A DATA BASED EPIDEMIOLOGICAL STUDY OF COVID - 19 IN INDIA WITH REFERENCE TO BASIC REPRODUCTION NUMBER (R_0) AND EXPONENTIAL GROWTH RATE (K).

NARENDRA SRIVASTAVA[1], RAVINDRA SHRIVASTAVA[2], BRAJESH KR SINGH[3], UMAPATI SAHAY[4], A.N JHA[5]

1. UNIV. PROFESSOR, ECO-PARASITIC RESEARCH LAB, DEPT. OF ZOOLOGY, B. N MANDAL UNIVERSITY, MADHEPURA- 852113, BIHAR, INDIA.
2. RESEARCH SCHOLAR, ECO-PARASITIC RESEARCH LAB, DEPT. OF ZOOLOGY, B. N MANDAL UNIVERSITY, MADHEPURA- 852113, BIHAR, INDIA.
3. RESEARCH SCHOLAR, ECO-PARASITIC RESEARCH LAB, DEPT. OF ZOOLOGY, B. N MANDAL UNIVERSITY, MADHEPURA- 852113, BIHAR, INDIA.
4. PROF AND HEAD (RETD), UNIV. DEPT OF ZOOLOGY, RANCHI UNIVERSITY, RANCHI -834001, JHARKHAND, INDIA
5. ASSOCIATE PROFESSOR(RETD.), UNIV. DEPT. OF ZOOLOGY, B.R.A BIHAR UNIVERSITY, MUZAFFARPUR-842001, BIHAR, INDIA

ABSTRACT

BACKGROUND: An emergency situation is developed globally due to COVID-19 SARS-CoV-2 virus developed in China, at first reported from its Wuhan province in last week of December'2019. It is declared pandemic by WHO in mid March'2020. As per the record of Government of India and WHO total number of COVID -19 positive cases in India was 8447 with 273 deaths and 1610909 positive with 99690 deaths in world on April'11,2020. The transmission of any infective disease is depended fundamentally on two epidemiological parameters, ie, Exponential Growth Rate and Basic Reproduction Number.

MATERIAL AND METHODS: The data of COVID -19 positive cases considered for the present study is covered period from March'11, 2020 to April' 11, 2020 and obtained from official website of the Government of India. The Basic Reproductive Number was calculated on basis of SEIR (Susceptible-Exposed-Infected-Removed) compartmented model. The formula used for calculation was $R_0 = 1 + K (\underline{T} + \underline{\hat{T}}) + K^2 (\underline{T}\ \underline{\hat{T}})$; where K represents exponential growth rate. The time intervals are stratified and randomized to neutralize the effect of confounding variables.

OBSERVATION: The mean exponential growth/day is calculated as 0.16 with a range of 0.12 to 0.19. For the stratified period the minimum value of exponential growth rate was observed for March'11, 2020 to March'16, 2020 where as maximum value of exponential growth rate was observed from March'31, 2020 to April'05, 2020. The Basic Reproduction Number for COVID -19 is calculated as 1.96 for total period with a range of 1.7 to 2.13. When stratified period is considered, the minimum was observed for March'11, 2020 to March'26, 2020 and maximum was observed for March'31 to April'5, 2020. The cumulative value of COVID -19 positive patients from March'11 to April'11, 2020 and its exponential growth rate was slow up to March'31 and after that the growth curve increased sharply.

DISCUSSION: The calculated value of exponential growth and Basic Reproductive Number of COVID-19 in India from March'11 to April'11, 2020 indicate that the problem of epidemics is under control. The exponential growth rate and Basic Reproductive Number is respectively lower than most of the countries of

world due to implementation of doctrine of quarantine of exposed group and isolation of symptomatic patients by Government of India. The method is also supported by epidemiological model.

CONCLUSION: The exponential growth rate and Basic Reproductive Number of COVID -19 SARS-Cov-2 in India is low in comparison to European countries and America. But 1.96 value of Basic Reproductive Number indicates that the possibility of epidemic has not been ruled out but its possibility exists. Hence the identification of probable exposed clusters, villages and states for COVID- 19 and its primary surveillance at population level and their quarantine and isolation are necessary.

KEY WORDS: COVID-19, BASIS REPRODUCTIVE NUMBER (R_0), EXPONENTIAL GROWTH RATE, TRANSMISSION DYNAMICS, INDIA

INTRODUCTION

Atypical contagious viral pneumonia has now infected to populations living in more than 210 countries of the world [1]. It was first reported in last week of December 2019 from Wuhan city of China. The virus is referred as COVID- 19 (SARS CoV-2) and recognized as seventh member of family Coronaviridae and kept with its earlier described members HKU 1, NL 63, OC 43, 229 F, SARS COV -1 and MERS. The COVID -19 is a fast transmissible virus and affecting all aspects of the society. In India the infection of COVID -19 has primarily entered through foreigners or foreign visitors. The record represent that the first fifty COVID -19 positive persons are either foreigner or foreign travelers. World Health Organization has declared the COVID-19 as global pandemic after considering its global spreading, high transmission rate and severity [2]. WHO reported the total COVID -19 positive cases up to April'11, 2020 in India was 8447 with 273 deaths. On the same date total global COVID -19 positive patients were 1610909 with 99690 deaths [3].

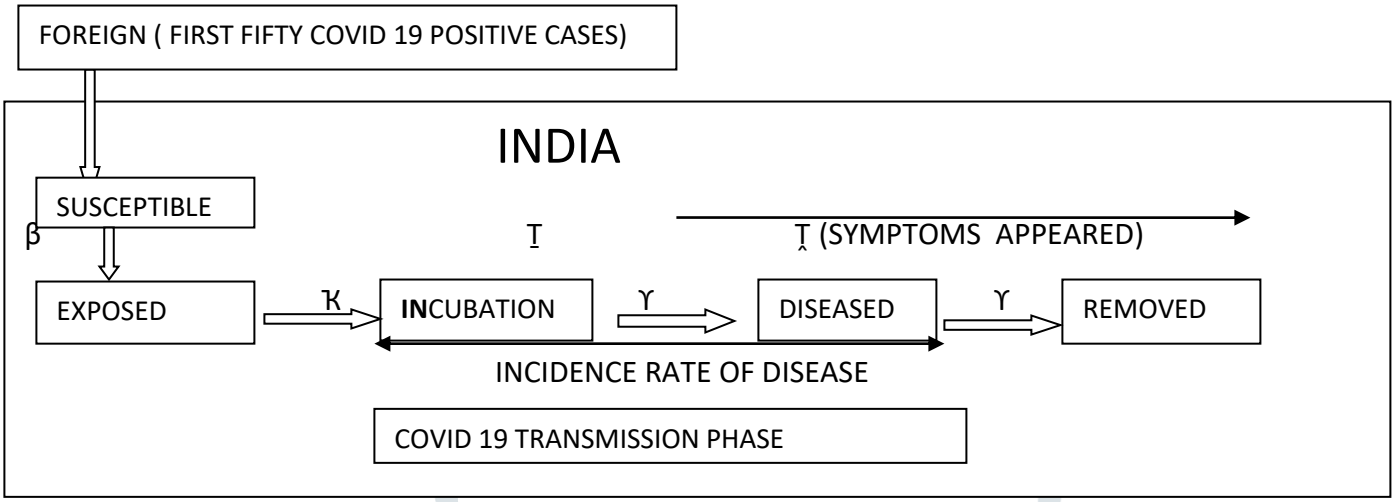
The pandemic of COVID -19 is considered as a global emergency and epidemiologists are analyzing its degree of transmission and suggested preventive measures, since no suitable pharmacological treatment is available. The degree of transmission is mainly determined by Basic Reproductive Number (R_0). It is an epidemiological parameter which represents expected number of susceptible person directly infected from one patient. When its value is more than 1, it indicates that the disease would spread in population [4]. The papers published by different workers, even from China, represented wide variation in the values of basic reproduction number of COVID-19 [1, 5, 6, 7, 8, 15]. It has been suggested that the key aspects of the transmission dynamics of COVID -19 remain unclear particularly due to uncertainty in period of infective asymptomatic stage, duration of contact period of exposed person, effects of seasonal periodicity in the transmission etc [9, 10]. In India first case of COVID -19 was reported in last week of January' 2020 from Kerala state. Now it is transmitted to 32 states and union territories.

MATERIAL AND METHODS

In the present study the data of COVID -19 positive cases is covered period from March'11, 2020 to April' 11, 2020, collected from official website of the Government of India. The total number of COVID -19 positive persons on March 11, 2020 was 60 and the cumulative value of COVID -19 positive on April' 11,2020 was 8446. The value of March'11, 2020 was considered base for calculation and analysis, as first fifty patients were foreigner or foreign travelers. The basic reproductive number was calculated on SEIR (Susceptible-Exposed-Infected-Removed) compartmented model (Fig – 1). The formula used for calculation is $R_0 = 1 + K(\underline{T} + \hat{\underline{T}}) + K^2(\underline{T}\,\hat{\underline{T}})$; where K represents exponential growth rate, $\underline{T}$ represents non-symptomatic but infective period and $\hat{\underline{T}}$ represents symptomatic and infective period [4, 11, 12]. In the present calculation the $\underline{T}$ value was considered as 6 days. Although the period of incubation is variable, its mean value is

commonly considered 5.2 days [5, 13, 14, 15]. The $\underset{\wedge}{T}$ value was considered as zero, as the symptomatic persons of COVID -19 were removed from population by the government agency or health department.

FIG: 1: COMPARTMENTED MODEL FOR EPIDEMIOLOGICAL STUDY OF COVID 19 IN INDIAN SUBCONTENENT WHERE 'β' REPRESENTS EFFECTIVE CONTACT RATIO, 'Ƙ' REPRESENTS PROGRESSIVE (EXPONENTIAL) RATE AND 'ϒ' REPRESENTS REMOVAL RATE



The calculation of both basic reproductive number and exponential growth rate total time period was divided into six time intervals each of five days and again to two time intervals each of fifteen days. The data was divided into different time intervals only for the randomization of time interval and neutralization of effect of confounding variables on calculation, may be possible due to duration of time [1]. The value of exponential growth/day and basic reproduction number were calculated for both stratified time intervals and total period considered for analysis and obtaining of inferences.

OBSERVATIONS

The mean exponential growth/day is calculated as 0.16 which is same as for the period from March'11, 2020 to April'11, 2020. For the stratified period the minimum value of exponential growth rate was observed for March'11, 2020 to March'16, 2020 where as maximum value of exponential growth rate was observed for March'31, 2020 to April'05, 2020. In the present study Basic Reproduction Number for COVID -19 is calculated as 1.96 for total period. When stratified period is considered, the minimum R_0 value 1.78 is observed for March'11, 2020 to March'26, 2020 and maximum R_0 value 2.13 is observed for March'31 to April'5, 2020 (Table-1). The cumulative value of COVID -19 positive patients from March'11 to April'11, 2020 and its exponential growth at the interval of each 5 days represents slow increase up to March'31 but fast growth after March'31.

TABLE :1: REPRESENTS DAILY LOGARITHEMIC GROWTH RATE (Ƙ) AND BASIC REPRODUCTIVE NUMBER (R_0) WHEN INCUBATIVE INFECTIOUS PERIODE ($\underset{\wedge}{T}$) AND DISEASED INFECTIOUS PERIODE ($\underset{\wedge}{T}$) ARE CONSIDERED AS 6 DAYS AND 0 RESPECTIVELY.

S.N	DATE AND PERIOD		Ƙ	$Ƙ^2$	R_0
	FROM	TO			
1	MARCH'11	MARCH'16	0.12837077	0.358288669	1.77022462
2	MARCH'16	MARCH'21	0.183958677	0.428904042	2.103752062
3	MARCH'21	MARCH'26	0.17729602	0.421065339	2.06377612
4	MARCH'26	MARCH'31	0.13992207	0.374061586	1.83953242

5	MARCH'31	APRIL'05	0.188039476	0.433635188	2.128236856
6	APRIL'05	APRIL'11	0.143194749	0.37841082	1.859168494
7	MARCH'11	MARCH'26	0.163208449	0.403990655	1.979250696
8	MARCH'26	APRIL'11	0.156186017	0.395203767	1.937116103
9	MARCH'31	APRIL'11	0.163904672	0.40485142	1.983428033
10	MARCH'11	APRIL'11	0.15958399	0.399479648	1.957503937
11	MEAN OT TOTAL		0.159768	0.399709895	1.958608

DISCUSSION

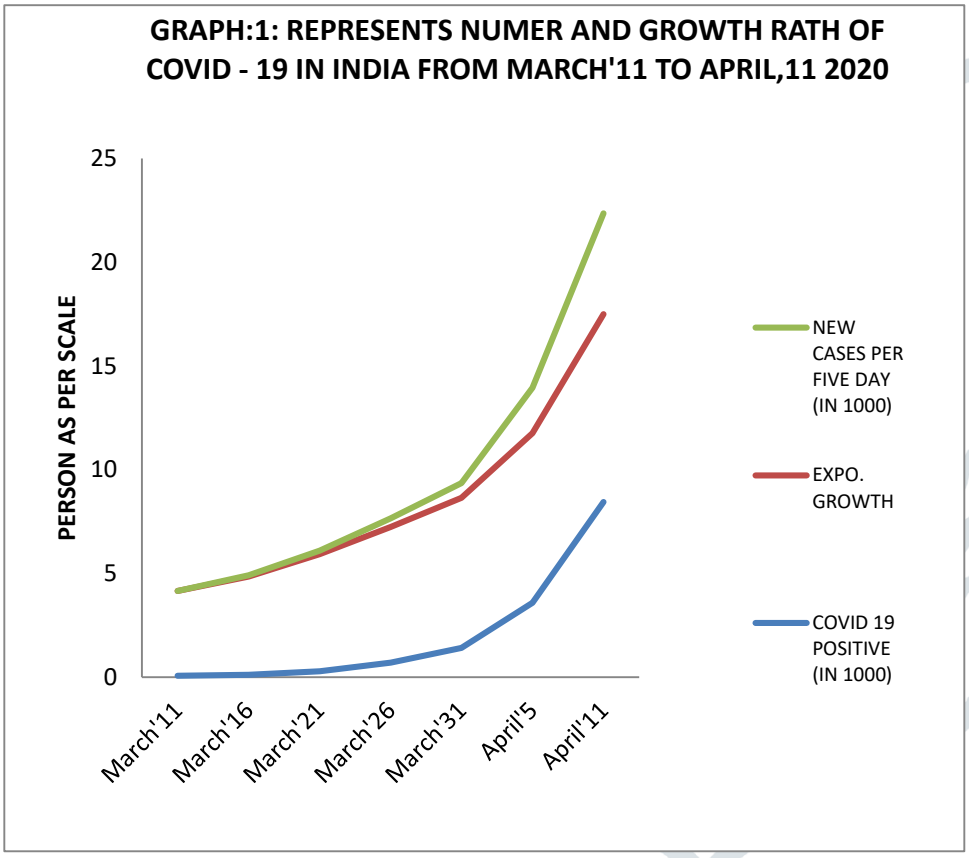
The calculated value of exponential growth rate/day (0.16) and Basic Reproductive Number (1.96) of India during March'11 to April'11, 2020 indicate that the problem of epidemics of COVID -19 is under control but its further spreading cannot be ruled out. The values are same as reported by workers for early transmission of disease in Wuhan, China and Africa [7,15]. The calculations are based on the basis of compartmental models and the populations are compartmented into susceptible, exposed, infected and diseased. The diseased are removed to prevent further infections. A compartmented model (figure-1) the factors β, Ƙ and ϒ are determinants of epidemiological dynamics. The factor β represents effective contact ratio between susceptible and exposed. The factor Ƙ represents progressive rate of exposed into diseased and ϒ represents removal rate of diseased. All these factors are time dependent (dt). In the present model the main challenge is to determine the real time between exposed and infected due to presence of longer asymptomatic incubation period or identification of infection in early stage due to lack of surveillance and confirmation at early stage [6,9].

In present study Basic Reproduction Number (R_0) 1.96 is more than the value reported earlier by the institute of Mathematical Science, Chennai (1.7) in third week of March'2020. Later on a paper predicted R_0 value of COVID- 19 in India as 1.5 - 4.0 after considering the infectiousness of asymptomatic COVID -19 positive as zero or half of the symptomatic patient [8]. The respective lower value of exponential growth rate (0.16/day) and Basic Reproductive Number is due to quarantine of exposed group and isolation of symptomatic patients. In the present calculation if we consider only two days for symptomatic infective phase the value of Basic Reproduction Number would change to 7.07. The data and values of epidemiological parameter suggest that first phase of lock down only decrease the value of R_0 but the value is still high and the chance of spreading is present.

FIG:2: REPRESENTS COVID 19 POSIYIVE CASES IN TERM OF 1000 AND VALUE OF EXPONENTIAL GROWTH IN INDIA .

PERIOD	POSITIVE CASE(IN 1000)	EXPO. GROWTH PER 5 DAYS	NEW CASES PER FIVE DAY (IN 1000)
March'11	0.06	4.094344562	0.001
March'16	0.114	4.736198448	0.054
March'21	0.283	5.645446898	0.169
March'26	0.694	6.542471961	0.411
March'31	1.397	7.242082359	0.703
April'5	3.577	8.182279739	2.181
April'11	8.446	9.041448235	4.869

It has been suggested that the delay in quarantine by a week increases epidemics by ten times whereas an early and rigid appropriate measures are responsible for a stable low incidence as Taiwan, Hong Kong and Singapore [17]. In India the epidemiological parameters like R_0 value and exponential growth rate had represented more accelerating trend after March'31,2020 (Table - 2, Graph - 1) suggested some faults in process of isolation and quarantine in spite of lock down by central Government or non-seriousness of population to maintain the direction based on epidemiological guidelines. The European Countries and American did not follow the doctrine of early quarantine and isolation and suffered most [18]. The R_0 value was 3.10 for Italy, 6.56 for France, 4.43 for Germany and 3.95 for Spain. The values suggest that these countries will still suffer from epidemic of COVID -19 [19].



CONCLUSION

The exponential growth rate (Ƙ) and Basic Reproductive Number of COVID -19 in India is low in comparison to European countries and America. But 1.96 value of Basic Reproductive Number suggests that the possibility of epidemic of COVID -19 has not been ruled out and the chance of epidemic situation exists. Even the chance of transmission from infected person to exposed person is twice. Epidemiologically it is not a good sign and it has been suggested that the Government should take proper and strong action for primary screening of all exposed population, isolation of risk group, quarantine of exposed population and sensitize the area resided by exposed population. The geographical, population demography and political system of India is quite different from other countries of the world. Here each state has its own population and geographical characteristics, may cause problem in control of its transmission. Hence the identification of probable clusters, villages and states vulnerable for COVID- 19 transmission and their isolation is necessary.

REFERENCE

[1] Liu Y, Gayle A.A; Smith A.W and Rocklov J: The reproductive number of COVID- 19 is high compared to SARS Coronavirus. *Journal of Travel Medicine*. (2020). 27.(2); pp-1-4 doi: 10. 1093/jtm/taaa021

[2] World Health Organization: WHO characteristics COVID -19 as a pandemic, 2020, 19-11, March 2020.

[3] World Health Organization: Novel Coronavirus Diseases (COVID -19) situation update report- 11. WHO, April'12, 2020.

[4] Diekmann, O and Heesterbeck, H: Mathematical Epidemiology of Infectious Diseases: Model Building, Analysis and Interpretation. New York. Wiley (2000).

[5] Li. Q, Guan. X; Wu. P; Wang, X; Zhou L and Tong. Y : Early transmission dynamics in Wuhan, China of noval coronavirus infected Pneumonia. *New England Journal of Medicine.* (2020) (online) Pub. Med.

[6] Kucharshi, J.A; Russell, T.W; Diamond, C; Liu. Y; Edmunds. J ; Funk. S and Eggo R.M: Early dynamics of transmission and control of COVID 19: A mathematical modeling study. *Lancet. Infect.Dis* (2020), http://doi.org/10.1016/S1473-3099(20)30144-4.

[7] Musa S.S; Zhao. S , Wang M.H; Habib. A.G; Mustapha U.T and He D: Estimation of exponential growth rate and basic reproduction number of the coronavirus disease 2019 in Africa. *Infectious disease*, (2020) (online) DOI. 10.21203/r.s.3.rs-19916/VL.

[8] Mandal. S ; Bhatnagar.T; Arinaminpathy. N; Agarwal.A; Chaudhary. A; Murhekar M; Gangakhedkar R.R and Shankar S: Prudent public health intervention strategies to control the coronavirus disease 2019 transmission in India: A mathematical model based approach,. *Indian Journal of Medical Research*, (2020) (online): DOI.10.4103/ijmr.IJMR-504_20.

[9] Du Z; Xu. X; Wu. Y; Wang . L; Cowling B.J and Meyers L.A: Serial interval of COVID- 19 among publically reported confirmed cases. *Emerging Infectious Disease* . (2020) 26. (Early release online).

[10] Wallinga. J and Lipstich. M : How generation interval shape the relationship between growth rate and reproduction numbers.. *Proc. Biol. Sc*; (2007), 274:599-604.

[11] Cao Z, Zhang Q, Lu X, Pfeiffer. D; Jia Z, Zeng D.D: Estimating the effective reproduction number of the 2019- nCov in China. *medRxim* . 2020. Doi http://doi.org/10.1101/ 2020.0127.20018952.

[12] Lipsitch, M; Cohen. T; Copper. B; Robins. J.M; Stefan M; Lyn J; Gouri. G; Saok Kai C; Chuan C; Samone M.H; and David. F: Transmission dynamics and control of Severe Acute Respiratory Syndrome. *Science.* (2003). 300 (5627): 1966-1970.

[13] WHO: Noval coronavirus (2019- nCov) situation Report- 7, World Health Organization, Jan'27, 2020.

[14] WHO: Coronavirus diseases 2019 (COVID -19). Situation Report- 73. 2020. World Health Organization. April'2, 2020.

[15] Park. M Cook; A.R: Lim J.T; Sun Y and Dickens, B.L: A systematic review of COVID -19 epidemiology based on current evidences. *Journal of Clinical Medicine*, 2020, 9 (967):1-13.

[16] Sun. J; Wan-Ting H; Wong L.et.al : COVID -19: Epidemiology evolution and cross- disciplinary perspectives. *Trends in Molecular Medicine*, (2020) (online)

[17] Sanche. S; Lin Y.T; Xu. C; Romeno- Severson. E; Hengarlnen N and Ke R: High Contagiousness and rapid spread of Severe Acute Respiratory Syndrome Coronavirus- 2. *Emerging Infectious Diseases*. (2020); 26(7). (Early release online).

[18] Hellewell. J; Abbott. S; Giamma A; BOsse N.I; and Janvis C: Feasibility of controlling 2019-n-Cov outbreak by isolation of cases and contacts. *medRxiv,* (2020) , online, DOI. 10.1101/2020.20.0820021162.

[19] Yuan. J; Li. M, Lv. G and Kevin Lu Z: Monitoring transmissibility and mortality of COVID -19 in Europe. *Int.J. Infec. Disease.* (2020). DOI: http://doi.org/10.1016/j.ijid.2020.03.050.