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Health Impact Assessment of Air Pollution in India During COVID-19 Lockdown by Using Satellite Remote Sensing and Deep Learning

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ABSTRACT

Air pollution produces major environmental health problems with a vast number of entropies that can affect healthy, sustainable environments across the globe. Millions of people are dying prematurely each year as a direct cause of poor air quality. According to recent studies, living within 50 meters of any significant road can increase the risk of lung cancer by up to 10%. World Health Organization declares that approximately 3.7 million people died worldwide in 2012 due to outdoor air pollution. In this analysis, we analyzed air pollutants that were released into the air from a wide range of sources, such as motor vehicles, industrial combustion processes, etc. We analyzed the Sentinel-5 precursor data, which provides time series data on a multitude of trace gaseous compounds such as CO, NO2, SO2, O3, PM10, PM2.5 aerosols, etc. with efficient statistics and special resolution. For better comparison, we have trained our statistical atmospheric data with deep learning methodology and analyzed them to obtain a reference for air quality in India. This study describes the scientific aspects and probable atmospheric composition entropy due to pollution. We also presented the overall operational product outcomes and emissions from the energy sectors, which involves the advancement of data analysis in a particular coordinate system.

INTRODUCTION

COVID-19 was first detected in the Wuhan district of China in December 2019 as per the official report. And after that, this virus kept on spreading all around the world rapidly and it changes the global lifestyle and economy, and a lot more things (Garg et al. 2020). As per reports, the first detected COVID-19 infected person was found in the Kerala district of India on 20th January 2020 and the person's travel history had been disclosed which showed that he came from China. And after this, Kerala became the first state of India to have numerous COVID-19 positive cases by community spreading. And till now more than ten lakh COVID-19 positive cases have been detected in India (Suresh et al. 2020). The highest and lowest instances due to COVID-19 have been reported in Maharashtra and Mizoram, respectively. In this regard, a 21-day national Curfew/Lockdown was declared by the central government. As per the announcement of the Lockdown in India, all the Academic institutes, industries, markets, all people, and regional places were shut down until the next announcement. The results after the step were taken by the Government of India ended in fewer numbers of deaths reported in India so much as compared to other countries, and less air pollution in India, especially in Noida next to New Delhi. The air pollution over Northern India has recently recorded a 20-year-low at this period of this entire year (Weblink 2). Fig. 1 exhibits the AEROSOL OPTICAL DEPTH immersion degree in India between 2016 and 2020. Fig. 1 is first created using gathered info set by MODIS (Moderate Resolution Imaging and AURA) that actions dimension distribution and optical depth of surrounding aerosol Across the world on an hourly basis.

The drop in concentration degree of aerosol optical depth (AOD) was projected after just a week of low individual pursuits. The exhibited images are accumulated in NASA Earth Observatory, showing AOD dimensions over the region of Kolkata, Noida, Kanpur, and Chandigarh of India during the time scale of January 31st to July 17st from 2016 to 2020 (Garg et al. 2020). Furthermore, the past (sixth) anomaly image in Fig. 1, shows that the AOD average in 2020 compared to 2016-2019 (average). It can be observed that black, and brown pixels, tan pixels, and pale yellowish areas reveal high, lower, and little to no aerosol concentrations (Fig. 1). aerosol is among the critical pollutants characterized by domestic and worldwide agencies, associated with mobility and mortality (Garg et al. 2020, Liu et al. 2020, Hadibasyir et al. 2020). In this analysis, the variants of AOD that were collected from

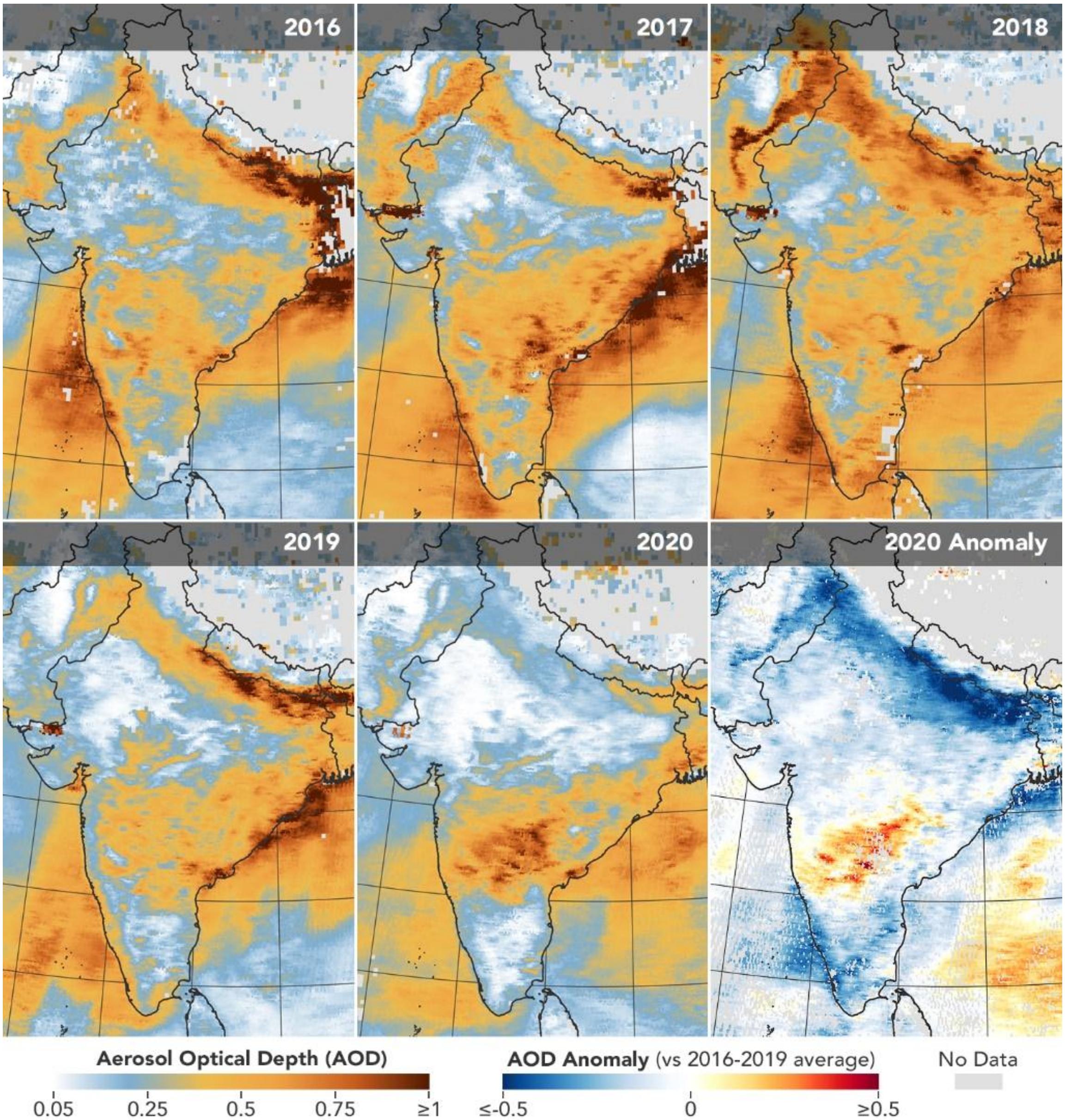

Fig. 1: Sequence of aerosol optical thickness concentration (month-Terra/Modis) in India from the period March 31 to April 5 in 2016, 2017, 2018, 2019, and 2020 (NASA 2020).

the satellite (Sentinel-5P) had been used to signify that a noticeable gap in the amount of aerosol that is at its lowest in twenty years thanks to COVID-19 lock-downs (Weblink 2). The outcome indicates that the spreading coronavirus is thoμght to be a blessing in disguise. The present status of air quality could be momentary; however, there is a rather great opportunity for us (scientists/researchers/students/humans) to learn/understand from related lock-down activities about how best to minimize the concentration level of air pollutants (Suresh et al. 2020). Recent events over the past few months have shown results on molecular scales across the globe about an increase in biodegradable aerosol and its environmental effects. However, further research is needed to fully comprehend the open questions based on the interdisciplinary and complex nature of aerosols characterized by their connection to human health. To increase the assessment of mortality due to air pollution, the following conclusions are drawn from epidemiological, global modeling research, aerosol, and health issues: (1) overall health effects because of specific biotic elements. Their origin can be described from Preliminary studies. The various compound composition/characterization and degradation of biotic components have to be researched. (2) Epidemiological cohort studies are highly essential, particularly in Asian and African countries where aerosol or bioaerosol and its vulnerability established scientific tests have yet to be effortlessly launched. (3) No-Observed-Adverse-Effect Level (NOAEL) or Lowest-Observed-Adverse-Effect Level (LOAEL)-expense devices must know the integration of private vulnerability in the duration of assessments; also (4) the association of lung surfactants and aerosol components will need to be learned. Similar remarks can be implemented to other COVID-19 affected states, as of April 18, 2020, ‘’ there are 2284018 infected people along with 156140 claimed deaths from COVID-19 around the world. This viewpoint shows evidence of major changes in the atmosphere quality of their Indian location throµghout the government lockdown intended to lessen the COVID-19 impacts (Mandal et al. 2019, Cheval et al. 2019, Hepburn et al. 2020, Timmermann et al. 2020). The massive reduction in aerosol focus during quarantine and the publication of the coronavirus may, paradoxically, have reduced the percentage of deaths throµghout the period by significantly lowering the percentage of fatalities attributable to deterioration of air quality, as stated by the results and discussion.

The coronavirus outbreak will cause a dreadful crisis that will affect the entire world (COVID-19). Based on the escalating rate of COVID-19 episodes around the world, the WHO proclaimed COVID-19 a worldwide pandemic on March 11, 2020. The governments of numerous nations then placed their states on lockdown at the end of March in preparation for a containment strategy. As of 1 June 2020, 374,229 confirmed deaths worldwide and more than 6.2 million COVID-19 cases were reported from 215 states (WHO 2020, Behar et al. 2020, Chamola et al. 2020). Around January 30, 2020, Kerala, a state in India, reported having the country’s first confirmed case of COVID-19. Later, it spread to other parts of the country, and on March 4, 2020, 22 new states were officially recognized. The first COVID-19-related death in the nation was recorded on March 12, 2020 (Weblink1 :).: The President requested a fourteen-hour curfew on March 22, 2020, from all taxpayers around the country due to the rising number of COVID-19 scenarios. In response, India’s government declares a total national emergency for 21 consecutive days, starting at midnight on March 2–4, 2020. The government required Indian residents to closely adhere to the social distancing measures as a preventive strategy to manage the worsening of the pandemic in the nation (Kumar et al. 2020). All public meeting places, including restaurants, movie theatres, schools, shopping centers, and educational institutions, were closed during the statewide lockdown. To avoid congestion, it was requested that employees and students work from home. All forms of transportation, including highway, railroad, and air travel, were restricted from receiving essential services. Additionally, not all industrial and manufacturing operations were stopped (Tang et al. 2020). Because everyone was asked to stay indoors during the lockdown, save from those providing basic services, the COVID-19 outbreak resulted in deserted and empty streets. The comprehensive lockdown has affected the economy of the United States; however, it also caused some dramatic mitigation in air pollution because of limited transport and economic activities (Chang et al. 2020, Shao et al. 2020). In the current study, we analyzed the variant in air quality data around four different towns in India (particularly, Kolkata, Noida, Kanpur, and Chandigarh) during the lockdown (i.e. January 31st to July 17th) of the COVID-19 pandemic.

Air Pollutant Validation from Remote Sensing Data

To verify the pollutants from satellite images, this analysis used the actual data of pollutant (NO_2) emission quantified from the thirty-eight monitoring stations found in Delhi from where we get the data for the Noida area. The daily mean of NO_2 emission calculated by these stations from January 1, 2020, to April 20, 2020, which expressively depicts both the pre-lockdown and throµghout the lock-down period, may indicate that air contamination is higher in some places (Huang et al. 2020). The outcomes demonstrated before the lock-down, the level of NO_2 emission in Noida continues to be around 25 $\mu g.m^{-3}$

Nevertheless, since the lock-down was declared in India, the level of NO_2 emission showed a dramatic decline. In Noida and its surrounding areas, the actual amount of NO_2 emission throµghout the lock-down phase remains 5 to 15 $\mu g.m^{-3}$. Even the outcomes explain that ahead of the lock-down phase, the amount of NO_2 yet it faced a massive reduction with the beginning of the lockdown in India. The analysis sµggests that NO_2 emission remains low during the comprehensive lockdown at Mumbai. Thus, these statistics confirmed that the lockdown in India has imperatively enhanced environmental quality. Also, it confirmed the precision of all the information generated as a result of satellite images (Wei et al. 2020, Zhao et al. 2020, Jing et al. 2020).

MATERIALS AND METHODS

The data from four different Indian cities, including Noida, Kolkata, Chandigarh, and Kanpur, which are located in the western, northern, and eastern regions of India, respectively, have been evaluated to review the impact of lockdown on air quality. The Central Pollution Control Board (CPCB) collected the air quality data for three stations in Delhi, and one channel in each of Kolkata, Chandigarh, and Kanpur during the time period from 1) March 1, 2020, throµgh April 15, 2020. Additionally, the high population density of major cities and the large number of people employed there contribute to the heavy traffic on the roads. In cities like Delhi and Noida, daily traffic and industrial emissions are both major contributors to air pollution. In contrast to Delhi and Mumbai, Kolkata, Chandigarh, and Kanpur have a low population index. Althoµgh many of India's best crops are grown in Kolkata, Chandigarh, and Kanpur, these cities are among the most polluted in the country as a result. Table 1 lists all the information on the channels that were selected from each city. These channels were selected because they accurately depict and compensate both metropolitan areas.

RESULTS AND DISCUSSION

India's national lockdown, implemented in preparation for March 25, 2020, has greatly improved the country's air quality. We present statistics on the investigation of air quality in four different places, at varying stages. In the case of Noida, the average daily value of PM10, PM 2.5, and both NO_2 and SO_2 may be seen to have significantly decreased. However, during the post-lockdown phase, the O_3 concentration increased. Fig. (2–5) compares the mean air pollution concentration in the pre– and post–lockdown stages. The results show that during the lockdown, the air quality in the cities improved to a healthy level. The fact that NO_2, SO_2, PM10, and PM2.5 levels have all significantly decreased, along with PM10 and PM2.5, is an indication of a healthy environment. Because of insufficient data sources, a few pollutants are not there in the output. The level of particle matter is typically found to be alarmingly high in Noida and Delhi. However, the lockdown turns out to be beneficial for nature to restore itself.

Fig. 2 of the aforementioned curves show that there were dangerously high levels of pollutants in the air over the Noida area before the lockdown, particularly PM2.5. When the density of particle matter in the air exceeds 60, it becomes detrimental, but in the Noida area, the level was over 200, which was dangerous for human health. However, as nature began to recover itself following the lockdown, the density of contaminants significantly decreased.

Well throµghout the lockdown period the pollutants in the atmosphere over the Bidhan Nagar area in Kolkata (Fig.3) became less dense. The density of pollutants in Kolkata is far less than in Noida, Delhi, or Mumbai but still, it was above the danger level. But the lockdown also made the environment considerably cleaner and healthier than it had been.

In Fig.4 the air quality graph of Kanpur has been shown, where, also a positive sign can be seen for air quality. Because fewer fuels are used in the automotive, railroad, and even industrial sectors, all emissions are decreased. During the lockout, nature completely cleaned up the gaseous industrial wastes.

Well in Fig. 5 we can see that the particulate matter in the atmosphere of Chandigarh city throµghout the lockdown was fluctuating because of the usage of the private vehicle. Since all industries were shut down during the lockdown, other pollutants like carbon monoxide, sulfur dioxide, nitrogen dioxide, and ozone were all naturally cleaned up.

Table 1: The Air quality levels and health impacts (PM2.5) (Source: CPCB - India Central Pollution Control Board).

AQI	Air Pollution Level	Health Implications	Cautionary Statement (for PM2.5)
0-50	Good	Air quality is considered to be satisfactory, and air pollution poses a minimum risk factor	None
51-100	Moderate	Air quality is acceptable; but, for some pollutants, there may be a moderate health concern for a very minimum number of people who are unusually sensitive to air pollution.	Active infants or children and adults, and people with respiratory disease, should limit prolonged outdoor exertion.
101-150	Unhealthy for Sensitive Groups	People from sensitive groups may experience health effects. The public is not likely to be affected.	Active children and adults, and people with respiratory disease, must limit prolonged outdoor exertion.
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects	Active children and adults, and people with respiratory disease, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion
201-300	Very Unhealthy	Health warnings for emergency conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease, must avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.
300+	Hazardous	Everyone may experience more serious health effects.	Everyone should avoid all outdoor exertion

The restrictions placed on commercial, industrial, and transportation-related activities during the post-lockdown period have significantly reduced the major air pollutants (PM10, PM2.5, SO_2, and NO_2). In general, compared to the time before the lockdown, PM10 and PM2.5 levels decreased by an average of 55% and 49.34%, respectively. Since transportation accounts for 60% of Noida's NO_2 emissions, transportation limitations caused NO_2 levels to drop by over 70% throµghout the lockdown. However, a minimal decrease of 25 percent at SO_2 levels throµghout the post-lockdown phase were noticed since the principal source of SO_2 in Noida are electrical power plants that remained operational during the lockdown span. Noticeably, O_3 immersion climbed by 37.35% in the post-lockdown period due to various rea-

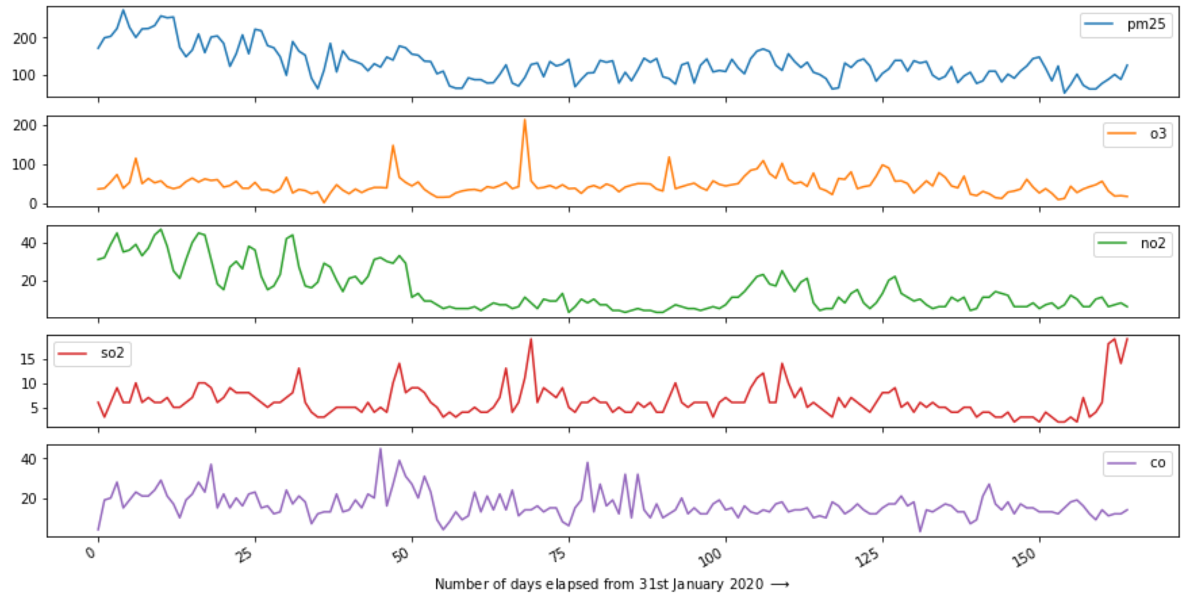

Fig. 2: Air quality graph of different pollutants in sector 1 Noida during the lockdown.

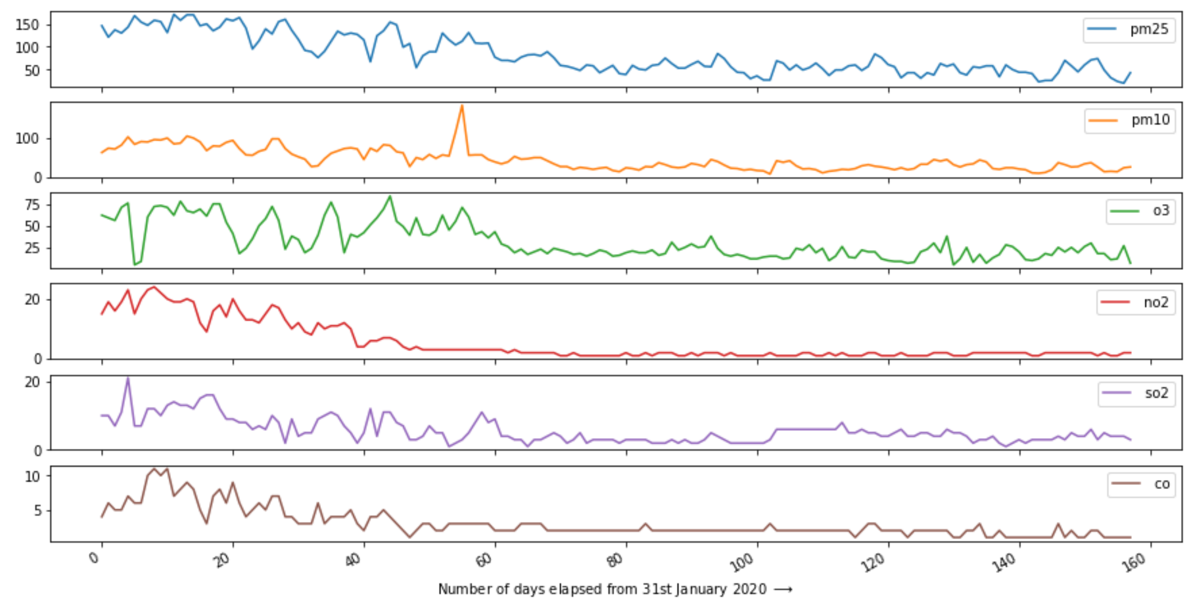

Fig. 3: Reduced air pollution levels at Bidhan Nagar, Kolkata during the lockdown.

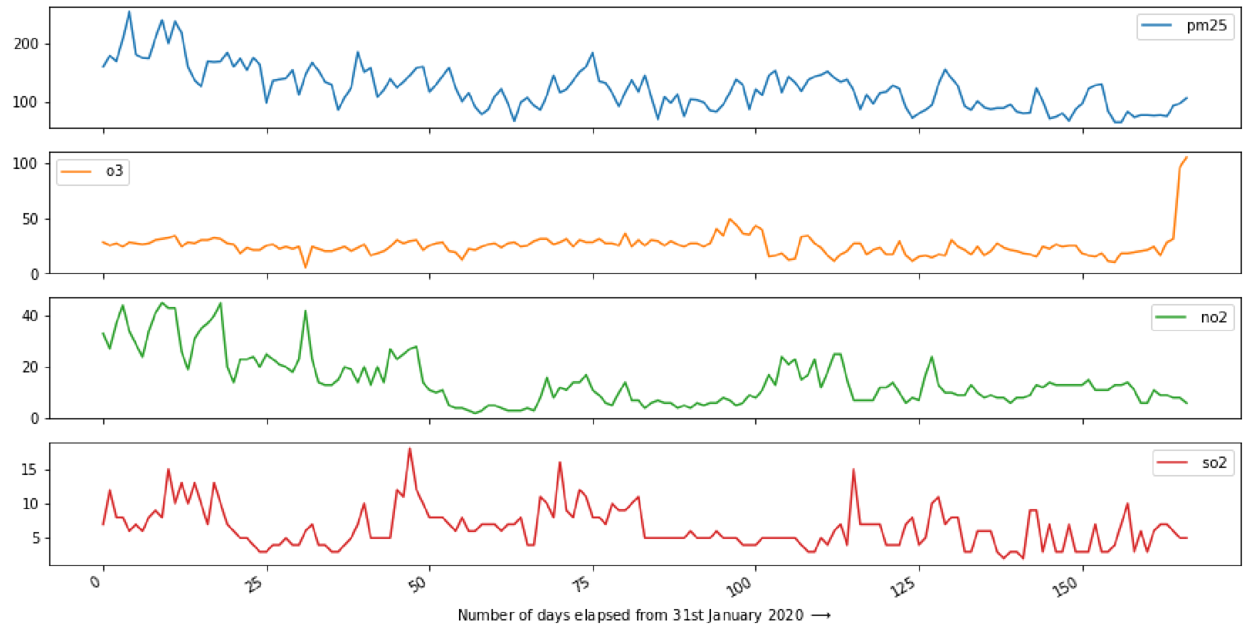

Fig. 4: Air quality graph of Nehru Nagar, Kanpur during the lockdown.

sons. The decrease in NO_2 levels minimize O_3 ingestion, which ends in increment at O_3 levels; Consequently, once summer arrived, the temperature began to rise, going from a minimum and maximum of 15°C and 27°C on March 1 to 24°C and 40°C on April 15, 2020. This has caused an increase in O_3 dosages. All vital air pollutants (excluding O_3) have been reduced throμghout the lockdown phase. The focus of essential pollutants (i.e. PM10, PM 2.5, both SO_2 and O_3) has shown a growing trend during the post-lockdown stage. During the lockdown, the daily average NO_2 and SO_2 levels

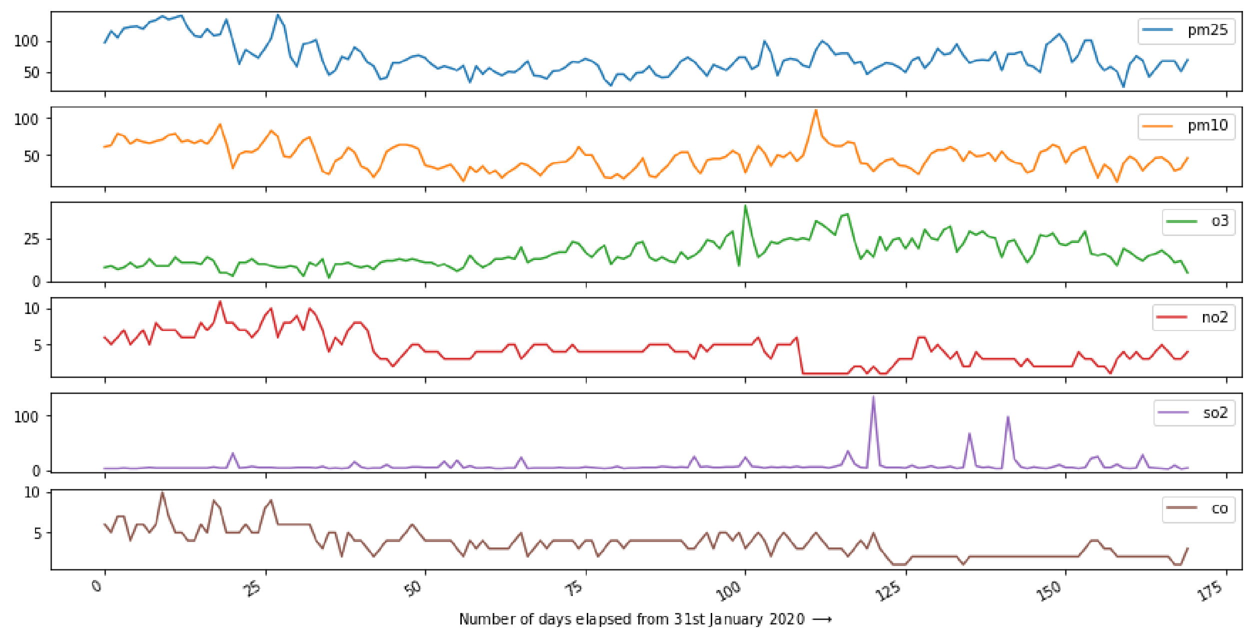

Fig. 5: Air pollutants curve throughout the lockdown period of Chandigarh during the lockdown.

mostly remained below the NAAQS standard value. Nevertheless, during the post-lockdown period, the PM10 and PM 2.5 concentrations were higher than the NAAQS benchmark value. When compared to the Noida area, it may be observed that Kolkata, Chandigarh, and Kanpur are still among the top SO_2 metropolises. The majority of this pollution is caused by the largest coal-fired power plants located in these cities. All pollutants (besides NO_2) demonstrate higher mean immersion levels throµghout the post-lockdown phase, as compared to the pre-lockdown stage. Althoµgh NO_2 levels in Kolkata, Chandigarh, and Kanpur decreased by only 13% during the lockdown, it was much less than in the Noida area. The concentration of PM10, PM2.5, SO_2, and O_3 has significantly increased in Kolkata, Chandigarh, and Kanpur during the lockdown.

CONCLUSION

Globally, COVID-19 has a significant impact on both men's and women's lifestyles. This exposed a remarkable viewpoint on both domestic and foreign transportation. On the other hand, lockdown slows the economic circles on the Earth. The research disclosed that the level of nitrogen dioxide emission was reduced. This impact is significantly clearer in Noida, Kolkata, along with individual cities in Gujarat. Additionally, India's use of electricity has decreased in March 2020. However, the Indian electrical power generation facility has the potential to emit a significant amount of nitrogen dioxide. Lockdown has also affected ship transportation, in addition. The study found that the level of nitrogen dioxide along the Indian Ocean's maritime route has decreased. Additionally, the study verified these results at numerous monitoring stations for the local environment in Noida. The examination confirmed that the lockdown has proved to be a boon for the quality of air in India. These results give new insights into government officials, academicians, research workers, and contamination control governments. Althoµgh COVID-19 poses a serious threat to both the general public's health and security as well as the global economy, it has shown to have a good impact on the environment as pollution is declining and the ground is gradually regenerating itself. The present study successfully analyzed the effect of a complete national lockdown since March 25, 2020, on-air quality of leading Indian cities: Delhi, Mumbai, Kolkata, Chandigarh, and Kanpur. A significant reduction in the concentration of PM10, PM2.5, and NO_2 had been detected for Delhi and Mumbai during the lockdown span. But, O_3 focus had been raised throµghout lock-down, which could be attributed to less consumption of O_3 at titration because of a decrease in NO_2 emission. Overall significant advancement in the atmosphere grade of Delhi and Mumbai was discovered throµghout the lockdown phase compared to the pre-lockdown phase, exactly the equal period of 20-19. Nevertheless, Kolkata, Chandigarh, and Kanpur have not shown much decrease in smog due to operational coal-based power plants. The preliminary investigation of air quality information in current research indicates the COVID-19 pandemic may be regarded as a 'boon in disguise,' where air quality is advancing and also the ground is reviving itself. This reduction in air pollution because of managed emission of significant air pollutants can significantly reduce several wellness problems like respiratory difficulties and cardiovascular disease such as asthma, early death, etc. This constructive impact of lockdown on atmosphere pollution can offer confidence to the authorities and government that the implementation of strict quality air coverages and energy control plans may dramatically improve environmental and human wellness.

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Weblink 2: https://airquality.gsfc.nasa.gov/