Analysis of Air Quality During and After Nation Wide Lockdown in India

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Abstract. The Indian subcontinent came to a standstill on 22nd March 2020 with the nationwide lockdown due to COVID -19. Its repercussions were both positive and negative. This paper is an attempt to provide a quantitative analysis of the particulate matter (PM2.5 and PM10) and the air quality index with the aid of satellite-based data from the beginning of January 2020 till end of June 2021. Based on the analysis, we conclude that there was significant improvement in air quality all over India during the first phase of lockdown but as the lockdown gradually uplifted, the condition again started to deteriorate. This study also shows the lockdown effects of different atmospheric compositions, specifically through massive traffic reductions on roads. This effect has been significant for a few brief environmental trace species, with a huge decrease in NO_2 fixations, a lower decrease in Particulate Matter (PM) and a moderate impact on ozone fixations due to nonlinear chemical effects.

Keywords: Air pollution, COVID 19, India, Lockdown.

1 INTRODUCTION

The Novel Coronavirus originated at the end of 2019 from Wuhan which is the capital of Hubei province of China [1]. As this deadly virus spread from one human to another so the number of confirmed COVID cases increased more quickly than expected [2]. The official name "coronavirus disease 2019 (COVID 19)" was given to it by World Health Organization on February 11 2019. By that time almost 3000 positive cases had been detected and 97 people were known to have died, most of them from the Hubei province of China. The transmission of this virus was so rapid that within a very short span of time this deadly virus covered almost the whole world into its lap. As the focal point of the pandemic, China was the first nation to force city lockdown on January 23, 2020 [3]. Many more countries had to enforce lockdown after March 2020 when this deadly virus started to spread very rapidly worldwide [4]. The only good thing that has happened during the lockdown was that there was reduction in the air pollution worldwide. Many researchers worldwide have studied about the environmental ef-

ICIDSSD 2022, March 24-25, New Delhi, India

DOI 10.4108/eai.24-3-2022.2318958

fects of lockdown focusing on how the nationwide lockdowns have impacted the quality of air pollution at different places.

In [5] the authors primarily focused on the daily air pollution and weather data in order to look over the changes in air quality at the global level and establish it's relation to the spread of pandemic so that proper response strategies can be designed. The experimental setup used data from January 1 to July 5, 2020, covering the individual air quality index of different hazardous gases like (AQI) of PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, and O_3 across 597 major cities in the world and corresponding lockdown information, which contributes to quantifying the impacts of pandemic-induced lockdowns on cities' air quality from a global perspective and it was noticed that the quantity of these pollutant gases reduced by a sufficient amount during the lockdown days.

Keeping all the dreadful effects of covid-19 into consideration, it is also necessary to look into the post pandemic effects, which has hit the economy in particular and whole of the business workflow in general. This has compelled the leaders throughout the world to think of a way out, for parallelly running the economy and saving people's lives [6]. People were bound to stay at their homes as all other outdoor activities like Sports, Musical events, Dramatic exhibitions etc. were put under halt during this pandemic. Some financial experts and councilors from the world have time and again warned the people due to the downsizing of their economies, that some countries with weak financial health may have to collaborate with other nations to run their economy in a smooth way, because of the long-term lockdown measures imposed.

Due to the lockdown most of the face to face activities have moved to the virtual world in most of the domains including education, business, corporate as well as social connections. But as the use of technology has increased many folds, this again will have negative impact on environment due to drastic increase in Carbon footprint.

2 AIR POLLUTION MONITORING

The monitoring and calculation of air pollution has been a phenomenal challenge to counter during this ongoing pandemic. That said, there is no dearth of pollutant sensors and particulate matter detectors today. But the extent of accuracy, the nature of analysis, the validation methods and the assignment modules deployed have been subjected to thorough investigations.

Departing from the traditional trends [7] of carrying assessment of air pollution, we strive to utilize the development of machine learning techniques like regression models that deal with assessment challenges. Some of the traditional techniques used for such study are:

2.1 The Proximity Method

In this method the average concentration of pollutants at two or more observation sites is measured and the distance weighted method is used if the number of observation sites is large or geospatially segregated [3].

The overall exposure can be determined as given by equation (1):

$$E_p = \sum Q_P C_q t_{pq} \quad (1)$$

where,

Ep is the time weighted exposure for an individual p in the given time duration.

C_q is the concentration of a pollutant at any specific site q.

t_{pq} is the time for which the person was exposed at any specific site q.

Q is the number of distinct sites visited.

2.2 Interpolation

This is the method in which the spatially distributed components are correlated. The crux of this method is that adjacent substances have related characteristics [8]. Usually inverse distance weighting method and Kriging is used and the formula is given by equation (2):

$$S(Lo) = \sum_{j=1}^{K} \lambda j S(Lj) \quad (2)$$

where,

S (Lo) = weighted sum of data

S (Lj) = value measured at location j

λj = weight for value at j^{th} site

L_0 = prediction location

K = number of measured values

2.3 Land Use Regression Model

Using this regression method, we are able to integrate data of air pollution sites with the one that is collected through geographic information systems. In the regression model, we are able to display the advanced machine learning algorithms to predict output based on a continuous quantity, which is fed as an input. The measurement of air pollution density across various locations or the computation of the concentration of particulate matter across various stations, the regression model provides a one stop solution to many problems associated with the other models [8].

2.4 Dispersion Model

This model is deterministic in nature in which the chemical properties of the pollutants is used to find out the concentration at any particular place. Estimation techniques have improved a lot which helps us to find a concentration with high degree of accuracy [9].

The level of these pollutants is much higher in the regions having industries and as the people working in these setups are normally from the lower socioeconomic background so their exposure level is also quite high. They are also not in a position to stand for their rights and hence are exploited by the industrialists which results in high mortality as well.

2.5 Satellite Remote Sensing

In this artificial intelligence world, the data obtained from the satellites is being used for calculating the level of air pollution in the environment. Aerosol Optical Depth (AOD) is used for getting an estimate of the fine particulate matter which is then combined with the transport

model for transmission of chemicals and finally interpolated to get the i^{th} concentration at the ground level. Two satellites from which this data is obtained are Aura satellite and Terra satellite. This technique was used for the estimation of PM2.5 concentration in Lima, Peru in [10].

2.6 Wearable Devices

Smart devices have also emerged as a major source of data collection. Many Start-ups are coming up which are working in the field of developing smart wearable devices with sensors to collect all this data [11]. A few examples of Apps with sensors are AIRBEAM, Flow and Clean Space which can be connected through Bluetooth.

These are the different scientific tools or Methods through which we can easily Access or Monitor the Air Quality index in the Atmosphere.

3 STEPS NEEDED FOR REDUCING THE IMPACT OF AIR POLLUTION

3.1 Green Spaces

Green space is a land which is totally covered with grass, trees, bushes, or other vegetations). Green space incorporates parks, local area nurseries, and burial grounds.

3.2 Environmental Benefits- Pollution Check

Major sources of pollution in urban areas are toxins from synthetic material and particulate matter which can exist in the form of solid, liquid or gas. Green spaces are place for reproduction of species and protection of the ecosystem which includes plants, animals, land and water. An adequate amount of green spaces is important for the maintenance of natural habitat for birds as well as animals in a metropolitan city and it also adds to the scenic beauty. Citizens should also try to have some green space around them which will help in reduction of pollution [12].

3.3 Ecological benefits

Sun powered radiation, air temperature, wind speed and relative dampness has shifted essentially because of the human created climatic changes in the urban areas[13]. Urban warmth island impact is brought about by the enormous spaces of warmth engrossing surfaces along with high energy use in urban communities. Increasing the plantation area, vegetation around metropolitan occupant's home, increase in water bodies by specialists etc. are some of the measures that can assist in alleviating the deteriorating circumstances [14].

3.4 Social and Psychological Benefits- Human Health

The degree of stress diminished quickly in individuals who were presented to indigenous habitat, in contrast to individuals who were presented to metropolitan climate whose feeling of anxiety stayed high. In a study, patients in a clinic with room ambience similar to a recreation center had a 10% quicker recuperation and required lesser medication as compared to patients whose rooms were less comforting [14]. This is an obvious sign that metropolitan green spaces can expand the physical and mental prosperity of metropolitan residents.

4 RELATED WORK

In their work, authors in [15] studied the deviation in absorption of the major constituents of air pollution including PM2.5, PM10, SO_2, NO_2 and O_3 for the period before and after lockdown in India. In their work they concluded that the total amount of PM2.5, PM10, SO_2 and NO_2 reduced by 49%, 55%, 19% and 60% in Delhi and by 37%, 44%, 39% and 78% in Mumbai during the first phase of lockdown stage. They considered the lockdown as a blessing in terms of reduction in the air pollution levels and concluded that a substantial improvement in air quality can be accomplished in the future, whenever upgraded contamination control mechanisms are stringently applied.

In contrast to Delhi and Mumbai the level of hazardous gases (with the exception of NO_2) in the atmosphere increased during the post-lockdown phase in Singrauli. The level of NO_2 decreased by 12.5% during the entire lockdown time frame which is lesser than the reduction in with Delhi and Mumbai. This increase in the level of PM2.5, PM10, PM2.5, O_3 and SO_2, and moderate decrease in NO_2 levels during the post-lockdown stage can be attributed to the presence of coal-based plants in Singrauli.

Authors in [15] have studied the relationship between the level of PM 2.5 in the atmosphere and the severity of COVID 19 and deaths associated with it. They studied the daily changes in the direction of wind at the country level and concluded that the changes in the air quality affected both the number of cases and the death rate. They found that on an increase of one $\mu g/m^3$ PM 2.5 value the number of COVID 19 confirmed cases increased by 2%.

In [16] the air quality of United States has been assessed for fine particulate matter (PM2.5) and nitrogen dioxide (NO_2) for the duration spanning January 8th-April 21st for the years 2017 to 2020. The total study period was divided into pre-COVID-19 duration (January 8th-March 12th) and COVID-19 duration (March 13–April 21st). The data of this duration for the year 2020 was compared with the corresponding data for 2017–2019. It was found that the level of NO2 decreased by 25.5% and PM2.5 decreased by approximately 4%.

Air pollution has been found to have significant impact on the rate of infection as well as death. Patients with comorbidities were more seriously impacted in regions which had higher pollution level [17]. An increase in the level of PM 2.5 was found to have added to the COVID-19 seriousness. It was found that reduction in the level of contamination decreased the rate of infection and mortality. Air quality data from January 1, 2020, to July 5, 2020 from the Air Quality Open Data Platform was studied by authors in [18].

5 METHODS AND MATERIALS

Total number of officially confirmed cases of the Novel Coronavirus COVID 19 worldwide was around 190 million by the end of June 2021 and it has taken approximately 40 million lives. Governments have been trying to come up with strategies that can keep the economies running along with devising methods to stop the spread of this deadly virus. Air pollution data studied in this work has shown that the level of pollution decreased significantly due to the lockdown and this trend can be a guiding path for the Government to move to technologies which can help us maintain the level of pollution for sustainability.

Data collection: In this work data from 2 most polluted cities and 2 least polluted cities in India has been studied to find out the impact of lockdown during the two waves of the Pandemic. The four cities that are considered are Delhi and Patna which are the most polluted cities and Shillong and Aizwal which are the least polluted cities. The data was taken from Central Pollution Control Board (CPCB) portal which receives data on various environmental aspects from different agencies. We have taken the automatic monitoring data taken from the link: (https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing). The data from 1st January, 2020 to 30th June 2021 has been analyzed in order to study the impact of lockdown on the level of air pollution in these 4 cities. We have also tried to see the level to which we were able to maintain the reduction in the pollution after the lockdown was uplifted.

6 Results And Discussions

The 24-hour average concentration of five major elements which contribute to the air pollution has been analyzed here. These include PM2.5 (fine particles that have diameter less than 2.5 micrometers and can be inhaled), PM10 (particulate matter having diameter less than 10 micrometer), NO_2, SO_2 and Ozone.

Particulate Matter: Both PM2.5 and PM10 consists of tiny droplets of solid or liquid which can cause serious health hazard when inhaled. PM10 can affect the lungs very badly and can mix with the blood. Particles less than 10 micrometre in diameter (PM_{10}) once inhaled can reach the lungs and even enter the bloodstream. Exposure to PM2.5 can result in cardiovascular ailments. The concentration of these two particulate matter has been analysed for the aforementioned time period and as depicted in figure 1 and figure 2. It can be seen from the figures that there was good amount of drop in the level of both these elements during the lockdown in India from March 25th which continued till mid of September, 2020. But it can be seen that after things started to get back to normal, these levels again started to rise and reached it's peak in the month of November, 2020. Rise in the PM level during this time of the year is a normal trend and several factors contribute to it. The changes in the level are not only evident in the most polluted cities (Delhi and Patna) but also in the least polluted cities (Shillong and Aizwal) although the level is much less in the later cities.

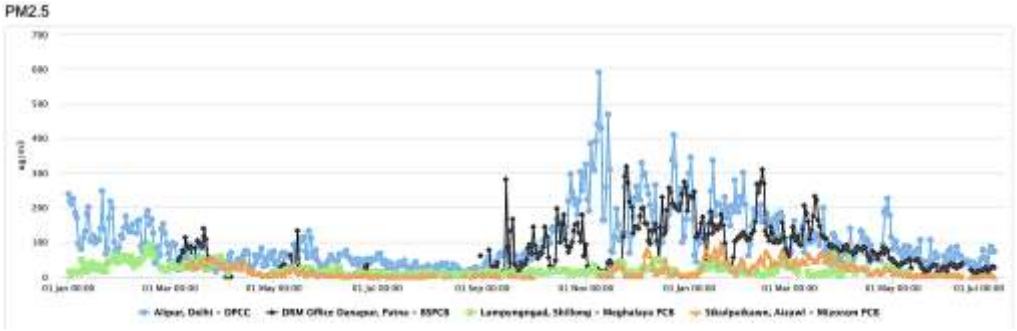

Fig. 1. Change in Level of PM2.5 in the four cities

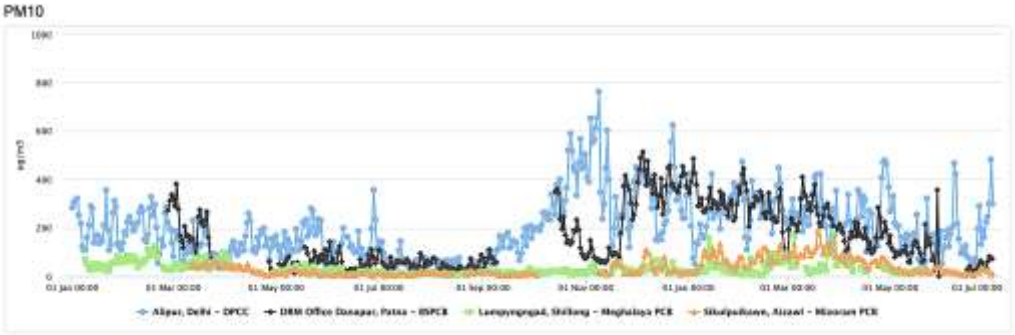

Fig. 2. Change in Level of PM10 in the four cities

Nitrogen Dioxide (NO_2): Main sources of Nitrogen in the air are plastic material, textile, proteins from food waste and combustion of fuels. It is one of the major reasons for respiratory ailments such as cough, wheezing, pulmonary edema and even chronic lung diseases. As can be seen from figure 3, the concentration of NO_2 is negligible in Shillong and Aizwal for the complete duration of study. For Delhi the level drops during the lockdown, remains low for some time, but then in the month of November it increases significantly. Thereafter is remains at an average level almost same as during the pre-lockdown phase. Although data is not available for some duration for Patna, but the trend here also is more or less similar to Delhi.

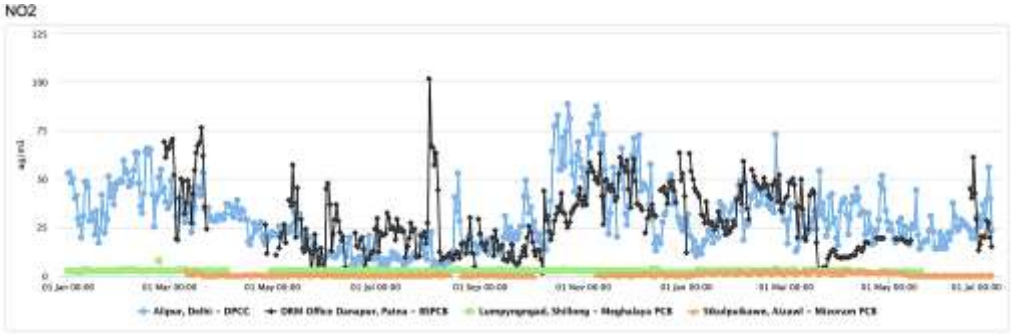

Fig. 3. Change in Level of NO_2 in the four cities

Sulphur Dioxide (SO_2): The main concentration of Sulphur Dioxide in the atmosphere is due to the burning of fossil fuels and industrial activities. Higher concentration of this gas affects animals, plants as well as humans. It also leads to respiratory diseases and effect on skin and eyes. Variation in the level of SO_2 for the study duration can be seen in figure 4. Interestingly, the concentration of this gas for the two least polluted cities shows periodic rise and fall which could be attributed to some local factors. It's concentration in Delhi also shows a trend different from the other pollutants in the sense that it did not hit the least level during the lockdown period, but remained low from June to October, 2020. Thereafter it remained at an average level but again increased significantly in the month of April – May 2021.

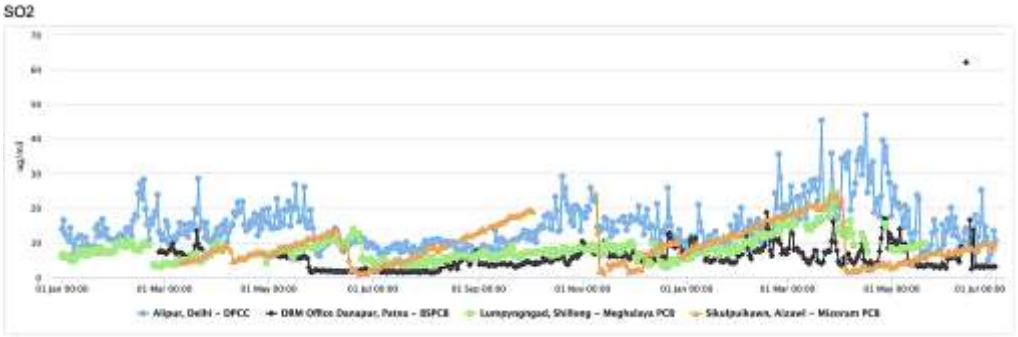

Fig. 4. Change in Level of SO_2 in the four cities

Ozone(O_3): This gas is formed from oxygen when it is subjected to under high voltage electric discharge. It is mainly generated in the stratosphere layer of the atmosphere, but could also be formed in the troposphere due to the chain reactions of photochemical smog. This gas is also very harmful for humans, animals and vegetation. Upper layer of skin and tear ducts are severely affected due to Ozone. As can be seen from figure 5, the level of Ozone is very low in Aizwal and it remains low for the complete duration of study. However, the trend of concentration of this gas is very different in Shillong as compared to Aizwal. Although the levels are on the lower side during the lockdown period, but the difference is not very significant. For the two highly polluted cities of Delhi and Patna the level remains high during the lockdown period, decreases a bit during July to October 2020, but then again increases and remains at an average level.

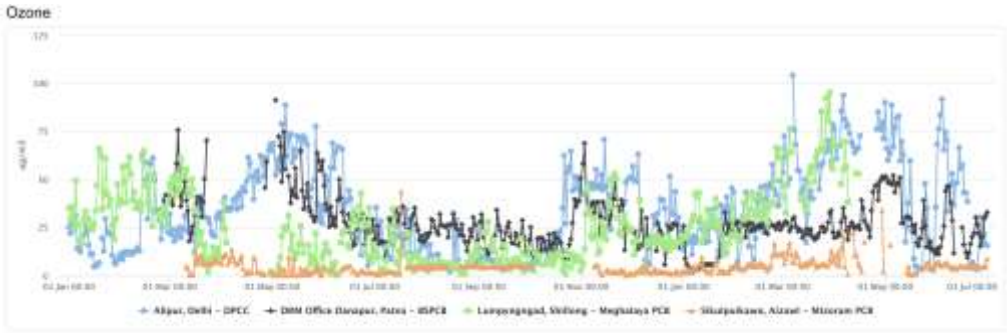

Fig. 5. Change in Level of O_3 in the four cities

7 CONCLUSION

In this work data from 2 most polluted cities (Delhi and Patna) and 2 least polluted cities (Shillong and Aizwal) in India has been studied to find out the impact of lockdown during the two waves of the Pandemic. The data from 1st January, 2020 to 30th June 2021 has been analyzed in order to study the impact of lockdown on the level of air pollution in these 4 cities. The 24-hour average concentration of five major elements which contribute to the air pollution has been analyzed here.

From the study it can be concluded that there was good amount of drop in the level of PM2.5 and PM10 from March 25th which continued till mid of September, 2020. But after things started to get back to normal, these levels again started to rise and reached its peak in the month of November, 2020. This trend was evident in all the four cities under consideration. The concentration of NO_2 was found to be negligible in Shillong and Aizwal for the complete duration of study. For Delhi and Patna the levels dropped during the lockdown but started to increase again as the lockdown was gradually uplifted.

Interestingly, the concentration of SO_2 for the two least polluted cities shows periodic rise and fall which could be attributed to some local factors. It's concentration in Delhi also shows a trend different from the other pollutants in the sense that it did not hit the least level during the lockdown period, but remained low from June to October, 2020. Thereafter it remained at an average level but again increased significantly in the month of April – May 2021. The level of Ozone is very low in Aizwal and it remains low for the complete duration of study. However, the trend of concentration of this gas is very different in Shillong as compared to Aizwal. Although the levels are on the lower side during the lockdown period, but the difference is not very significant. For the two highly polluted cities of Delhi and Patna the level remains high during the lockdown period, decreases a bit during July to October 2020, but then again increases and remains at an average level.

From this study we can conclude that the concentration of all the pollutants was on the lower side during the lockdown. Studies have shown strong correlation between the level of pollution and the rise in cases and deaths due to the Novel Coronavirus. The results obtained from this study can be used by policy makers to devise new methods for addressing the concerns of health risk due to air pollution.

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