Does Environment has any role in recovery from COVID-19 pandemic? A case study from India.

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Abstract

The present study has investigated the role of meteorology and air quality for recovering from the COVID-19 pandemic in India. Using Pearson's correlation method, we look into if there is any significant association occurs between the district level recovery case counts and different remote sensing based environmental variables. Among weather parameters, only precipitation and air temperature found to be significantly correlated with recovery situation. However, all the pollutants' concentration was negatively correlated with count of recovery cases. It depicts that air quality might has greater importance in recovery from this disease. During late monsoon onwards, recovery rate was getting more than the infections which indicate that lesser temperature and good rainfall could help the air to be freshen. Through air pollution was greater during winter and post monsoon than the summer season in India the higher recovery rate was counted during post-monsoon and winter which suggest that patients may require lesser temperate ambient for better recovery. Spatial patterns also suggest that north-eastern hilly region followed by districts located in the northern mountain had better recovery where the pollutants' concentration was also quite lower during the study period. Therefore, improving air quality with proper preventive precaution could help to combat the pandemic situation in India.

Introduction

In the year 2020, world has experienced one of the deadliest pandemics in human history ever with a death count of 2501229 and confirm cases count of 112649371 globally as of 03:39 pm CET, February 26, 2021(<https://covid19.who.int/>). It started since December 2019 when a pneumonia infection broke out in Wuhan, Hubei province, China, which was then named as Novel Coronavirus Pneumonia (NCP), started spreading all over the country ((Liu et al., 2020). Gradually it has spread all over the world ((Bertuzzo et al., 2020; Gorbalenya et al., 2020). WHO started with epidemiological and operational updates about COVID-19 on their website since January 21 of 2020 and by March 11, 2020 the director general of the organization briefed the media by declaring COVID-19 as pandemic. In the situation report-10 that was published on January 30, 2020, WHO had already announced the first confirmed case of India and also stated it to have a travel history to Wuhan.

A few researchers have already exhorted about significant association of environmental parameters to COVID-19 transmission (Azuma et al., 2020; Bherwani et al., 2020; Eslami and Jalili, 2020; Gupta and Pradhan, 2020a; Kifer et al., 2021; Rume and Islam, 2020; Saadat et al., 2020; Shakil et al., 2020). There are also a few global as well as regional studies that had been carried out in the context of China, USA, England, Germany, Spain, Italy, Indonesia, Iran, Pakistan, Bangladesh, India, and found significant correlation between weather parameters and the COVID-19 cases (Ahmadi et al., 2020; Chen et al., 2021; Fadli et al., 2020; Ficetola and Rubolini, 2021; Gupta et al., 2020a; Gupta and Pradhan, 2020b; Islam et al., 2020; Liu et al., 2020b; Ma et al., 2020; Mehmood et al., 2021; Nottmeyer and Sera, 2021; Oliveiros et al., 2020; Qi et al., 2020; Tosepu et al., 2020). Studies carried out by Bochenek et al., 2021; Borah et al., 2020; Briz-Redón and Serrano-Aroca, 2020; Emediegwu, 2021; Guo et al., 2021; Gupta et al., 2020b; Mecenas et al., 2020; Runkle et al., 2020; Şahin, 2020; Sil and Kumar, 2020 suggested that warm and humid condition

seem to foreshorten the proliferation of COVID-19. On the other hand, Al-Rousan and Al-Najjar, 2020; Awasthi et al., 2020; Bashir et al., 2020a; Fawad et al., 2021; Gupta and Pradhan, 2020a; Kumar and Kumar, 2020; Pani et al., 2020; Sangkham et al., 2021; Selcuk et al., 2021; Sharma et al., 2021 reported that hotter days might be more susceptible for COVID-19 dissemination while the role of humidity was still incongruous (Aidoo et al., 2021; Auler et al., 2020; Gupta et al., 2020c; Kumar, 2020; Yuan et al., 2021). Menebo, 2020 found negative association between precipitation and COVID-19 cases, contrary to Byass, 2020; while Gunthe et al., 2020 found no significance of precipitation and cloudiness for this outbreak.

On the other hand, the carbonaceous pollutants i.e. CO and BC and OC, which also includes the primary and secondary organic carbon, are mainly produced during different anthropogenic activities of biomass burning and fossil fuel combustion, with relatively little contribution from various natural sources (Li et al., 2016; Prabhu et al., 2020; Schmidt, 2011; Wang et al., 2019; Winiger et al., 2016; Zhang and Wang, 2011). AOD, an indicant of Particulate Matter pollution (Chudnovsky et al., 2014; Engel-Cox et al., 2004; Gupta et al., 2021; Karimian et al., 2016), has not been often related to such malady study. Since the significant relation between prevailing weather conditions and regional pollution level is well demonstrated by various studies, it becomes very crucial to behold the role of meteorology and air quality togetherly to conceive the seasonality of such savage seizure of coronavirus.

Human respiratory viruses transmit through human contact, mainly through coughs and breathes of the infected person (Leung et al., 2020) as the virus generated through sneeze and coughs are contained by the aerosols (Srivastava, 2021; Barcelo, 2020) for which WHO has given several guidelines regarding travelling, public gathering and personal care with an aim to minimize the physical contact. In a tropical country like Bangladesh no direct relation between the number of COVID-19 cases and meteorological parameters were detected but there was significant positive correlation of them with the contact transmission (Islam et al., 2021). In a case of Iran, it was estimated that population over 1.7 million can trigger the transmission (Jahangiri et al., 2020). However, there are several environmental factors those influence the transmission of respiratory viruses such as humidity, temperature, airflow etc. (Pica and Bouvier, 2012). Air quality also has serious impact on it inducing various respiratory problems since, exposure to some air pollutants can worsen the infection (Domingo and Rovira, 2020; Li et al., 2020). It was found that higher concentration of ambient carbon mono-oxide can play a key role in greater transmission (Lin et al., 2020). It was also found that PM_{2.5} can significantly increase both confirm (Sharma et al., 2021) and death counts (Jain et al., 2021). Even, different countries, with their different climatic scenario have shown different kinds of association with the spread of COVID-19 (Doğan et al., 2020; Pani et al., 2020; Singh and Agarwal, 2020). Sometimes humidity is found to be the best predictor of COVID-19 transmission (Runkle et al., 2020) with absolute humidity having a positive correlation with the number of cases (Luo et al., 2020). Low temperature countries were advised to adopt strict measurements to combat the situation (Wang et al., 2020). A study in Kuala Lumpur, Malaysia, with the help of Spearman's correlation test has shown a positive correlation of COVID-19 transmission with relative humidity and air pollutants such as particulate matters and gaseous contents but displayed a negative correlation with the ambient temperature (Suhaimi et al., 2020). In Turkey with the help of spearman's correlation test it was found that higher the average temperature of the first day of the 14

days incubation period, lower the number of cases (Şahin, 2020). Another study that had taken national and region-specific data from Germany, Italy, Spain and United Kingdom and put them into a non-linear model has concluded that cold and dry environments are likely to facilitate the COVID-19 transmission (Fu et al., 2021). With low temperature, studies have explored mild diurnal temperature range and low humidity to play significant role in rise in transmission (Liu et al., 2020). Studies have even shown that in the context of China increase in the temperature will significantly decrease the doubling rate of cases (Oliveiros; et al., 2020). These results started piling up hope amongst people from all over the world that the situation will get back to normal in the upcoming summer season (Karapiperis et al., 2020; Shi et al., 2020; Kaplin et al., 2021). However, several studies, have shown completely opposite results (Kumar, 2020; Sahafizadeh and Sartoli, 2020; Ceylan, 2021; Hridoy et al., 2021; Jain et al., 2021). A study in the equatorial country Brazil, with the help of principal component analysis and linear regression analysis, has shown that higher mean temperature and average relative humidity favor the COVID-19 transmission (Auler et al., 2020). A very recent study in China added rainfall in the same category i.e., positively correlated with case counts (Chen et al., 2021). In India it has been suggested that hot and dry regions of lower altitude shall be most affected by the COVID-19 transmission (Gupta et al., 2020a). A study in Turkey has found positive correlation of number of cases with almost all the parameters (temperature, wind speed, population density etc.) except humidity (Saraç and Koyuncu, 2020). Amidst this turmoil situation, the major question in front of the world now is when shall the situation get back to normal and how?

A Delhi based study, during the initial period of pandemic, estimated that it will take almost 10 months for complete recovery from COVID-19, having said that with an increase in 1°C in the temperature about 30 cases will recover every day (Awasthi et al., 2021). A study in Jakarta, Indonesia shows that exposure to sunlight is showing a significantly better recovery among patients (Asyary and Veruswati, 2020). Bhattacharjee et al., 2021 predicts that in India the number of patients will start declining when the case load rate (Confirmed cases – Recovered cases – Deaths) goes lesser than the recovery rate. As of now, there is no significant study available to explain how under existing climatic condition of India the recovery of COVID-19 patients shall be influenced. Hence, this paper aims at taking a close look into the relationship between the meteorological factors and recovery rate in the country.

Scanty studies have been carried out on the importance of fresh air for the melioration of human health and to elude any convalescence (Cragg et al., 2016; Kampa and Castanas, 2008; Manisalidis et al., 2020; White et al., 2019). Likewise, scarcely any study has been fanatical about the significance of weather parameters on COVID-19 recovery, even though 93.88% of the sufferers have been healed in India, slightly lesser than the global recovery rate (97.42%) till March 31, 2021. Since a handful of studies had reckoned that the inferior air quality had efficaciously swayed to aggravate the COVID-19 emanation, hence it becomes also requisite to investigate whether the convivial air quality has been benevolent to convalesce the COVID-19 patients in India. Till date, seldom study might have inspected the yearlong period of pandemic situation while minimal have rendered any estimation on this. Therefore, the present study has been firmed to analyse the association of COVID-19 incidences (i.e. transmission) and recovery

cases with weather and air quality parameters across the country, as well as proffered a comparative assessment for estimating confirm and recovery cases availing the non-linear complex relationship.

Data And Methodology

Counts of Confirmed and Recovered cases for all the available districts in India have been acquired from <https://www.covid19india.org/>. Spatial data for total six different meteorological parameters - 2-m Air Temperature (AT), Bias-corrected Total Precipitation (PRC), Specific Humidity (Hm), Cloud Cover (CLD), Incoming Short-wave Radiation (ISWR), Wind Speed (WS), and six different air quality parameters - Aerosol Optical Depth (AOD), Tropospheric Column Nitrogen di-Oxide (NO₂), Total Column Ozone (O₃), Surface concentration of Carbon Monoxide (CO), Sulphur di-Oxide (SO₂) and Black Carbon (BC) have been incorporated in the present study. Remote Sensing based datasets are highly useful for various environmental studies (Bhatt et al., 2021; Das et al., 2017; Das and Gupta, 2021; Gupta et al., 2020b; Gupta et al., 2019; Moniruzzam et al., 2018; Nanda et al., 2018; Roustia et al., 2020), hence we have used such dataset from different sources. Monthly mean of these twelve environmental variables were further processed in ArcGIS software, adjoined and related with the monthly cumulative counts of confirmed and recovery cases for each months for each of those selected districts.

Infections and recoveries during 1st COVID-19 waves in India

The district wise spatial distribution of COVID-19 confirmed cases and recoveries during the 1st COVID-19 wave (up to March, 2021) are shown in Figure 1. It shows that most of the districts have registered counts of recoveries within the range of 2500-5000 following the range of 10000-25000. Comprehensively, 20 states had recoveries of that same count; among them only Maharashtra and Kerala had registered more than 10 lakh. All states had more than 90% recovery cases except Maharashtra, Chandigarh and Punjab; whereas Mizoram and Arunachal Pradesh incidentally had more than 99% of recovery. Approximately 15% of the total districts in India mostly from the North-Eastern hilly areas and very few from the interior of Peninsular Plateau region had reported more than 99% of recovery. During summer, the average recovery rate of all provinces was unanticipatedly lower (56.96%), whereas a progressive improvement was perceptible during monsoon (78.87%), post-monsoon (119.62%) and winter (130.02%). Noteworthy, recovery rate of higher than 100% in any province during a month or season indicates that a greater number of people had been recovered than being infected in that duration, i.e. recovery counts had surpassed the count of confirmed cases. The daily count of recovery cases was lower than infective cases throughout the summer and since late September the recovery cases were far ahead in count than infections.

Pearson's correlation test

Pearson's correlation technique was applied to explore the degree of association of environmental parameters with infected and recovered cases at 95% confidence interval using equation 1. A correlogram is also being prepared to better represent the interrelation of the variables of the input dataset.

$$r = \frac{\sum_{i=1}^n (En_i - \overline{En})(C_i - \overline{C})}{\sqrt{\sum_{i=1}^n (En_i - \overline{En})^2 \sum_{i=1}^n (C_i - \overline{C})^2}} \quad \dots \text{Equation 1}$$

Here, r is the correlation coefficient, En represents the environmental variables, C denotes the count of confirm and recovery cases individually.

Statistical Measures

The descriptive statistics (mean, median, mode, standard deviation, standard error, range) of the input variables used for the analysis have been put in Table 2 (descriptive statistics). The entire dataset of 4020 observations was alienated into a 70:30 ratio, where 70% of the data were used to train the models and the rest 30% data were used for its evaluation. Furthermore, in order to investigate the spatial influence of environmental parameters, monthly average values of all 12 variables were appended with monthly cumulative counts of confirmed and recovery cases noted over 335 major affected districts across the country during the yearlong period.

Results And Discussion

Through the Pearson's correlation test we found non-significant association between the recovery counts and ISWR (0.163), Hm (0.104), WS (0.063) and CLD (-0.127), while only AT (-0.216) and PRC (0.398) found to be significantly correlated with recovery. Moore and Little, 2007; Al Ashry and Modrykamien, 2014; Kelly et al., 2010 also highlighted the relevance of humidification. Besides, precipitation results scavenging of aerosols (Andronache, 2016; Kim et al., 2014; Pan et al., 2017; Zhang et al., 2004),. The negative correlation between the AT and recovery cases suggests that patients might have recovered comparatively better in lesser temperature conditions. Recently, Y. Liu et al., 2020d; Shahri et al., 2021; Yang et al., 2020b have found that thrombocytopenia could increase the mortality risk among COVID-19 patients. It was also noticed that the daily count of recovery cases exceeded the confirmed cases after mid-September, 2020 and this parallel pattern continued up to the end of January, 2021 when the AT was continuously decreasing. Simultaneously, we have also noticed that the districts located at higher altitudes in north and north-east India, naturally experience relatively lesser AT, had registered more than 97% of recovery which was considerably better than the other districts located in the plain or low-lying region. Since AT started to rise February onwards the daily infections also noted to rise and outpaced the daily count of recoveries. Hence, the surrounding AT can be adjudged as a vital factor both in case of transmission and recuperation of COVID-19 in India. The non-significant correlation of recoveries with CLD, WS, Hm still remains subject of further investigations in this context.

Precipitation is a key factor in the reduction of air pollution (Roldán-Henao et al., 2020; Zheng et al., 2019). Greater CLD also slows down the rising trend in AT by radiative cooling effect (Gettelman and Sherwood, 2016). According to Akimoto et al., 2015; Desideri et al., 2007; Steffens, 2020; Wang and Su, 2020, the O_3 decrease during the presence of higher humidity levels, hence the O_3 formation also got reduced during the rainy season and depleted by depositing on water droplets. The negative correlation

between fine PM and precipitation is often registered in umpteen studies (Gupta et al., 2020e; Pandey et al., 2017; Wang and Ogawa, 2015; Wu et al., 2018b). Thus the concentration of fine PM including the dust which was earlier conjectured for probable expeditious recrudescence of COVID-19 also got reduced during the monsoon precipitation. Earlier Jayamurugan et al., 2013; Shukla et al., 2008 had discussed the deduction of gaseous pollutants due to higher humidity and raindrop formation processes during the rainy season. Therefore it is well understood that the change in weather pattern reduced the air pollution during monsoon season, and during the post-monsoon and winter seasons the pollution levels had regained their peak due to the shortage of precipitation and humidity. We have also noted that recovery counts had significantly negative correlation ($p < 0.05$) with all the pollutants during the study period. O_3 had better inverse association (-0.384) followed by AOD (-0.355), CO (-0.353), NO_2 (-0.328), BC (-0.264), SO_2 (-0.216). It depicts that convalescents had a facile recuperation where the concentration of air pollutants were considerably lower. It also explains why finer air quality over the hilly regions in the North-East India might have helped to heal better from this disease. Though the overall country had exhibited notable rise in pollution level during post-monsoon and winter, spatial scenarios depict that the pollutant gases namely CO, NO_2 and SO_2 were mostly concentrated over Northern IGP and Eastern Indian region only. BC and AOD values (hence PM levels) were also lesser in Western parts of the country. With a significant congruence, the states located in North-East India had registered more than 135% and 160% of recovery during Post-Monsoon and Winter; whereas during the same seasons, the states from West and South India heeded around 124% of average recovery, fairly better than the provinces in IGP (around 98%). Therefore we can reasonably descry the escalating betterment of health in less adulterated areas while a gradual revival over tainted regions in the country, which eventually indicates that the recuperation followed by rehabilitation from this pandemic could be attainable in a less polluted environment. Hence ameliorating the air quality by strict regulations and proper preventive measures could help not only to deduce the dissemination of COVID-19 but also preferably assist to convalesce from this disease sooner.

Conclusion

In short, the correlation of the number of recovered cases with the environmental parameters through the Pearson's correlation test reveals that, increasing PRC and RH have slight impact in increasing the recovery. GRN is strongly positively correlated with the number of recovered cases. It means that, humid areas with higher vegetation cover and precipitation are supposedly going to induce high counts of recovery while the dry areas with lesser precipitation are going to experience surge in the number of confirmed cases. Areas of higher temperature are going to experience a rise in number of confirmed cases along with a slow recovery. Association cloud and wind with both the cases in weak or very weak. Among the other parameters, presence of O_3 and AOD shows strong correlation with both the cases, negative with recovery cases. All the other parameters like NO_2 , BC, CO, OC, SO_2 and ISWR are showing weak or moderate correlation with the cases, negative for recovery cases.

In accordance with the outcomes from the studies carried out by Huang et al., 2020b; Sarkodie and Owusu, 2020, we found precipitation to be beneficial for the better recovery. People residing in the area with lesser Temp recovered in greater count while Hm, WS, CLD didn't pose any significance as observed during the study period. During or in a later stage of treatment, several patients are also condemned to various post-syndrome infections mostly related to cardiovascular and respiratory disorders which might be the ramifications of virulent vulnerability to the gaseous pollution. Hence it altogether asserts that the environment needs to be ameliorated immensely by its standards to alleviate such deadly pandemic. The injurious impact of traffic pollution has also been discussed through various global and regional studies (Gauderman et al., 2007; Laumbach and Kipen, 2012; Urman et al., 2014). Considering those cognizance along with the observations throughout the study, it may be opined that the complete lockdown with strict regulations could substantially decrease the pollution levels, and so the dissemination rate of COVID-19 too. The pre-eminence of weather parameters on air quality is indubitable and evinced globally (Bhaskar and Mehta, 2010; Fisher, 2002; Yansui Liu et al., 2020e; Panofsky and Prasad, 1967; Qin et al., 2020; Seo et al., 2018; Zhang et al., 2015), hence its significant association with COVID-19 dissemination during a year-long period over India has been certainly revealed through the present study. We also postulate that amelioration from this pandemic could be viable, preferably in a freshened (less polluted) environment with non-scorching weather conditions. The outcomes conjectured that patients might recover better breathing freshened moist air and if surrounding air quality can be eloquently moderated, the current pandemic can be assuaged as well. This disquisition will irrefutably succour the government administrations including the policy makers across the country to instigate proper preparedness and effectuate requisite manoeuvres impeding the parlous ramifications of COVID-19 in forthcoming days.

Declarations

Authors declare no conflict of interest.

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Figures

Figure 1

Distribution of recovery cases

Figure 2

correlogram representing correlations among environmental parameters and recovery cases.