Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 11 [8] July 2022 : 40-42

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD

ORIGINAL ARTICLE **OPEN ACCESS**

Understanding the Preliminary Progression of COVID-19 through Case Fatality Rate: From Indian Perspective

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ABSTRACT

This manuscript tries to encapsulate preliminary data of first 100 days related to COVID-19 disease in India, to bring out insight visualization of the pandemic, so that needed steps can be taken timely, to tap the dynamics of this infectious disease. Matrix plots have been drawn to describe the trend of confirmed deaths and new cases on daily and cumulative basis. Double Exponential Smoothing Model has been fitted on collected data and it additionally forecasted the death trend for next 100 days in India. Case Fatality Rate has been reviewed ascritical metric to understand the dynamics of COVID-19 and its dependency has been chalked out with Multi-Regression Model. The prediction model has forecasted more than 4,000 confirmed deaths till the end of July 2020, which can exponentially increase further. Case Fatality Rate of India has risen from 0 to 3.2 within 28 days and should be taken care of, to restrict this pandemic. Moreover, a negative relation of Fatality Rate with Maximum Temperature and Average Humidity has been erupted from the model. Present study observed a quadratic relation with time (Days), which confirmed the COVID-19 as a highly communicable disease and also proved that 'Total Tests Performed' is a serious factor to reduce CFR. It depicts a live forecasting practice with conceivable inferences for planning and decision making. It also implicates behavioral exploration of Case Fatality Rate with respect to some quantitatively important factors, as far as Indian scenario is concerned.

Keywords: *SARS-CoV-2, Pandemic, Trend Analysis, Multi-Regression Modeling, CFR.*

Received 16.11.2021 Revised 26.11.2021 Accepted 25.05. 2022

INTRODUCTION

On 31st December 2019, Chinese government reported to World Health Organization (WHO) country office about an epidemic with unexplained low respiratory infections categorized as "pneumonia of unknown etiology", discovered in Wuhan [1, 2]. WHO declared this as a "COVID-19" disease caused by the new virus SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2) which appears to be highly communicable and has spread worldwide [3]. The mode of transmission in humans includes; person-to-person by respiratory droplets, contact and fomites, zoonotic / nosocomial / faecal-oral routes and aerosol transmission [4]. Mild symptoms comprise fever, respiratory symptoms and radiographic features, whereas critical symptoms include respiratory failure, septic shock and multiple organ failure [5-7]. Viral shedding of patients peaked on or before symptoms onset, with a substantial proportion of transmission, before first symptoms in the index case occurred [8]. The importance of having a model to determine the morbidity and mortality is obvious, from the infectivity rate associated with this pandemic [9, 10].

MATERIAL AND METHODS

The aim of this paper is to understand the dynamics of COVID-19 particularly in India, after analyzing and synthesizing related data of first 100 days, so that vital inferences can be made to realize the seriousness of this on-going world's largest problem. Suitable statistical modelling can regress 'critical to pandemic factors' efficiently. The data has been collected from the European Centre for Disease Prevention and Control (ECDC), a European Union agency based in Stockholm [11]. The meteorological data (from

January to April 2020) of India has been collected from AccuWeather website [12].
To visualize the Indian status, firstly confirmed Daily and Total Deaths in various countries were delineated graphically. Next Matrix Plots chalked out the detail breakup of the Total Confirmed Deaths and Daily New Deaths in India. Then after, the best-fit Statistical Model was fabricated to predict on going Pandemic effectively. The Case Fatality Rate (CFR) was validated as a crucial metric and its behavioral investigation was performed through suitable Multi-Regression Model, which instigated the necessary discussions and conclusions, without ignoring the limitations of the present study.

RESULTS AND DISCUSSION

This work is based on data collected from 31st Dec 2019 onwards and tries to delineate the progression of COVID-19 in around first 100 days of 2020. By 11th April 2020 world has lost more than 1 lakh people due to this erupting pandemic and observed about 7 thousand daily deaths. Till now around 210 countries and territories in the world, have reported confirmed cases of the Coronavirus (COVID-19 disease). The comparisons of confirmed daily and cumulative deaths, among prominent ten countries have been illustrated through figure 1.

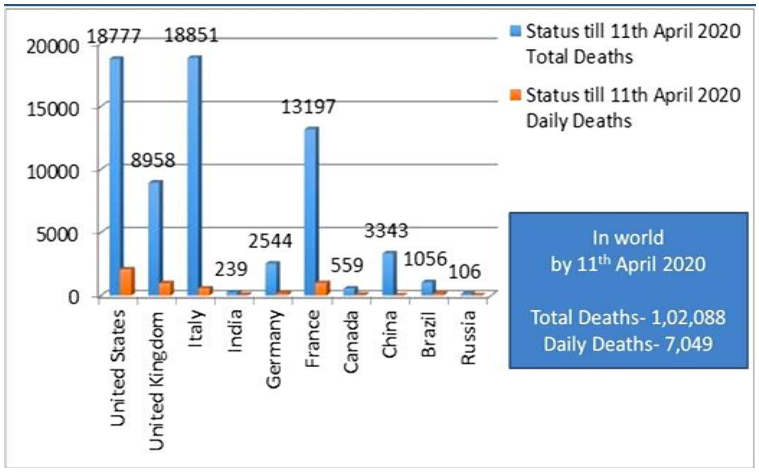

Figure 1: Assessment of deaths among leading countries.

Countries like US, Italy had more than 18,000 total deaths and other had huge variation from 106 to 13,000 deaths till 11th April 2020. As far as India is concerned, net 239 Indian became victims with daily death toll of 40 by 11th April, with death rate of about 8 per cent. About 205 deaths were reported till 9th April, with a mortality rate of up to 3 per cent, which is quite low as compared to the European countries [13]. The low death rate can be attributed to the reason that most of the Indian population (1.3 billion) is relatively younger and are less susceptible to develop complications after catching the infection. Quick action of imposing 'Lockdown' by Indian government may be the other reason [3].
The matrix plot was plotted (Fig. 2) to visualize this picture clearly. First sanctioned death in India took place on 13th March (i.e. on 73rd day of outbreak) besides 75 cases of active infection. No death was found in whole January, February and first 12 days of March. But from 74th day onwards, death toll had started rising with geometric progression and reached up to 29 on 90th day itself. This trend started leaping up to 166 confirmed deaths on just 100th day of the spread. Within next couple of days, number of deaths almost doubled (i.e. 239 on 11th April 2020), which seemed to be more scary and pushed India into more uncertain future. The daily death figure acquired momentum on 26th March onwards, which reached a nasty number of 40 deaths on very 100th day. On the similar pretext, dynamics of total coronavirus cases and daily newly added cases had been illustrated in figure 1. The red line showed the best fit line along with its curvilinear upward trend from 5th March (i.e. 66th day) onwards. There were 29 confirmed cases on 6th March which touched the count of 125 on 17th March and exponentially raised to 5734 on 100th day (i.e. on 9th April). But after this within two days, it reached the milestone of 7447 and daily new cases became 1035 from 678 correspondingly. Rise in daily new cases actually happened more after 84 days, as plot pinpointed uplift from 53 new cases to 336 in mere ten days and next week pushed the daily new cases count up to 1035 till 11th April.

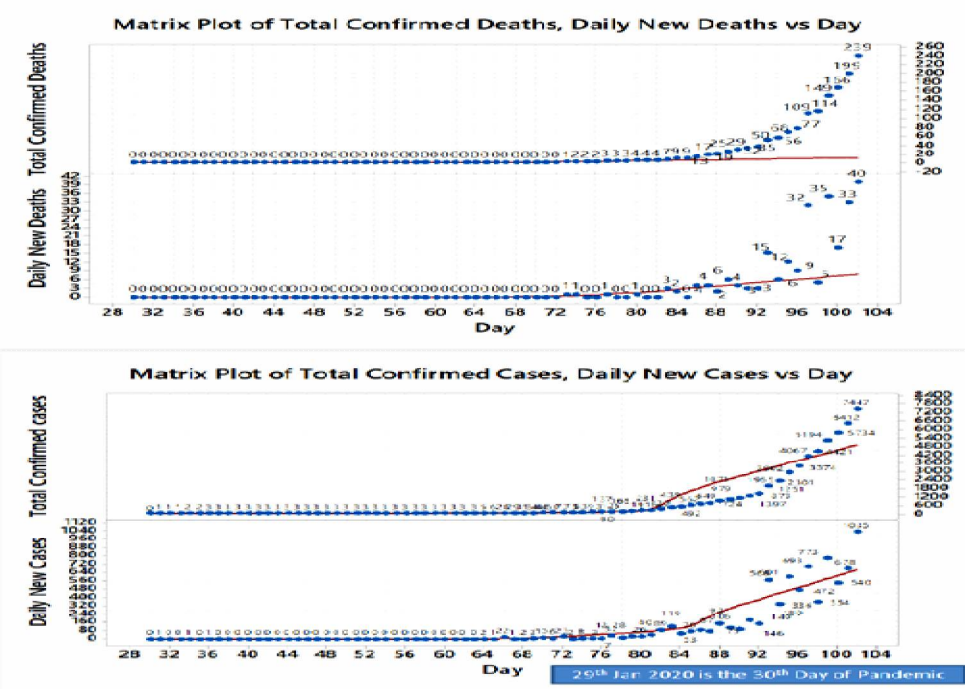

Figure 2: Progression of COVID-19 in India.

To assess the degree of seriousness of this on-going pandemic, it is very necessary to map its progression, because then and only then one can understand its devastating effect in near future and can make vital arrangements to combat this gruesome situation appropriately. The Double Exponential Smoothing Method had been deployed through Minitab statistical software, to draw death trend and was observed as best fitted method (Fig. 3). Data up to 11the April was fed in the software and the four green dots (or in blue ovals) reflected the forecasted values of deaths on 12th, 13th, 14th and 15th April, respectively. There corresponding actual deaths were encapsulated in orange ovals. The trend chart clearly predicted the efficacy of Double Exponential Smoothing Model, as the percentage error in each forecasted value was less than 10%.

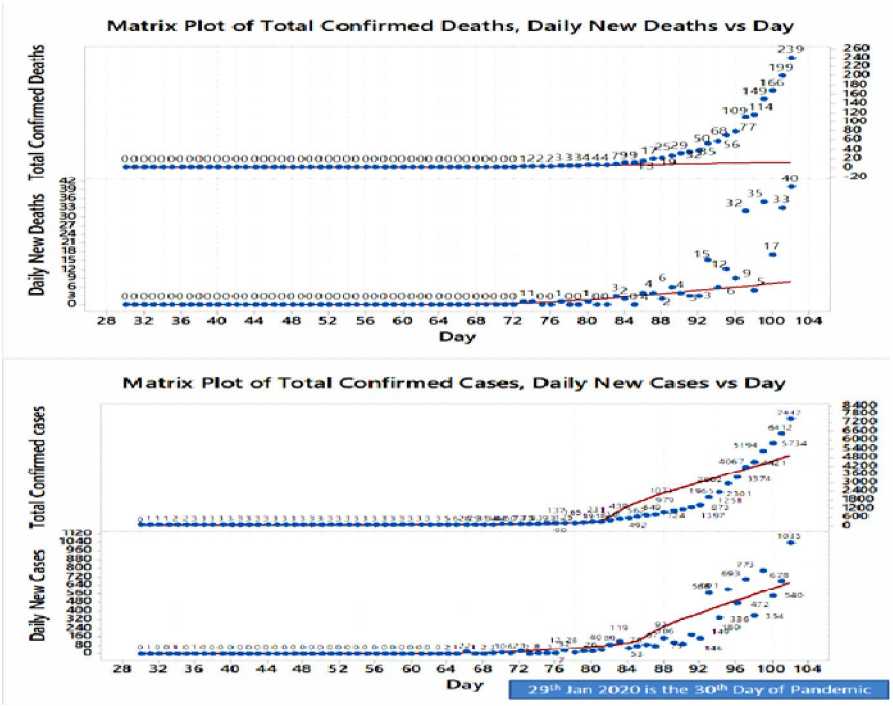

Figure 3: Predictions of deaths in India.

If this trend continues, then on 150th day death toll in India will be around 2,254 and on 200th day, it will be massive 4,365 approximately. Situation is really alarming for a 1.35 billion population and circumstances seem to be quite horrible, if something rigid will not be planned and executed strategically.
From Literature, Case Fatality Rate (CFR) seems to be the best measure to assess the risk of death from COVID-19 [11]. It is the ratio of the number of confirmed deaths to the total number of confirmed cases, which estimates the acuteness of the disease at a specific time, for a specific population [13]. The values of CFR may vary over time, existing medical facilities, and location and/or by the features like age, sex and pre-existing health problems of the concerned population [14, 15]. Moreover, respiratory diseases like influenza increase during the conditions of extreme cold and low absolute humidity [16]. As the virus is spread by droplet infection, so during high humidity the droplets settle down very quickly, thus hindering the spread [17, 18]. This may also be true for SAR-COV-2 infection, as high absolute humidity may decrease the propagation of the disease [19]. There is a negative association between the temperature and mortality [20]. Actually, SARS-COV2 cannot survive at elevated temperatures as the virus is quite sensitive to heat [21-23]. Besides above factors, number of tests carried out also directly affects the overall CFR of any country [24].
During any pandemic, time is the signal factor and can change CFR value independently [25]. At the moment, COVID-19 outbreak is in its initial phase and its growth will depend upon the capability and capacity of any country to manage its CFR [26, 27]. In order to snap the real picture of pandemic at any time, CFR is realized as better derived parameter (metric), since its variation contains the effect of varying confirmed deaths with confirmed cases, by taking care of all the existing personal or responsible medical or meteorological parameters, simultaneously. Data related to Confirmed Deaths, Confirmed Cases, and Total Tests Performed day- wise had already been gathered from World Health Organization website [11]. Daily CFR had been calculated since March 17th 2020 onwards, as confirmed deaths were almost negligible before that. To see the impact of meteorological factors, Maximum Temperature and Humidity data had been gathered from 31st Dec 2019 to 11th April from AccueWeather website [12]. Here CFR was presumed as dependent factor (or response) which might further depend upon the values of independent factors like; Days, Tests Performed, Maximum Temperature and Humidity in a day, respectively. The data was fed into Minitab 18 software for executing multi-regression analysis and related statistics were calculated. Only the p-value of Total Tests Performed daily was around 0.845, rest all the factors had p-values less than 0.05. This outcome statistically proved with 95% confidence, that the factors like Days, Maximum Temperature and Humidity had significant impact on CFR. Moreover, square of Days, interactions like 'Days X Avg. Humidity' and 'Max. Temperature X Avg. Humidity' also had significant impact on CFR. Further R-square value was around 92% which was fairly high, as it is an indicator about how well the selected model fits with on-going progression. Finally, CFR was predicted by a quadratic equation in terms of significant factors as described below.
The coefficient of each factor or its interaction demonstrated its relative weightage or the importance of each factor to predict CFR accurately [28]. It was clear from derived regression equation that humidity (with coefficient -21.71) was more impactful then temperature (+26.3). CFR was increasing with days (+0.016) because pandemic was in initial phase and with time confirmed deaths were rising quadratically. With upsurge in temperature and humidity simultaneously (0.443), of course CFR would start showing downtrend. Next, figure 4 highlighted the Model Building Report and described how the software arrived at the final regression model. With each step, new factors (Xs) and its significant interactions were added in the model and its impact was watched through corresponding p-value and R-Square (adjusted) values. The value of R-Square (adjusted) increased from 57.8% to 89.6% and stopped further escalating. The factor 'Days' contributed 19.4% information to predict CFR, whereas Humidity assimilated second largest number of facts (8.8%) and so on.
The Effect Plots were plotted to depict the Individual impact of each factor or its interactions on CFR, graphically (Fig. 5). The first graph demarcated the negative effect of humidity. As the humidity increased from 59% to 61% (with change in season from January to April 2020), the corresponding CFR reduced from 3 to 2.1 approximately. Similarly, maximum temperature of the day had also been scored from January to April, as India was moving towards her summer season. As average maximum temperature of India surged from 320C to 360C, the CFR exhibited slight downtrend from 2.8 to 2.1 roughly. Total Tests Conducted factor had revealed faintly positive inclination towards CFR. Last plot portrayed the effect of Days on CFR in India. Initially, ratio of death to confirmed cases decreased from 4 to 2.5 (i.e. from 31st Dec., 2019 to 25th March, 2020), since confirmed cases were coming at high rate than confirmed deaths.

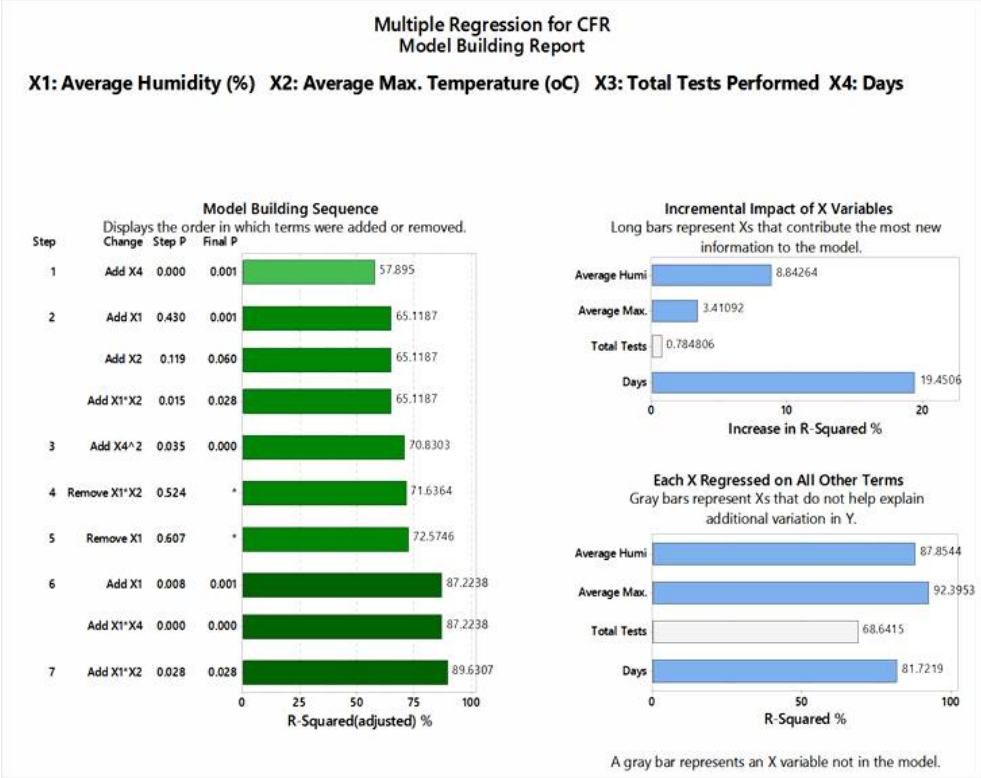

Figure 4: Model building report.

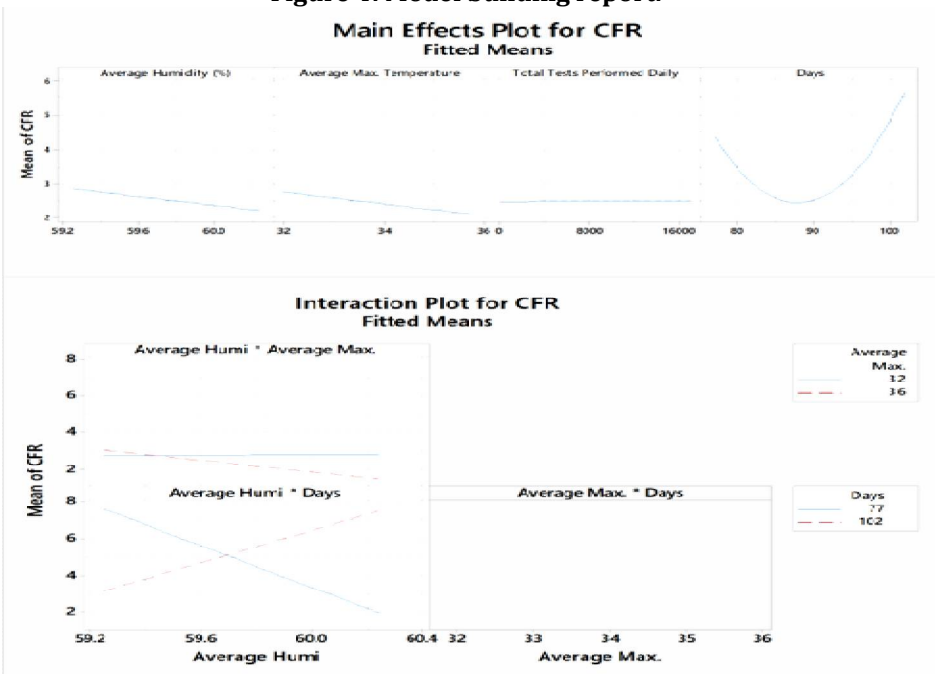

Figure 5: Individual and interaction effect plots.

Then after, CFR started upward trend due to relative increase in high deaths, from 86th day (13 daily deaths) to 100th day (166 deaths) and this momentum continued till 11th April (239 daily deaths) consecutively. This phenomenon had raised the CFR value from 2.5 to more than 3.2 within next 15 days only. COVID-19 Pandemic was realized in its introductory phase during April 2020, that's why it was spreading exponentially with time (Days). Time was the only factor, which had not only an individual effect, but its interaction with humidity and with self (Day X Day) had quadratic contribution to CFR, as found in derived regression equation.

On 77th day the average humidity had its negative impact on CFR, but as time passed, the pandemic swelled rapidly and humidity's combined affect was almost diluted after 100th day. That's why CFR

flourished continuously on 102nd day (as indicated in dotted lines). The top graph in figure 6 illustrated the combined consequence of 'Max. Temperature X Avg. Humidity'. It was obvious from plot that combined upswing in humidity and temperature, had more negative impression on CFR. This effect was more pro at higher Temperature side. Effect of Humidity was observed more rigorous at 36^{0}C, as CFR reduced almost from 3 to 1.5, while at 32^{0}C, this reduction seemed to be negligible.

In order to understand the dynamics of CFR more closely with interactions, suitable contour plot had been generated for above significant interactions (Fig. 6). Colored contour bands were chalked out on the surface of two factors that represented the ranges of the CFR. First graph provided the bands (ranges) of CFR in different colors on the pretext of Max. Temperature and average Humidity variations. Dark blue region earmarked the region with less CFR (1.5 or less) at temperature range of 35^{0}C to 36^{0}C and humidity variation from 60% to 61% respectively.

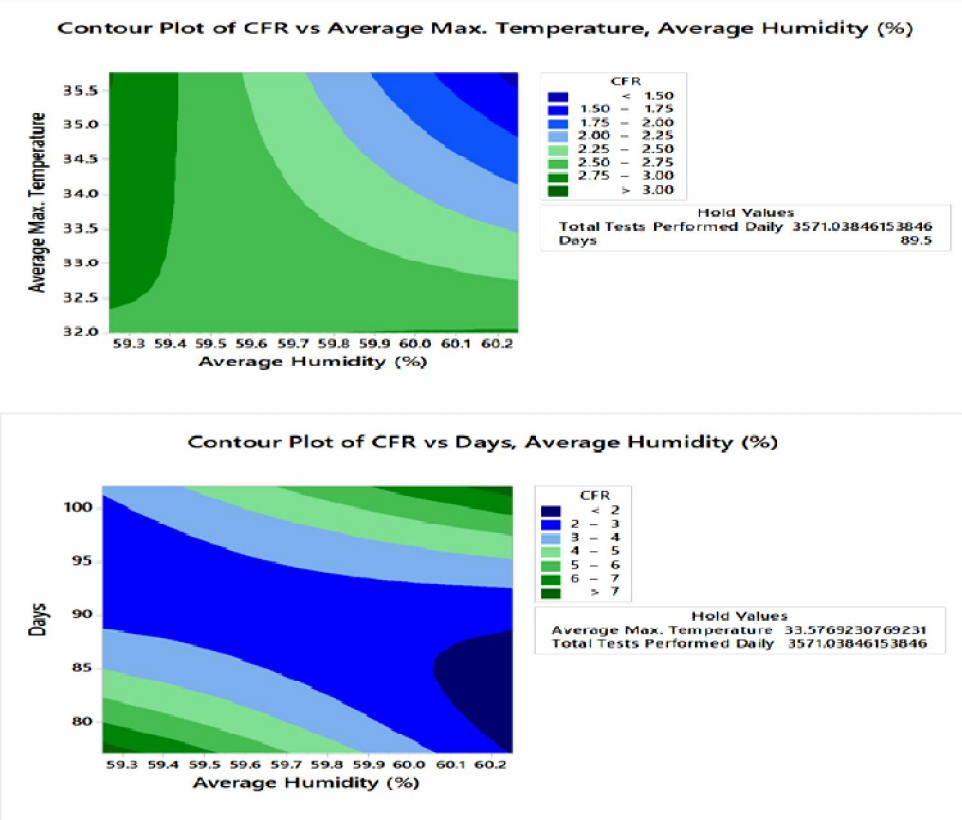

Figure 6: Contour plots for CFR.

Similarly second graph, encapsulated the interaction of Days and Humidity together, to find optimum CFR. Again dark blue region (band) predicted the values of factors corresponding to which CFR would be even less than 2%. By June or July, maximum temperature often reaches 45^{0}C to 49^{0}C with corresponding humidity of 75% to 85%. These operating conditions will definitely impair the spread of this deadly virus. Though proper vaccine of Corona Virus will be the sustainable solution of this progression, but the findings of this study will be useful for medical practitioners, Indian government and individuals towards making timely decisions and taking the necessary actions, to restrict the scattering of this deadly virus. Definitely, this research work will be revised as the pandemic will progress, but it tells a lot regarding the outbreak from scratch, particularly in India. The outbreak and challenges of novel coronavirus were also discussed in the Indian Scenario [29-32]. The dynamics of COVID-19 has been explained with respect to critical metric 'CFR' [33-36]. The impact of personal factors like age, sex and pre-medical history of the infected individuals have been totally ignored. These limitations may be assumed as the scope for future research and will definitely be helpful to further robust the forecasting model of COVID-19 pandemic.

CONCLUSION

The on-going COVID-19 pandemic is the global truth. After 73rd day of the pandemic, confirmed cases were flooded from 75 to 7447 in mere next 27 days and death toll reached from 1 to 166. This exponential trend really frightened the India and the government had decided to lockdown the whole country even at the stake of economic crisis. The generated 'Double Exponential Smoothing Model' has

demonstrated the Indian death trend with least possible error (<10%) and forecasted around 4,126 deaths in the very next 100 days. This study successfully validated CFR as a better 'Metric' to understand the dynamics of COVID-19. Present research has proved the effectiveness of rise in daily Maximum Temperature and Average Humidity to control the CFR through suitable Multi-regression modelling. The quadratic Impact of time (Days) during this pandemic was also illustrated, quantitatively.

FUNDING
It's a non-funded analytical work.

CONFLICTS OF INTEREST
The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

AVAILABILITY OF DATA AND MATERIAL
Free to use data (from European Centre for Disease Prevention and Control (ECDC) and World Health Organization (WHO) websites) has been gathered and analyzed.

CODE AVAILABILITY
Analysis was performed on appropriately licensed statistical software 'Minitab-18'.

ACKNOWLEDGEMENTS
We acknowledge the support of all the related medical practitioners of M.M. Institute of Medical Sciences and Research, Mullana-Ambala, Haryana, for their time to time guidance and help. Special thanks to medical staff of Base Hospital, Barrackpore Cantonment, Kolkata for their much needed advice and suggestions.

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CITATION OF THIS ARTICLE

B J Singh, H M Singh, Rippin, S K Upadhyay, V Kumar, P Sharma and R Singh. Understanding the Preliminary Progression of COVID-19 through Case Fatality Rate: From Indian Perspective**.** Bull. Env.Pharmacol. Life Sci., Vol 11 [8] July 2022 : 54-61