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Impact of COVID-19 Pandemic on Particulate Matter (PM) concentration and harmful gaseous components on Indian metros

Rajiv Suman a, Mohd Javid b, Sushil Kumar Choudhary c, Abid Haleem b, Ravi Pratap Singh d, Devaki Nandan e, Shokat Ali e, Shanay Rab b

a Department of Industrial & Production Engineering, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttrakhand, India
b Department of Mechanical Engineering, Jamia Millia Islamia, New Delhi, India
c Mechanical Engineering Department, Mahamaya College of Agricultural Engineering & Technology, Akbarpur, Ambedkar Nagar, UP, India
d Department of Industrial and Production Engineering, Dr B R Ambedkar National Institute of Technology, Jalandhar, Punjab, India
e Department of CSE, Government Polytechnic College Bidram Chowk, Jammu, J&K, India

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A B S T R A C T

The COVID-19 pandemic has created a heartbreaking situation across the globe. It is affecting the human population both in terms of health issues and food safety concerns. Most of the countries are struggling to save their economies during the lock-down conditions. The fight against the COVID-19 is very tough; either one can save the economy or save his country’s human population. It seems COVID-19 have all the negative impact across the world. However, there is also some positive impact of this pandemic, where we observe much reduced environmental pollution. There has been significant improvement in the air quality at almost all the places where lock-down is implemented. Air pollution directly affects our health and hence the quality of life. In India, air quality has improved much beyond our expectations during the lock-down. This paper studies the positive impact of the COVID-19 pandemic on air pollution in major Indian cities. In the air quality rating, the paper considers types of air pollutants like Particulate Matters and Gaseous Components as benchmarks. Authors have also used available literature to study the ongoing pollution measurements, impact, and change over time. The study analysed available air quality data of four metros, i.e., Delhi, Kolkata, Mumbai, and Chennai, over the four months (National Lockdown). Two particulate matters (PM-2.5 and PM-10) pollution levels are compared with last year’s values to identify the significant variations. Moreover, Gaseous components are used to analyse their impact on the country’s human health and food ecosystem. The study analyses the effect of COVID-19 on air pollution, and the general recommendations are given. Paper identifies that there is a very good or positive impact of closing polluting units and vehicular movements.

1. Introduction

Air pollution comes into the picture when the atmosphere’s air quality gets degraded in terms of having excessive injurious elements. Air pollution is caused by various sources, which include harmful gases from different genesis like CO2, NO2, CO, CH4, and SO2, etc., particulate matters (PM) suspended in the air which are microscopic elements either solid or liquid (aerosol) and bimolecular responsible for the activities like cell division, morphogenesis, or development [1]. Biomolecules, particulate matter, and harmful gases may develop or turn the atmosphere to deliver various diseases, illnesses, or allergies and be a significant cause of the human population’s early death. Other living mechanisms are also not untouched by air pollution, which indicates that the animals and food crops can also get affected by it. Both human activity and natural processes are responsible for air pollution.

Various studies carried out by many researchers across the globe show that air pollution has a more significant effect as a cause of premature deaths and disabilities [2]. A study of Global Burden of Disease (GBD) shows that almost around 9.0 million deaths are due to this air pollution, which includes 4.2 million deaths from atmospheric air pollution and 2.9 million deaths from in house or household air pollution [2,3]. Various other factors or forms of pollution with air pollution can increase the threat of its interrelation to cardiovascular phenomenon [2,4].

Many studies are also depicting the direct relation of the SARS-COV-2 virus or COVID-19 to respiratory problems, which is the prime charge area of this virus. This leads that the patients who have some diseases caused due to air pollution, such as pneumonia can be grievously affected by COVID-19.

* Corresponding author.
Therefore, to understand the pattern of air pollution, the present study depicts the Impact of the COVID-19 pandemic on particulate matter (PM) concentration and harmful gaseous components on 4 Indian metropolitan cities, i.e., Delhi; Kolkata; Mumbai, and Chennai. For this study, we emphasise the good impacts of Covid-19 globally as the various responsible factors for air pollution are in shutdown conditions as the world is fighting against an invisible enemy by going under the lock-down to check the fast transmission of COVID-19. However, all transport means like private and commercial vehicles, railways, airplanes, and cargo/ passenger ships are interluded due to this lock-down. It may not be suitable for the economy, but it contributes to oxygen to improve air quality in various parts of the world.

2. Sources of air pollution

The matter which is dependable for causing air pollution is called air pollutants. Primary sources of air pollution are natural sources of pollution which caused due to natural incident. These include fires, volcanic eruptions, Biological decay, Marshes, Pollen grains, radioactive materials, etc. Another source is anthropogenic sources of pollution, which are generally created by human activities, i.e., Industrial emissions, Thermal power plants, Fossil fuel burning, Vehicular emissions, Agricultural activities, etc. There are several classifications of the various sources summaries in subsequent subsections;

2.2. Classification based on the source of origin

i) Natural air pollutants: Natural air pollutants include radon, fog, salt spray, volcanic activity, dust, sea-salt, forest fires, lighting, soil outgassing, etc.

ii) Anthropogenic air pollutants: These pollutants include emissions from stationary point sources (e.g., emission from industries), burning of fossil fuel, vehicular emission, marine vessels, aeroplanes, controlled burning, etc.

2.2. Classification of air pollutants based on the method of origin

i) Primary air pollutants: Those pollutants emitted directly into the air from any emission source are called primary air pollutants. E.g., Sulphur dioxide (SO₂), Carbon monoxide (CO), Nitrogen oxides, Lead (Pb), Ammonia (NH₃), Volatile organic matter, etc.

ii) Secondary air pollutants: Secondary pollutants are concerning as they can be formed by the reactions between primary air pollutants and normal atmospheric constituents. In several of the cases, these pollutants are formed by consuming solar energy. Such as Peroxyacetyl nitrate (PAN), Nitrogen dioxide (NO₂), Ozone, Smog, etc.

2.3. Classification of air pollutants based on the chemical composition

i) Organic air pollutants: These pollutants include hydrocarbons, ketones, amines, aldehydes, alcohols, etc.

ii) Inorganic air pollutants: these types of pollutants are carbon compounds (CO and carbonates), nitrogen compounds (NO and NH₃), halogen compounds (HF, HCl, etc.), Sulphur compounds (H₂S, SO₂, SO₃, and H₂SO₄), fly ash, silica, etc.

2.4. Classification of air pollutants based on the state of matter

i) Gaseous air pollutants: Pollutants present in the atmosphere in the form of gas are called gaseous air pollutants, i.e., SO₂, O₃, NOX, and CO, etc.

ii) Particulate air pollutants: Particulate air pollutants are defined as the microscopic liquid or solid matter suspended in the earth’s atmosphere. There are many subtypes of particulate matter defining as, Particles that lie between 10 micro-metre to 2.5 μm are termed as coarse particles, whereas particles with less than 2.5 μm are known as Fine particles. Fine particles include ultrafine particles of size less than 0.1 μm (PM0.1).

3. Components of air pollution and its effects on the human being

3.1. Main component of air pollution

The air quality varies according to the period, location, or geographical conditions of that particular place/ city. Air pollution depends mainly on the concentration of different gaseous phases and particulate matters [5–8]. Thus, to understand the chemistry of air pollution, it is necessary to quantify particulate matter’s size, so this element of air pollution is broadly quantified based on aerodynamic diameter, as discussed in Table 1.

Further, the concentration of these particulate matters are quantified by the mass (of particles) present in per cubic metre air (mg/m³) and decides the air quality, whether it is breathable or not. In the urban areas, air pollutants’ concentration includes PM and vapour phase compounds, including volatile organic carbons are also there [5].

3.2. Effect of air pollution

The effects of various pollutants can be understood in terms of health aspects and environmental aspects. Table 2 summarises the major effects of pollutants on human health.

Air quality is measured by the air quality index (AQI), which is the air quality indicator for that particular city or place. India, the second most populated country globally, was one of the ten most polluted cities in the world. The causes of this air pollution in these cities are most human activities, but under the lock-down condition, these cities have AQI indicating the air quality as moderate air. This indication points out the fact that human activities are mainly responsible for air pollution.

### Table 1

| Aerodynamic diameter | Particulate matter          |
|----------------------|-----------------------------|
| <10 mm               | Thoracic Particles [PM10]   |
| <2.5 mm              | Fine Particles [PM2.5]      |
| <0.1 mm              | Ultrafine Particles         |
| between 2.5 and 10 mm| Coarse Particles [PM2.5–10] |

### Table 2

| S. No. | Pollutants | Major health effects                                                                 |
|--------|------------|---------------------------------------------------------------------------------------|
| 1.     | Sulfur oxides (SOₓ) | Respiratory problems, Visual impairment, Heart and lung disorders                      |
| 2.     | Nitrogen oxides (NOₓ) | Increased susceptibility to respiratory infections, Pulmonary disorders                |
| 3.     | Particulate matter (PM) | Respiratory problems, Heart stroke, lung/liver cancer, liver fibrosis, Bone problems |
| 4.     | Carbon monoxide (CO) | Anoxemia is leading to different cardiovascular problems, newborn, pregnant women and old age people are at high risk |
| 5.     | Ozone (O₃) | Asthma, respiratory problems, bronchitis, etc. for all age groups                       |
| 6.     | Lead (Pb) | It causes severe effects on the central nervous system (CNS) since it is absorbed quickly in blood flow. It causes anaemia in bones and toxic for soft tissues etc |
| 7.     | Ammonia (NH₃) | Immediate effects lead to the burning of the eyes, throat, nose, and lung irritation. Prolonged effects result in lung damage, blindness, or death at a very high concentration |
Table 3
Air quality rating by AQI.

| AQI values | Air quality | Health effects |
|------------|-------------|----------------|
| 0–50       | Good        | People are no longer exposed to any health risk |
| 51–100     | Moderate    | Acceptable air quality for healthy adults but still poses a threat to the sensitive individual. |
| 101–200    | Poor        | Low air quality can affect health issues such as difficulty in breathing |
| 201–300    | Unhealthy   | Toxic air can provoke health difficulties, especially for young kids and older people. |
| 301–400    | Severe      | Breathing polluted AQI may lead to chronic health issues. |
| 401–500+   | Hazardous   | AQI exceeding 400 is highly unacceptable to humans, and it can lead to premature death. |

Table 4
Methods of pollutant measurement.

| S No | Pollutant         | Methods of measurement                     |
|------|-------------------|--------------------------------------------|
| 1    | Sulphur Dioxide (SO2), \(\mu g/m^3\) | Improved West and Gaeke Method - Ultraviolet Fluorescence |
| 2    | Nitrogen Dioxide (NO2), \(\mu g/m^3\) | Jacob & Hochheiser modified (NaOH-NaAsO2) Method - Gas-Phase Chemiluminescence - Gravimetric - TEOM - Beta attenuation |
| 3    | Particulate Matter (Size less than 10 \(\mu m\)) or PM10, \(\mu g/m^3\) | Gravimetric - TEOM |
| 4    | Particulate Matter (Size less than 2.5 \(\mu m\)) or PM2.5, \(\mu g/m^3\) | Gravimetric - TEOM - Beta attenuation |
| 5    | Carbon Monoxide(CO), mg/m3 | Non-dispersive infrared (NDIR) Spectroscopy |
| 6    | Ozone (O3) \(\mu g/m^3\) | UV Photometric - Chemiluminescence - Chemical Method |
| 7    | Ammonia (NH3), \(\mu g/m^3\) | Chemiluminescence - Indophenol method |
| 8    | Phenolic compounds | Gas Chromatography (GC) |
| 9    | Heavy metals      | AAS/ICP Method after sampling on EPM 2000 or equivalent filter paper |

Fig. 1. Flowchart adopted for the study.

[4]. Table 3 discusses the quality rating given by AQI India, with its effects on health.

4. Research design and research questions

Taken data of different pollutants to measure the air quality collected from the Central Pollution Control Board (CPCB), India, and relevant websites. The research methodology depicts in the form of a flow chart is shown in Fig. 1.

Under the provisions of the Air (Prevention & Control of Pollution) Act, 1981, the CPCB has notified the national standard of National Ambient Air Quality Standards (NAAQS), which aims to provide uniform air quality, irrespective of land use pattern, across the country. Measurement of a different air pollutant is done manually using the following methods. Table 4 shows the methods of pollutant measurements by CPCB at different locations in India [26].

5. Results

Delhi, India’s capital, also a union territory, was one of the most polluted cities before the COVID-19 situation; the local government tried hard to control the pollution levels by putting smog towers and water sprinklers around. With the onset of the COVID-19 pandemic, many countries declared the lock-down, and then the city saw a considerable drop in pollution level.

It seems that the COVID-19 pandemic era has come up with a support system to clean the atmospheric air pollution globally. It also gave indicated the reason which is responsible for air pollution.

Every country is recording its air quality data to keep an eye on the increasing air pollution due to various human activities. Many parts of the world show similar significant positive changes in air quality during the lock-down time of COVID-19. It is also observed from the data, as given on www.cpcb.nic.in that climatic conditions in many Indian cities improved during a short period of three days of lock-down. The open, accessible data (https://app.cpcbccr.com/ccr) of air quality in Delhi before & during COVID19 Lockdown, as shown in Fig. 2.

The above data indicates that for the period from 01 to 20 to 23–03–2020, the average air quality index (AQI) is about 147 (Poor). Still, the span in March from the date of lock-down, 24–03–2020 to 07–04–2020, shows a considerable drop in April to an average air quality index (AQI) of 70 (Moderate). Similar trends in AQI levels, PM-2.5, and PM-10, can be seen during the lock-down period from data of four major cities of India. The graph of pollution levels shows the good impact of COVID-19 on air pollution of Delhi, Kolkata, Mumbai, and Chennai, as shown in Figs. 3, 4, 5, 6, 7, 8, 9, and 10.

From the above information, we can find that PM data levels are towards the higher side as the lock-down started in different major cities in India. However, with the due course of lock-down due to COVID-19, the PM data trends are going towards the lower sides. It indicates that there is a significant positive change in the quality of air in these major cities. This result gets confirmed from the average data of PM of these four cities.

In India, the PM level is 4–5 times higher than in US cities. It affects public health and increases mortality due to respiratory disease [9–14]. The major breakpoints for PM 10 and PM 2.5 are shown in Tables 4 and 5.

From the above, it is clear that air quality is surely improving as the lock-down is going on. Similarly, the trends for PM-2.5 and PM-10 show good signs for environmental air pollution due to the COVID-19 pandemic. Trends for PM-2.5 and PM-10 are also studied for the same period to ensure the good or positive impacts of COVID-19 on air pollution. PM-2.5 data of Delhi, Kolkata, Mumbai, and Chennai from 24 to 20 to 22–04–2020 are shown in Figs. 4, 6, 8, and 10.

All the above trends for PM-2.5 indicates almost a linear decline in the concentration of PM-2.5 except Chennai, which is showing a different or zigzag manner as its AQI data. PM-10 data of Delhi, Kolkata,
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Fig. 2. Quality of air of Delhi before and after the lock-down.

Fig. 3. PM-10 data of Delhi 24–03–2020 to 22–04–2020.

Mumbai, and Chennai from 24 to 20 to 22–04–2020 are shown in Figs. 3, 5, 7, and 9.

PM-10 data also confirms the declining trend of air pollution in four major cities. During the initial trends of lock-down up to Apr.06, 2020, the hills and valleys are towards the upper side of the concentration column. After Apr.06, 2020, the hills and valleys are tending towards the lower side of the concentration column. Concentration levels are going down in this COVID-19 lock-down period. Which is the direct indication of air quality improvement in the different cities within a short period of one month?

Thus, to confirm the trends of PM-2.5 and PM-10, the average values were studied, here we followed the AQI range for both of the particulate matters. Table 6 discusses the average data of PM-2.5 and PM-10 for Four Major Cities.

As the above data for PM-2.5 during lock-down lies in the range of 0–50 for Delhi, Kolkata, Mumbai, and Chennai, the air quality got into the good category. This data is for the period of lock-down due to COVID-19. It is well known that Delhi’s air quality was very bad due to many reasons like transportation, construction work, and other human activities. During the COVID-19 lock-down, Delhi’s air quality has improved positively. The same condition or similar trends are for other metros.

Similarly, the PM-10 levels also show satisfactory and moderate air quality for Delhi, Kolkata, Mumbai, and Chennai. It is now clear that due to the COVID-19 lock-down, air pollution has decreased, and the environment or ecology is working to purify itself rapidly. For Chennai, the air quality data of PM-10 showing the reverse trend from good to moderately polluted and is still in the unhealthy zone, but as compared to the historical data before the COVID-19 lock-down, Chennai has also improved its air quality or PM concentration from the range of 400–500 to 100–200. Which is the sign of improvement in air quality even if it lies in an unhealthy zone?
Fig. 4. PM-2.5 data of Delhi 24–03–2020 to 22–04–2020.

Fig. 5. PM-10 data of Kolkata 24–03–2020 to 22–04–2020.

Fig. 6. PM-2.5 data of Kolkata 24–03–2020 to 22–04–2020.
Fig. 7. PM-10 data of Mumbai 24–03–2020 to 22–04–2020.

Fig. 8. PM-2.5 data of Mumbai 24–03–2020 to 22–04–2020.

Fig. 9. PM-10 data of Chennai 24–03–2020 to 22–04–2020.
The data is for the period before lock-down dated 24th March 2019 to 22nd April 2019. As the above data for PM-2.5 lies in the range of 0–50 for Mumbai and Chennai, the air quality belongs to the good category, but the AQI of Delhi and Kolkata is under moderate condition under the range of 51–100. As the data for PM-10 lies in the range of 0–50 for Chennai is in good condition, 51–100 for Kolkata and Mumbai is in moderate condition, 200–300 for Delhi is in Unhealthy rating. Average PM-2.5 and PM-10 for Four Major Cities like Delhi, Kolkata, Mumbai, and Chennai before lock-down and after lock-down are shown in Figs. 11, 12, 13, and 14.

From the above observations, it is clear that the PM concentration is going towards good condition. The average data for PM-2.5 concentration for all the metros during the COVID-19 lock-down shows that the concentration is good for the human population. This further means the PM-2.5 concentration is surly decreasing in air, and it can also be confirmed from the average data before the lock-down period of COVID-19.

Similar trends are for the average data of PM-10 concentration for all the four metros. The average value of each metro indicated that the concentration levels are decreasing during the COVID-19 lock-down period. Air quality guidelines (AQG) issued by WHO recommends the exposure
Table 6
Average data Comparison of PM-2.5 and PM-10 for Four Major Cities (Metros) of India During and Before COVID-19 Lockdown Period.

| PM(µg/m³) Breakpoint Response for Average data for 2020 and 2019 |
|---------------------------------------------------------------|
| Cities | Avg. data PM-2.5 (During Lockdown)24–03–2020 to 22–04–2020 | Break Point Response | Avg. data PM-2.5 (Before Lockdown)24–03–2019 to 22–04–2019 | Break Point Response | Avg. data M-10 (During Lockdown)24–03–2020 to 22–04–2020 | Break Point Response | Avg. data PM-10 (Before Lockdown)24–03–2019 to 22–04–2019 | Break Point Response |
|--------|-------------------------------------------------------------|----------------------|-------------------------------------------------------------|----------------------|-------------------------------------------------------------|----------------------|-------------------------------------------------------------|----------------------|
| Delhi  | 44.104                                                      | Good                 | 80.50                                                       | Satisfactory        | 97.115                                                      | Satisfactory        | 209.02                                                      | Moderately polluted  |
| Kolkata| 31.213                                                      | Good                 | 53.83                                                       | Satisfactory        | 55.308                                                      | Satisfactory        | 98.36                                                       | Satisfactory        |
| Mumbai | 25.092                                                      | Good                 | 24.81                                                       | Good                | 73.155                                                      | Satisfactory        | 93.07                                                       | Satisfactory        |
| Chennai| 19.519                                                      | Good                 | 33.216                                                      | Good                | 137.226                                                     | Moderately polluted | 30.95                                                       | Good                |

Fig. 11. Bar Chart for PM-2.5 (Before Lockdown).

Fig. 12. Bar Chart for PM-2.5 (During Lockdown).
limits as <10 mg/m^3 yearly and <20 mg/m^3 daily [15]. So, according to the above comparison, it can be seen the exposure to polluted air is decreasing. This decrease is notified during the COVID-19 lock-down from 24 to 20 to 22–04–2020.

5. Discussion

Comparing these four cities confirms that in Delhi, Kolkata, and Chennai, the air pollution has come to a range of good to moderate quality according to the AQI range limits. Also, Mumbai’s air quality is improving. As in the Asian region, 99% of the population exposed themselves to levels exceeding 35 mg/m^3 yearly, way beyond the limits of AQG. The above data of AQI is a good sign of nature as well as humans. This data is for a short period (one month), and it is only showing the increasing trends of air pollution trends [15–17]. So from these trends, we can estimate the good impact of COVID-19 on human health and crops. Table 7 discusses the significant benefits of COVID-19 Impact on Air Pollution.

The above table directly links air pollution to the human population’s health and its food source. We observed that during COVID-19, air pollution decreased substantially. Thus, other risks that are linked directly with air pollution came on the decreasing side. From the above data, it is observed that the human population faces many diseases linked to bad air quality. It also affects food quality, as pollution alters agriculture’s input through diffusion, settling, and precipitation [23,24]. That is why, for the agriculture sector, air pollution negatively influences the agricultural yield and its quality (Table 8).

6. Future research and limitations of the study

The COVID-19 lock-down has led to cleaner air, but it cannot control air pollution in the long run. The question is whether this good air run
is sustainable once the lock-down ends [26]. For that, we need to leave back our habit of burning coal, oil, and gas. A transition to clean, renewable energy and transport will seriously reduce air pollution, greenhouse gas emissions, and the impact of future pandemics [27–29]. Other various computational tools can be used to monitor and forecast the behaviour of air pollution data.

### 7. Conclusion

This paper presents a comprehensive study of the environmental status of four metros of India during the National Lockdown due to COVID-19. Air pollution or air quality can be directly linked to the human population’s health issues and associated food system. Air pollution’s main components are particulate matters (PM-2.5 and PM-10) and gaseous components (NOx, SO2, O3, and CO, etc.) and play an important role in health issues crop yields. Although there are various reasons for air pollution, human errors show humans’ carelessness towards Mother Nature as the main reason. We can assess ourselves that during COVID-19 lock-down and analyse our role to pollute our breathing air. The study shows that the COVID-19 lock-down will help purify the atmospheric air automatically. It leads to a decreased threat from various respiratory diseases and will help our food system. This study shows the pattern of change in air quality during the lock-down period in India. Such studies can further be explored in other urban and rural areas in India. The lock-down has brought good changes to the environment through improved AQI and pollutants level; the quality impact of COVID-19 on air pollution was that metros cities saw much cleaner air.

### Declaration of Competing Interest

None

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