVID-19 BASED ON MATHEMATICAL MODELING AND IMPACT OF LOCKDOWN IN INDIA

Ramesh Yadav[1*], Santosh Kumar Dixit[2] and Pravin Kumar Srivastava[3]

[1*]Assistant Professor, Mathematics, Department of Applied Science, Babu Banarasi Das Institute of Technology and Management, Lucknow, U. P, India, Pin. No. 227105

[2]Associate Professor, Mathematics, Amity School of Engineering and Technology, Amity University Patna, Bihar, India

[3]Assistant Professor, Mathematics, Department of Applied Science and Humanities, Bundelkhand Institute of Engineering & Technology, Jhansi, India

Abstract

The Covid-19 is an infectious disease. It is cause of concern over the world as human-to-human infections. It is caused by spreading or shake out by human at a fast pace. This virus is demonstrated by Wuhan in China. From China it is travelled across continents. Covid-19 virus leads the number of deaths in Italy, Iran, United State of America, India and Many other countries. Countries have informed that protect you from this virus. Scientists of many countries are working hard to develop the vaccine against the Covid-19 Virus. Some country has been developed the Covid-19 vaccine, which is protect this disease approximately one year but not to protect permanent of this disease. Health care facilities are updated and medical and staffs are getting to trained for the protection of Covid-19 disease. In this article, we discuss a predictive mathematical model which gives us some new ideas for the protection of Covid-19 diseases. Here we have explored the problem of mathematical modeling of new Covid-19 virus in country. The evaluation of new cases can be predicted and need preparation can be done. We suggest a new mathematical model for Covid-19 open out. This is proved by analytical and available data of Italy as well as USA also are in the third stage from the infection of Covid-19 disease. India is also passed in third stage after more time in the comparison of the other state and is more controlled as compared to others. Using of this present model, an approximate evaluation of new Covid-19 instance can be doing simply. In this study the effect of lock-down has been considered, because its plays an important role from the protection of Covid-19 disease. It is also useful to predict the number of cases in future.

. **KEYWORDS:** Corona virus, Lock-down, Number of days, spreads of Covid-19 virus.

1. INTRODUCTION

The corona virus is an infectious disease. It is called COVID-19 as well as novel corona virus. The case of COVID-19 was observed by various countries from November 2019 to till date. This disease is infected the lungs, cough, high fever, throat, cold, causes by respiratory illness and more difficulties in breathing. The active times of the Novel corona virus is of approximately 15 days. The Doctor suggested for precautions of this infectious disease is washing of hands frequently. It is not active or destroyed the alcoholic liquid. For precautions of these all human being use the sanitizer for wash of hands. All human being maintain 1 to 3 feet distance and use face cover for protection of this infectious disease. The World Health Organization (WHO) declares that COVID-19 pandemic on 30th March 2020. The rapidly changing the demand of health facilities and health workers threatens to leave. For this reason some health organization systems over stretched and not able to operate effectively. The World Health Organization (WHO) releases a guideline to help countries and maintain essential health service these trouble days of pandemic COVID-19.

Belinda and Fulford (2002) has been studied the mathematical modeling with case studies, a differential equation approach using Maple. Ksiazek et al. (2003) has been studied a novel corona virus associated with severe acute respiratory syndrome. Eubank et al. (2004) has been analyzed the modeling disease outbreaks in realistic in urban social networks. Cavanagh (2007)has been studied corona virus avian infections bronchitis virus. Kiparissides et al. (2009) has been presented global sensitivity analysis challenges in biological systems modeling. Chiu (2013) has been studied viral pathogen discovery. Babtie et al. (2014) has been presented topological sensitivity analysis for systems biology. Khoshnaw et al. (2017) has been studied identifying critical parameters in SIR model for spread of disease. The mathematical model for the Ebola virus disease has been studied by Akgul et al. (2018). He et al. (2020) has been studied a discrete stochastic model of the covid-19 outbreak: Forecast and control. Chen et al. (2020) has been presented a mathematical model for simulating the phase-based transmissibility of a novel corona virus. Murdoch and French (2020) has been studied Covid-19: another infectious disease emerging at the animal-human interface. Huang et al. (2020) studied clinical features of patients infected with 2019 novel corona virus in Wuhan, China. In this paper, we propose a mathematics model for the scenario of community spread of Covid-19 and new variant of corona virus. An approximate prediction for the spread of disease in coming day can be performed by employing this model.

2. MATHEMATICAL MODELING OF THE PROBLEM

In this modeling we have study the data of Italy, United State of America and India. This model may be used the other country for the prediction purpose of the number of COVID-19 cases. We

have considered the prediction of these updated COVID-19 cases in coming days in France as well as India.

This analysis establish that the proposed model. It can be used for prediction of the stage of COVID-19 also by matching the available data with analytical results. The data uses other statistics like number of deaths or number of recovered cases can also be predicted with a sufficient accuracy. The model is verified for the COVID-19 cases reported in France, USA as well as India and nest few days the number of some new situations is predicted for this country.

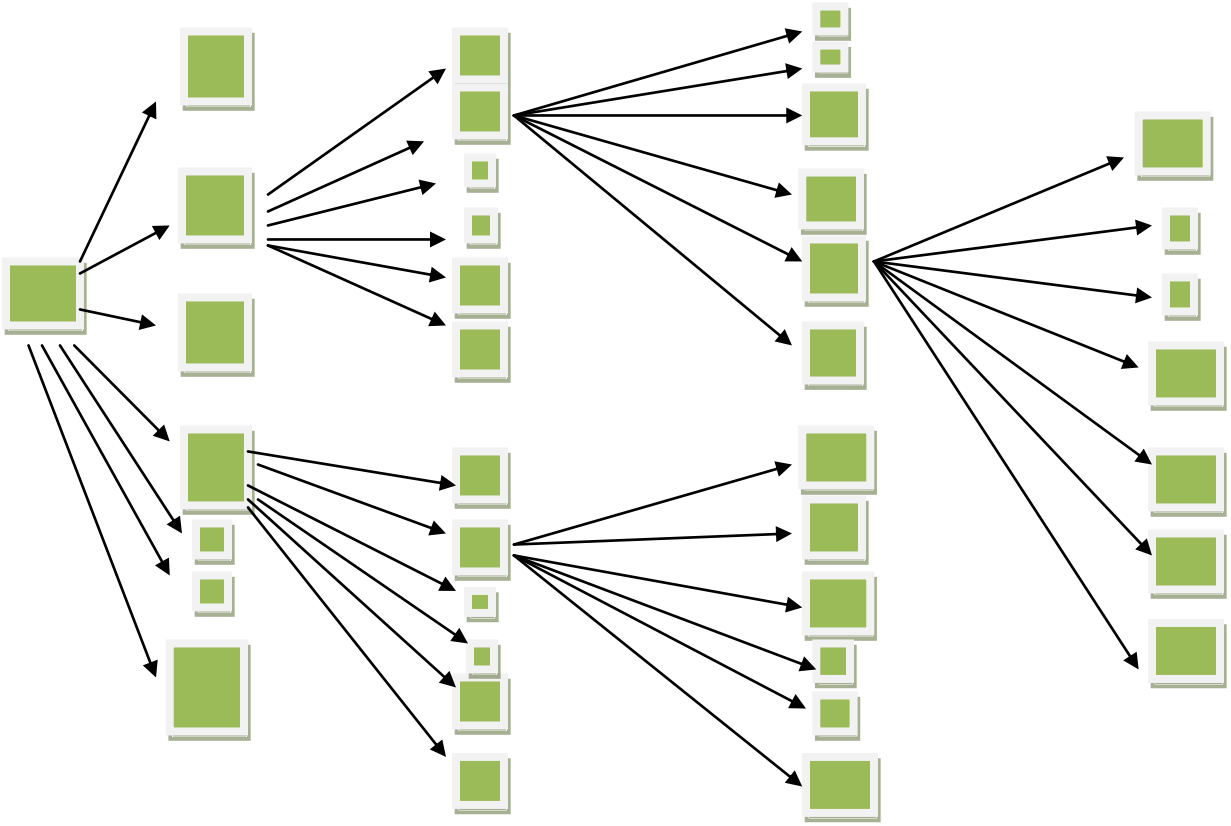

Fig.1. Proposed model for spread of updated COVID-19

3. MATHEMATICAL FORMULATION OF THE MODEL

We consider a positive corona comes into a country and comes into the contact of other person. Since it is infectious illness, therefore, it spreads in others. We denote the positive corona patient as active node. Since there is no identification of this active node, therefore, it is in contact will all

other nodes. A tree based structure is manufactured to clarify the scene in Fig. 1. This is clear from the figure that node A (an infected person) can infect disease C in other nodes of person in 1 unit time (unit may be day, hour, minute). Now all these new infected notes are active and each of them can be able to infect other C notes or person and so on. Therefore, we can write total number of active nodes or infected person as the sum of

$$S_{Total} = 1 + C^2 + (1 + C^2)C^2 + (1 + C^2)^2C^2 + (1 + C^2)^3C^2 + (1 + C^2)^4C^2 + (1 + C^2)^5C^2 \dots (1)$$

Where, C represents the No of Nodes or No of COVID-19 infected persons, and S is the total No of COVID-19 Infected Person.

We see that above equation (1) is in Geometric Progression from the Third Terms to Last Terms.

$$S = 1 + C^2 + (1 + C^2)C^2\{1 + (1 + C^2) + (1 + C^2)^2 + (1 + C^2)^3 + (1 + C^2)^4 + \cdots T_{n-2}] \quad (2)$$

Now adding the above equations we get

$$S = 1 + C^2 + (1 + C^2)C^2 \frac{[(1+C^2)^{n-2}-1]}{(1+C^2)-1} \quad (3)$$

it can be also written as

$$S = (1 + C^2)^{n-1} \quad (4)$$

Where n represent the number of term series, or no of days in which disease is more active cases with the increase of no of days without spread or lockdown. It is also indicating the unit of times of days which span over the spread of disease and is needed to pre-planned; in above equation (1) we can see that after first two terms it is a geometric progression with the common ratio $(1 + C^2)$ from third term to last term, and is considered as (n-2)th term. The sum of the series is represented by the equation (4). From the above equation (4) it is observed that this series grows fastly. For example if we assume the value of C = 1, i.e., one person can infect only a single person in one unit in a day or one time. i.e., also one unit, in that case the total population of a country will be infected when total cases from equation (4) will be equal to or greater than the total population (P). Therefore, from Equation (4), we get

$$P \leq 2^{n_p-1}, \quad (5)$$

Where n_p represents the smallest value of n which attains this inequality.

We know that the total population of India is not More than 150 crores, and then only 31 days needed to spread the COVID-19 Disease with an unconstrained environment or without restrictions. Let one person infect a single person in one day. In the case USA approximately 33 crores Populations, it shows the only 30 days needed to spread the COVID-19 virus without restriction. Whereas in the case of Italy with 6 Crores Population are needed to 27 days for the spread of COVID-19 virus and 4 days more time to spreads of virus in India comparison to Italy and one more time taken in comparison to USA.

As we know that the Omicron and Delta version of COVID-19 virus is very dangerous. Now let we assume that one unit can infect more than one person in a day. Now we take the value of C is more than one. Let it can be taken two units. From the above equation (4) it is observed that this series grows very fastly. For example if we assume the value of C = 2, i.e., in that case the total population of a country will be infected when total cases from equation (4) will be equal to or greater than the total population (P). Therefore, from Equation (4), we get

$$P \leq 5^{n_p - 1}, \tag{6}$$

Where n_p also stand the smallest value of n for the given inequality.

We know that the total population of India is not More than 150 crores, and then only 15 days needed to spread the COVID-19 Disease with an unconstrained environment or without restrictions. Let one person infect a single person in one day. In the case USA approximately 33 crores Populations, it shows the only 14 days needed to spread the COVID-19 virus without restriction. Whereas in the case of Italy with 6 Crores Population are needed to 13 days for the spread of COVID-19 virus.

Now, we assume the effect of omicron virus incubation period that is virus is active for K days. Therefore we consider that after K days the infected nodes and their effects are inactive. The total number of active cases can be represented by

$$S_{cases} = X_n - X_{n-K} - X_{n-K+1} = C^2(1 + C^2)^{n-2} - C^2(1 + C^2)^{n-K-2} - C^2(1 + C^2)^{n-K-1}, n > k, \tag{7}$$

Where X_n, X_{n-K}, and X_{n-K+1} are the nth, (n-K)th and (n-K+1)th terms of the given series (1 or 2).

4. RESULTS AND DISCUSSTIONS

In this study we considered three Country cases of COVID-19 virus which is Italy, USA and India. All of these countries, it is observed that an enormous increase in the number of patients each day, the disease has been spread at community level and it is difficult to get control of it now. These three scenarios suit that the assumption of unconstrained scenario as even after every measures taken placed, the number of infected persons is kept on the increasing day-by-day. For checking the validity of our proposed model, we take the data from equation (2). In the figure 2 and 3, n represents the number of days and C represents the number of persons or infected Covid-19 disease. In figure 2a, it is seen that increase of number of days, infection increases sharply whereas from figure 2b, when number of person increases, it is found that infection increases very sharply, these figure is taken as unconstrained or without restriction of covid-19 disease, when any restriction is used like as Lockdown, Medical facility, etc., From figure 3a, it is seen that increase of number of person in contact the disease leads sharply. When number of days increases then Covid-19 infection increases very sharply which is given in the figure 3b also.

Figure 4a and 4b represents graph, from the survey by World Health Organization. The graph is plotted total number of Infection cases in India against number of days in month January 2020 to June 2020, which is represented by the number of 1, 2, 3, 4, 5, 6. From these figures it is seen that increase of number of days Covid-19 infection is increases whereas is low increase as compared to unconstrained figure 2 and figure 3, because of this Lockdown and Medical facility is provided by the government, due to these effect Covid-19 cases decrease slowly as compared to unconstrained increase of Covid-19 disease. Figure 5a and 5b represents the death against number of days, it is seen the increase of days, death rate is increases whereas it is decreases slowly with the increase of lockdown and good medical facility.

In figure 6, the graph plotted the Total number of cases against number of days in the month of March 2020 in Italy. This graph is base on the real data which is provided by WHO. The rate of spread infection is taken and 1.5 per day. It means one infected person can takes 1.5 days to infect the other nodes or person. Also we have assumed C = 1 (Number of persons or node), i.e., one persons can be spread only one persons in 1.5 days. Further the value of K = 14 or 15, it means 14 to 15 days the person to recovers the Covid-19 infections. From the figure it is seen that the death rate in Italy is very high. Therefore in 14^{th} to 15^{th} days, more persons recovered, so we need to be removed from the system. Now the Italy and all country has taken the Lockdown and improved the medical facility, then the spreading of Covid-19 disease has been slowed down. In this reason we need correction factor of F from 14^{th} to 15^{th} day onwards. It can be taken from the figure from the proposed model with $F = 10590$ gives a very close index of the Covid-19 spread over the

assumption range of days. We have plotted the graph for unconstrained in same figure also. It has been seen that when no lockdown the Covid-19 infection disease goes in very worst position in the days.

From figure 7, we have taken the data of Covid-19 infection in United State of America (USA). The proposed model is applied to plot the number of Covid-19 infection cases each days. The death rate of United State of America is slower than the Italy. So we use the following relations obtained from the equations (8).

$$S_{Cases} = \begin{cases} X_n, & for \quad n \leq K, \\ X_n - X_{n-k+1} - F, & \text{for } n > K \end{cases}$$

(8)

The value of C is chosen at least one or two. Because we have taken the model in specific case is C > 1. Now if we choose at least one person is infected to this disease and considered F as 11000 approx; we know that the approx quarantine time K is 14 days considered. Now the rate of spread the Covid-19 disease is 2.3 per day. It means one person can spreads the disease to another person after 2.3 day. It is slower than the Italy and become the good for the countries. A close match of the proposed assumed model and real data is given from the figure. Hence the proposed model can be applied to predict the cases in coming days. An unconstrained plot of the total cases is also plotted in the figure, which shows that spread of Covid-19 disease can be very serious but die to the measure take hold of testing and quarantine.

The concept of this model use to check the current situation of Covid-19 infection spreading in our country India. We have been plotted the actual cases of 30th days April Month 2020, which is presented in the figure 8. In this figure we have also plotted the Covid-19 infection cases for each day by using the proposed unconstrained model. It can also be seen figure. Our India is well as compared to other countries. It is also keeping the pandemic away from taking a large jump in the terms of Covid-19 infected cases as compared to other country. Our output is the close measure take hold from the origination or beginning that the increase of Covid-19 diseases is very finite in India.

Here some states the Data of Covid-19, new infected latest data, which is provided by World Health Organization, is given below. In this data the Total cumulative cases, Newly reported cases in last 7th days, Total Deaths cumulative cases, Total Deaths-Newly Reposted in last 7 days, Total vaccine doses administered per 100 population, Person fully vaccinated with last dose of primary series per 100 populations and Persons Boosted per 100 populations has been given in Table 1.

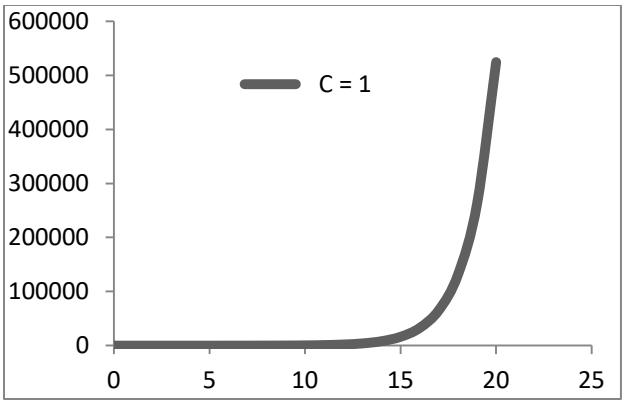

Fig. 2.a. Graph Covid-19 Infection (S) against number of Days (n), where x-axis no of days and y-axis Covid-19 Infection

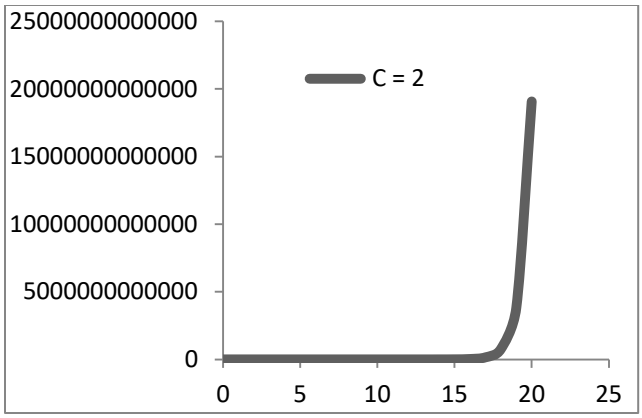

Fig. 2.b. Graph Covid-19 Infection (S) against number of Days (n), where x-axis no of days and y-axis Covid-19 Infection

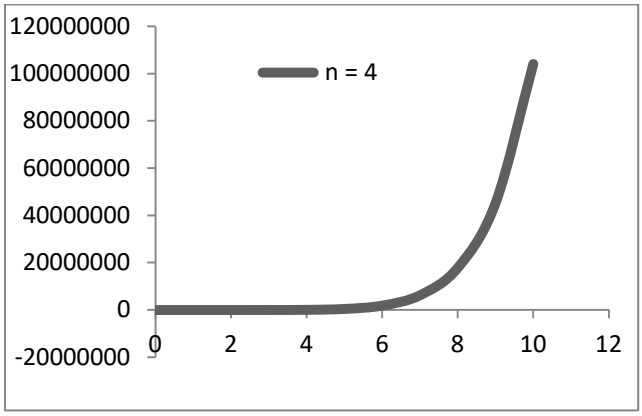

Fig. 3.a. Graph Covid-19 Infection (S) against number of Persons (C), where x-axis no of Person and y-axis Covid-19 Infection

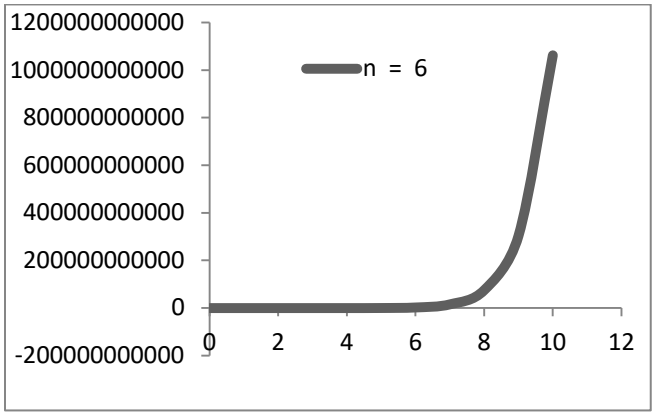

Fig. 3.b. Graph Covid-19 Infection (S) against number of Persons (C), where x-axis no of Person and y-axis Covid-19 Infection

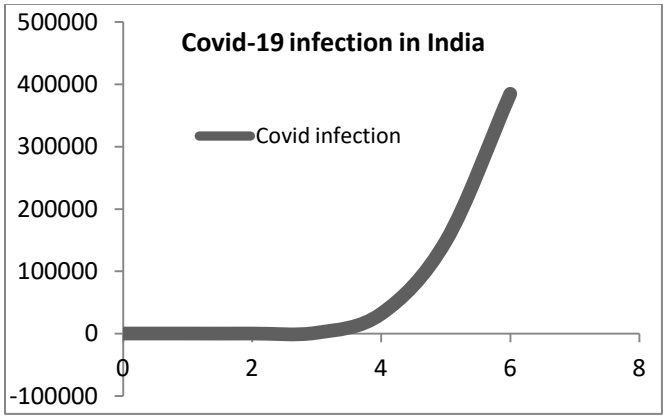

Fig. 4a. Graph of Covid-19 Infection (S) against Months of January 2020 to June 2020. Month January to June Represented in x-axis as 1,2,3,4,5,6 and Infection represented in y-axis

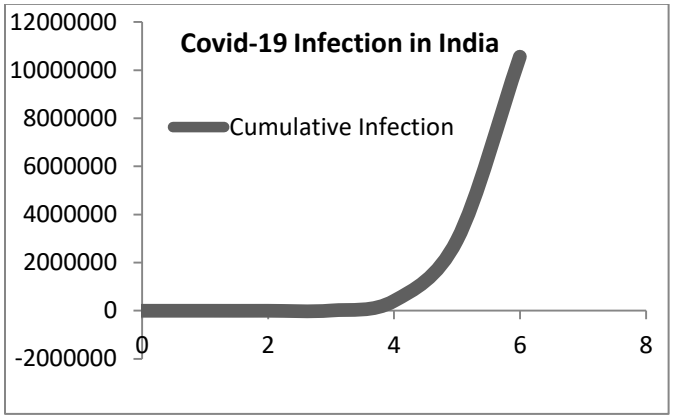

Fig. 4b. Graph of Cumulative Covid-19 Infection (S) against Months of January 2020 to June 2020. Month January to June Represented in x-axis as 1,2,3,4,5,6 and Cumulative Infection represented in y-axis

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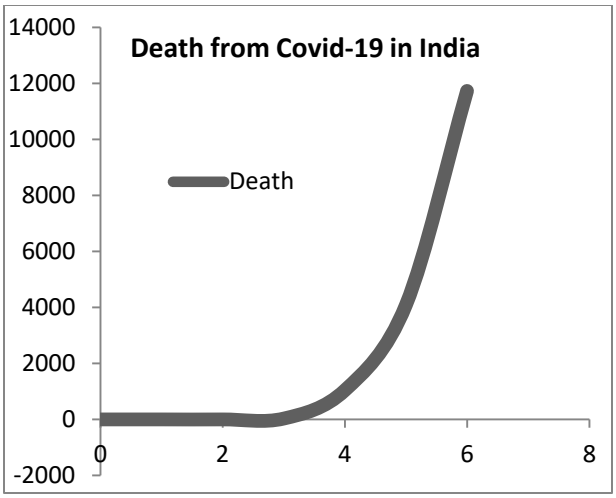

Fig. 5a. Graph of Covid-19 Infection death against Months of January 2020 to June 2020, Month January to June Represented in x-axis as 1,2,3,4,5,6 and Infection represented in y-axis

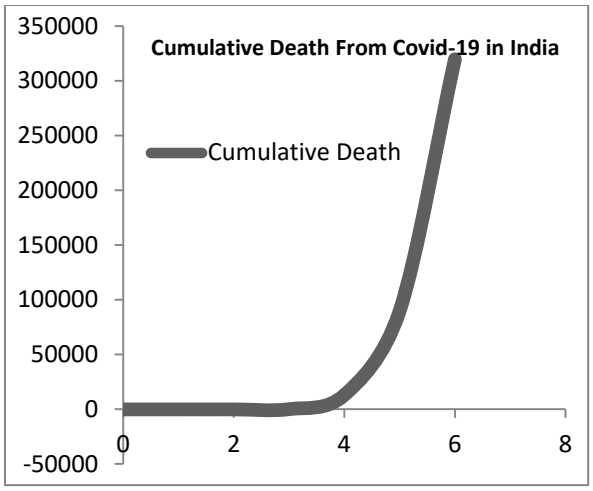

Fig. 5b. Graph of Cumulative Covid-19 Infection death against Months of January 2020 to June 2020, Month January to June Represented in x-axis as 1,2,3,4,5,6 and Infection represented in y-axis

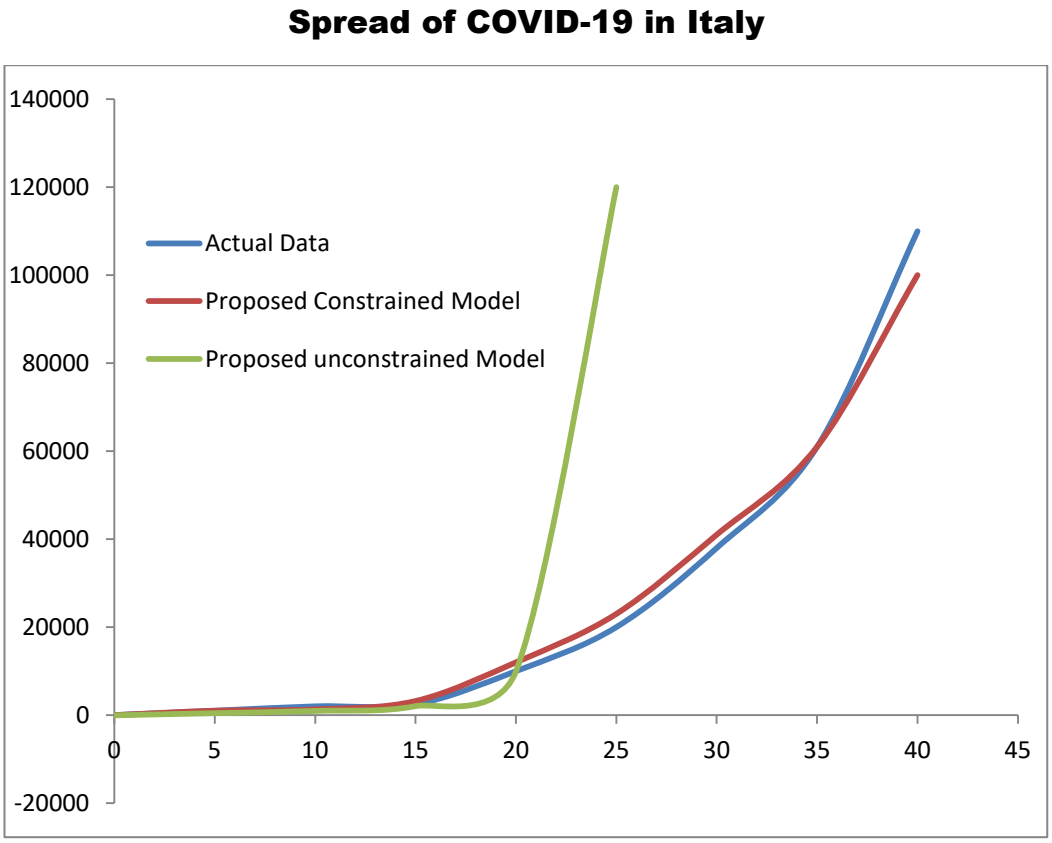

Fig. 6. Graph Represents the Total Number of Covid-19 infection cases against number of days in Italy, in which x-axis represented number of days and y-axis represented the Total cases.

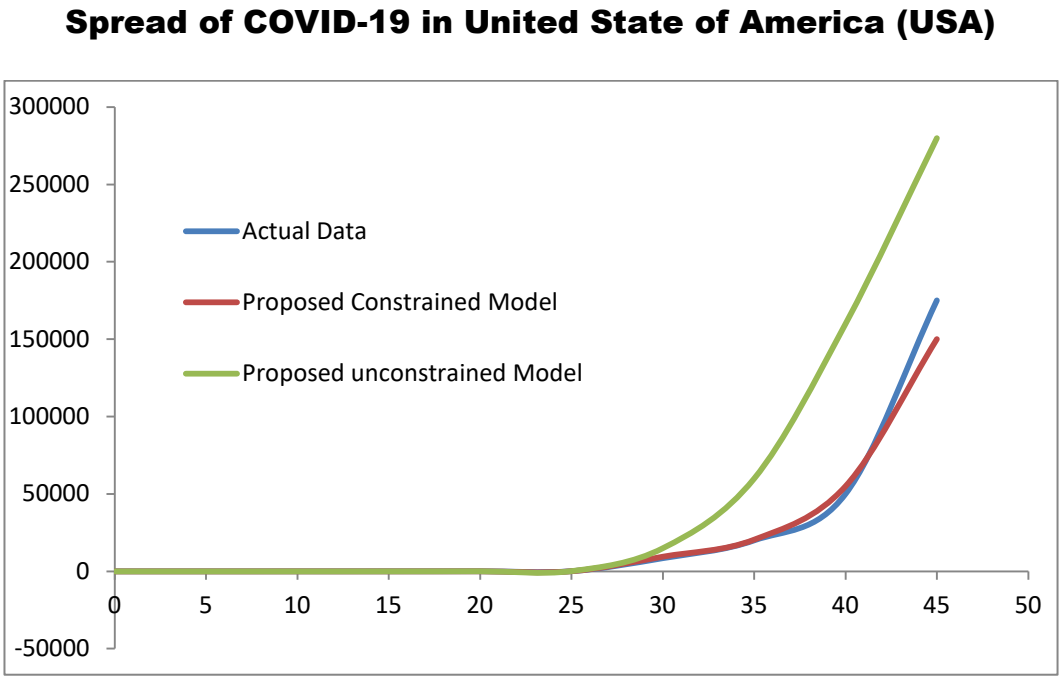

Fig. 7. Graph Represents the Total Number of Covid-19 infection cases against number of days in USA, in which x-axis represented number of days and y-axis represented the Total cases.

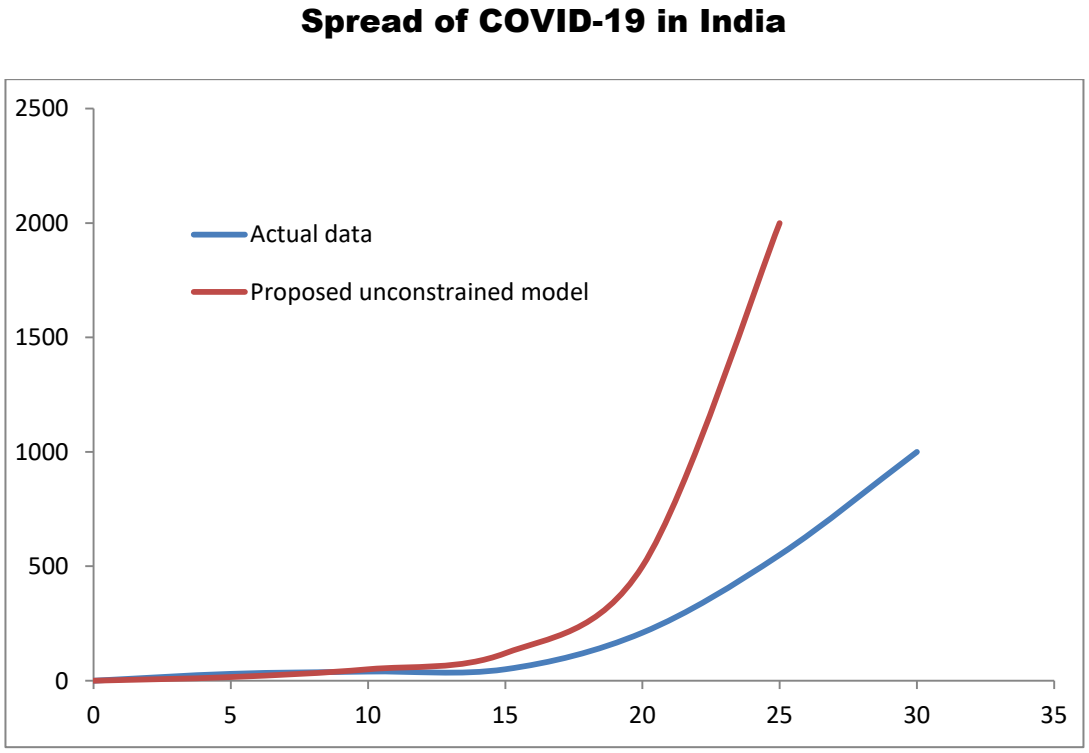

Fig. 8. Graph Represents the Total Number of Covid-19 infection cases against number of days in INDIA, in which x-axis represented number of days and y-axis represented the Total cases.

Table.1: Some Covid-19, new infected latest data, which is provided by WHO.

State	Cases Cumulative total	Cases Newly Reported in last 7 days	Deaths-Cumulative Total	Deaths-Newly Reported in last 7 days	Total Vaccine doses administered per 100 population	Person fully vaccinated with last dose of primary series per 100 Population	Persons Boosted per 100 population
United State of America	93580725	476675	1036949	2423	181.5	66.84	32.28
India	44472241	43848	528057	183	154.85	68.39	12.3
France	344775391	80334	684425	803	223.12	77.44	52.25
Italy	219697251	123782	175952	447	233.1	79.64	71.43
Japan	19635246	863242	41575	2011	228.41	80.99	62.36
Spain	13358722	16192	112903	303	217.3	79.15	54.64
Australia	10084917	67015	14152	318	247.76	85.33	55.72
Argentina	9689861	11636	129769	58	240.63	83.55	66.53
China	6655733	254259	25088	282	234.68	86.81	52.73
Mexico	7041181	7299	329622	54	162.62	62.01	44.16
Austria	4984809	29323	20678	22	213.5	74.94	59.56
Ukraine	5072533	16155	108885	44	72.4	34.65	1.7
Colombia	6302809	3214	141646	127	172.09	71.69	26.85
Malaysia	4795009	14725	36255	45	222.59	84.84	50.1
Thailand	4662569	11650	32464	161	203.57	76.49	45.49
Canada	4179337	20843	44085	261	233.11	83.22	50.61
Switzerland	4040285	10560	13539	4	182.3	66.43	46,78
South Africa	4012812	1155	102108	24	63.12	34.89	6.2
Israel	4638799	5847	11643	7	173.6	73.78	18.32
Bangladesh	2013689	1743	29329	6	180.03	73.67	26.79
Sri Lanka	670251	294	16716	18	185.88	68.18	37.78
Bahrain	672859	1375	1515	0	203.81	72.02	58.9
Saudi Arabia	813986	610	9309	16	194.47	72.56	44.74

5. CONCLUSIONS

In this paper we have investigated the infectious disease of covid-19 based on mathematical modeling and impact of lockdown in Italy, USA as well as India. The data is suggested the country to going to see a stream occurrence. However, we need to acknowledge that the variables such as physical distancing, staying indoors, hygiene and boosting immunity system of men can minimizes the virus of Covid-19 spreads. Raising consciousness through many platforms including the website network, social network, face book and twitter is one procedure to accommodate the disease. Every house hold must be accommodated and that can be done through vernacular language. Since big section of the population is still not conversant in English and Hindi. Our government has already take hold the measure such as setting testing centres and makes the isolation zone in hospitals. This would be easing the work load on the existing ones. Also, all country announced the lockdown by the government is assuredly going to act as Covid-19 disease infection control and optimistically help India

attend to this new challenge in the desired form. Our scientists require to gear up for this duty or job and approach onwards to do collaborative study of research work to acknowledge the spread, restriction and eventualities of the pandemic outbreak. Research team have been manufactured the vaccines for which funding, infrastructure and adequate facilities are required. So, Covid-19 disease is a prompting that science cannot take hold of back seat and health care, education and research should always hold a top priority. In this study the data have been taken from world Health organization (WHO) records. Predictive model is used the escape of Covid-19 disease.

REFERENCES:

[1]. A. Akgul, S. H. A., Khoshnaw and W. H. Mohammed, (2018); 'Mathematical Model for the Ebola virus disease', Jour. Of Adv., Physo., Vol. 7, pp. 190 – 198.

[2]. A. C. Babtie, P. Kirk and M.P.H. Stumpf., (2014): 'Topological sensitivity analysis for systems biology', Proc, Natl, Acad, Sci, Vol. 111, pp. 18507 – 18512.

[3]. A. Kiparissides, S.S. Kucherenko, A. Mantalaris and E. N. Pistikopoulos., (2009); 'Global Sensitivity analysis challenges in biological systems modeling', Ind. Eng. Chem, Res, Vol. 48, pp. 7168 – 7180

[4]. Belinda Barnes and Glenn R. Fulford., (2002); 'Mathematical Modeling with case studies, A differential equation approach using Maple' Taylor and Francis, London and New York.

[5]. C. Y. Chiu., (2013); 'Viral Pathogen discovery' Current Opinion in microbiology, Vol. 16, No. 4, pp. 468 – 478.

[6]. C. Huang., Y. Wang., X. Li., L. Ren., J. Zhao. Y. Hu., & Z. Cheng (2020); 'Clinical features of patients infected with 2019 novel corona virus in Wuhan, China', The Lancent, 395(10223), pp. 497 – 506.

[7]. D. Cavanagh., (2007); 'Corona Virus avian infections bronchitis virus' Veterinary research, Vol. 38, Issue 2, pp. 281-297

[8]. D.R. Murdoch and N. P. French (2020); 'Covid-19: another infectious disease emerging at the animal-human interface', NZ Med Jour., 133(1510), pp. 12 – 15.

[9]. S. Eubank., H. Guclu., V. A. Kumar., M. V. Marathe., A. Srinivasan., Z. Toroczkari., and N. Wang., (2004); ' Modeling disease outbreaks in realistic in urban social networks' Nature, 429(6988), pp. 180-184.

[10]. S. H. A. Khoshnaw, N. A. Mohammad and R.H. Salih, (2017); 'Identifying critical parameters in SIR model for spread of disease', Open Journal, Model. Simul. Vol. 5, pp. 32 – 46.

[11]. S. He, S. Tang and L. Rong., (2020); ‘ A discrete stochastic model of the covid-19 outbreak: Forecast and control’, Math. Biosci. Eng. Vol. 17, pp. 13.

[12]. T. M. Chen, J Rui, Q. I. Wang, Z.Y. Zhao, J. A. Cui and L. Yin, (2020); ‘A Mathematical Model for simulating the phase-based transmissibility of a novel corona virus’, Infect, Dis. Poverty, Vol. 9, pp. 1 – 8.

[13]. T. G. Ksiazek., D. Erdman., C. S. Goldsmith., S. R. Zaki., T. Peret., S. Emery., and P. E. Rollin., (2003); ‘A novel corona virus associated with severe acute respiratory syndrome’ New England Journal of medicine, vol. 348(20), pp. 1953 – 1966.

[14]. V. Tiwari, Namrata Dayal and Nandan S. Bist., (2020); ‘Mathematical Modeling based study and prediction under the impact of Lockdown in India’, Frontiers in Physics, Vol. 8, pp. 1 – 8.