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Analysis of the Air Quality Index (AQI) and Particulate Matter(PM) in Some Regions of the Metropolitan City of Delhi; Anthropogenic Activities Affecting the Quality of Air During, Before and After the Lockdown Period

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ABSTRACT
The problem of air pollution is a health emergency which needs to be addressed. The important indicator of the pollution of air of any area is the Air Quality Index (AQI). Particulate Matter (PM) is one of the main contaminant of the air majorly due to anthropogenic activities. The present study analyses AQI and PM levels of the four regions of metropolitan city of Delhi which indicate the degree of pollution in each region and the type of anthropogenic activities affecting air quality. The polluted air impairs the cardiovascular and pulmonary functions of susceptible individuals, especially the Covid survivors. It is suggested that a balance between the health of the air and human activities is essential, so that mandatory steps can be taken to heal the air. Lessons learnt from the lockdown restrictions imposed during Covid-19 may be applied as remedial steps to be taken to curb air pollution.

Key words: Air pollution, Contaminant, Health, Cardiovascular, Pulmonary, Urban

INTRODUCTION

Pollution of air is an important global public health emergency affecting the people of all the age groups. The polluted air, if breathed, impacts our body and quality of life causing inevitable damage to it, particularly the respiratory and cardiovascular systems (Brunekreef and Holgate 2002, Brook 2008, Kampa and Castanas 2008, Ghosh and Parida 2015, Hamanaka and Mutlu 2018, Sharma et al. 2018). The local quality of air changes on an hourly basis each day and different government organizations monitor it to evaluate the levels of pollution. AQI or Air Quality Index is the yardstick which is indicative of air pollution. When AQI level increases, the air becomes more dangerous and toxic, raising concerns for remedial steps to be taken for its improvement. Air quality index is grouped into categories of different ranges with color codes. This color coding is an easy and quick description of air quality for issuing immediate health advisory to the general public.

AQI not only measures the quality of air but can also be used to alert and warn the local residents about the levels of pollution so that they can plan their outdoor activities accordingly, may be to some extent. It also helps to take immediate steps especially for the continuance or discontinuance of specific anthropogenic activities to reduce the levels of pollutants before it reaches alarming levels. The most susceptible population groups affected by high levels of pollution are newborns, infants, elderly, COVID survivors and chronic patients of different diseases. The polluted air contains different types of contaminants like PM_{10}, $PM_{2.5}$, NO_2, NH_3, SO_2, CO and Ozone from various sources. Out of all the contaminants, $PM_{2.5}$ and PM_{10} are generated mainly due to anthropogenic activities (Popescu and Ionel 2010, Hamanaka and Mutlu 2018, Sharma et al. 2018, Singh and Tripathi 2021). The particulate matter of air is made of both solid particles and liquid droplets which vary in size, chemical and physical characteristics as well as the site and source of emission.

The present study explores the changes in the Air Quality Index (AQI) and particulate matter ($PM_{2.5}$, PM_{10}) at four different sites of Delhi viz. Alipur (North Delhi), Bawana (Northwest Delhi), Lodhi Road (South East Delhi) and Dwarka (South west Delhi). The results of the four regions (Alipur,

Bawana, Lodhi Road and Dwarka) for the months of April and May during the periods before lockdown (2019), lockdown (2020, 2021) and after lockdown (2022) were analysed and compared. The purpose of the study is to highlight different anthropogenic activities contributing to the increasing pollution especially particulate matter and their relation to restriction and relaxation in human activities in the pre, post and lockdown periods. The changes indicate lessons to be learnt from the past and a need to implement some forced mandatory steps in the near future for improving quality of air and health of the local residents of the area. The different regions were chosen as they have some varied pollution signatures, special geographic locations and infrastructure. Alipur is the village area located in the lap of nature which has large agricultural fields and many farmhouses near it. Bawana is a hub of micro and small scale industries and Lodhi road is an institutional area with the green belt of sprawling Lodi Park close to it whereas Dwarka is a sub city of Delhi with multistorey apartments, institutions, and is progressing to transform into a smart city.

METHODS

The average values of AQI and Particulate Matter ($PM_{2.5}$ µm and PM_{10} µm) of each day were collected from the stations DPCC (Delhi Pollution Control Committee) or IMD (India Meteorological Department) as reported by Central Pollution Control Board (CPCB) site (https://app.cpcbccr.com/AQI_India). The air monitoring stations did not have any information on ultrafine PM of the size 0.1µm, so it was not considered in our study. The collected data was tabulated and represented into the bar graphs (Figs.1, 2, 3). The levels of AQI and PM in the months of April and May during lockdown (https://en.wikipedia.org/wiki/COVID-19_lockdown_in_India#Lockdown_in_2021), pre- and post-lockdown periods were compared and analysed. The AQI levels were ranged between 0 to 500 as given in the National Air Quality Index, CPCB, the Ministry of Environment, Government of India. This range is classified into different categories of air quality indicators as 0-50 (minimal impact), 51-100 (satisfactory), 101-200 (moderate), 201-300 (poor), 301-400 (very poor) and 401-500 (severe). The category and range of AQI, $PM_{2.5}$ and PM_{10} were considered for reference as per CPCB (Table 1). The concentration above 30 and 50µg/m^3 of air for $PM_{2.5}$ and PM_{10}, respectively, are considered unhealthy for humans.

RESULTS

Air quality index of four regions of Delhi (Bawana, Alipur, Lodi road and Dwarka) for the months of April and May were taken and compared for the years 2019 to 2022 (Table 2). Among these four regions, Bawana showed poor or very poor AQI for the maximum number of days (Figs. 1, 2, 3, Table 2). The AQI levels did not reach above 400 (except for one day in Bawana) to cause a severe situation in any of the regions studied. The air quality index remained consistently poor for periods before, after lockdown and even in lockdown periods, but reached a very poor condition for 27 days in April-May 2022. Next to Bawana is the Dwarka region, where AQI level was below 200 only in the year 2020 and the levels increased considerably in 2022. In Alipur region AQI was good for 2020 and 2021, but increased in 2022, ranking it third in position amongst the regions studied, with respect to the quality of air. AQI of Lodi road became poor in 2022. It was also observed that most of the time PM_{10} level is high in comparison to $PM_{2.5}$ in all the four regions for the periods mentioned and levels of both were in the unhealthy range.

DISCUSSION

Pollution of air is a major problem of public health all over the world. The effect of different pollutants is detrimental to the human body (Sharma et al. 2008). The pollutants vary depending on the source from where they are generated. The level of pollutants can be checked and controlled by monitoring the anthropogenic activities. Out of different pollutants which make the air toxic, the particulate matter is more commonly observed in the air of the four regions of Delhi. Particulate matter is broadly categorised, as $PM_{2.5}$ and PM_{10} where PM_1 is a subset of $PM_{2.5}$ (https://www.epa.gov/pm-pollution/particulate-matter-pm-basics, https://en.wikipedia.org/wiki/Particulate). The fine particles ($PM_{2.5}$µm) penetrate

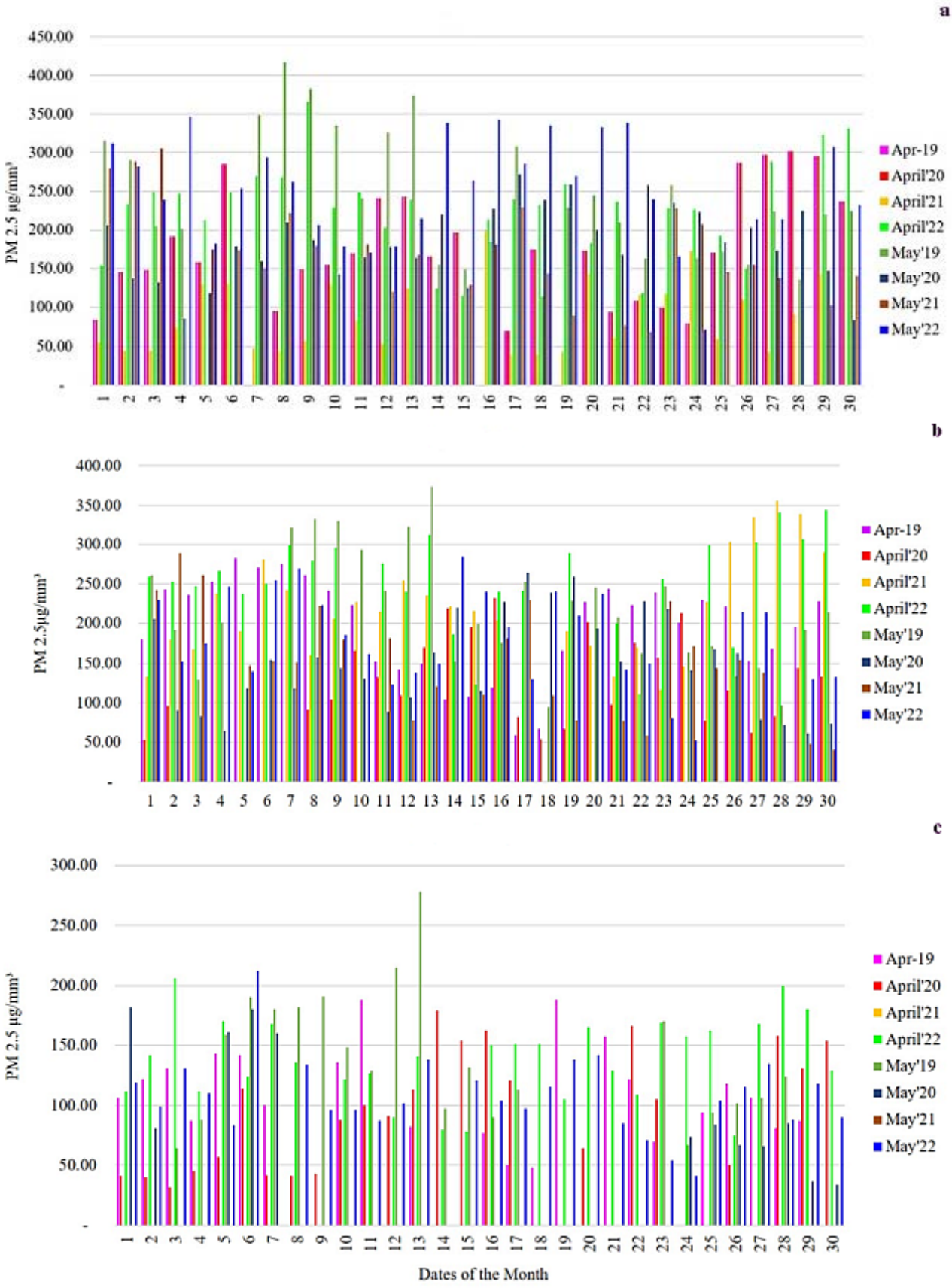


Figure 1. $PM_{2.5}$ µg/m³ of air in the April and May months for the years 2019-2022. a - Alipur, b -Bawana, c- Lodhi road

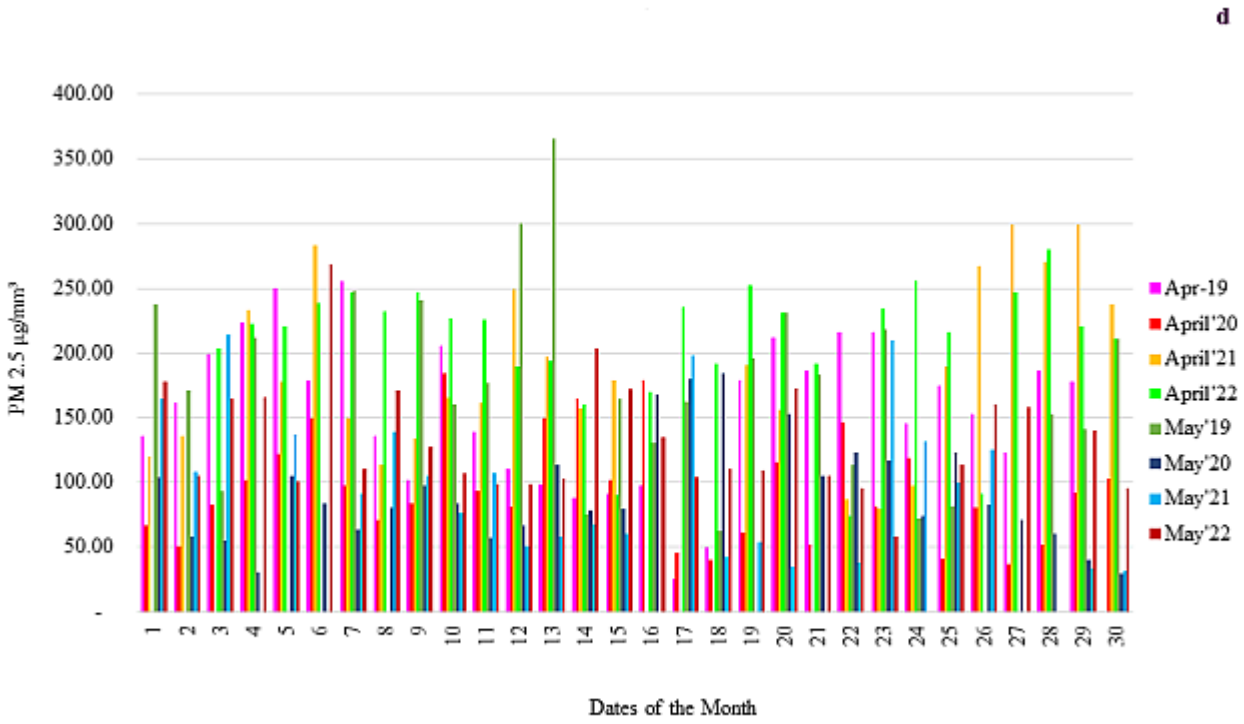


Figure 1. $PM_{2.5}$ µg/m^3 of air in the April and May months for the years 2019-2022. d- Dwarka

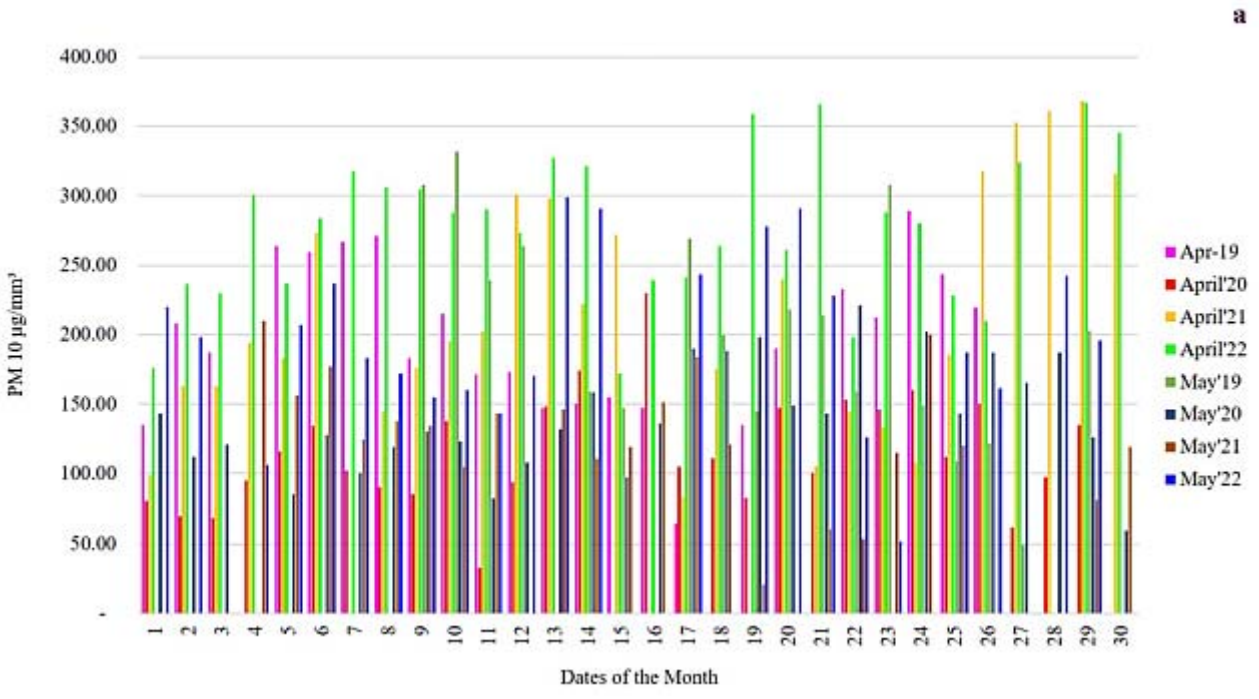
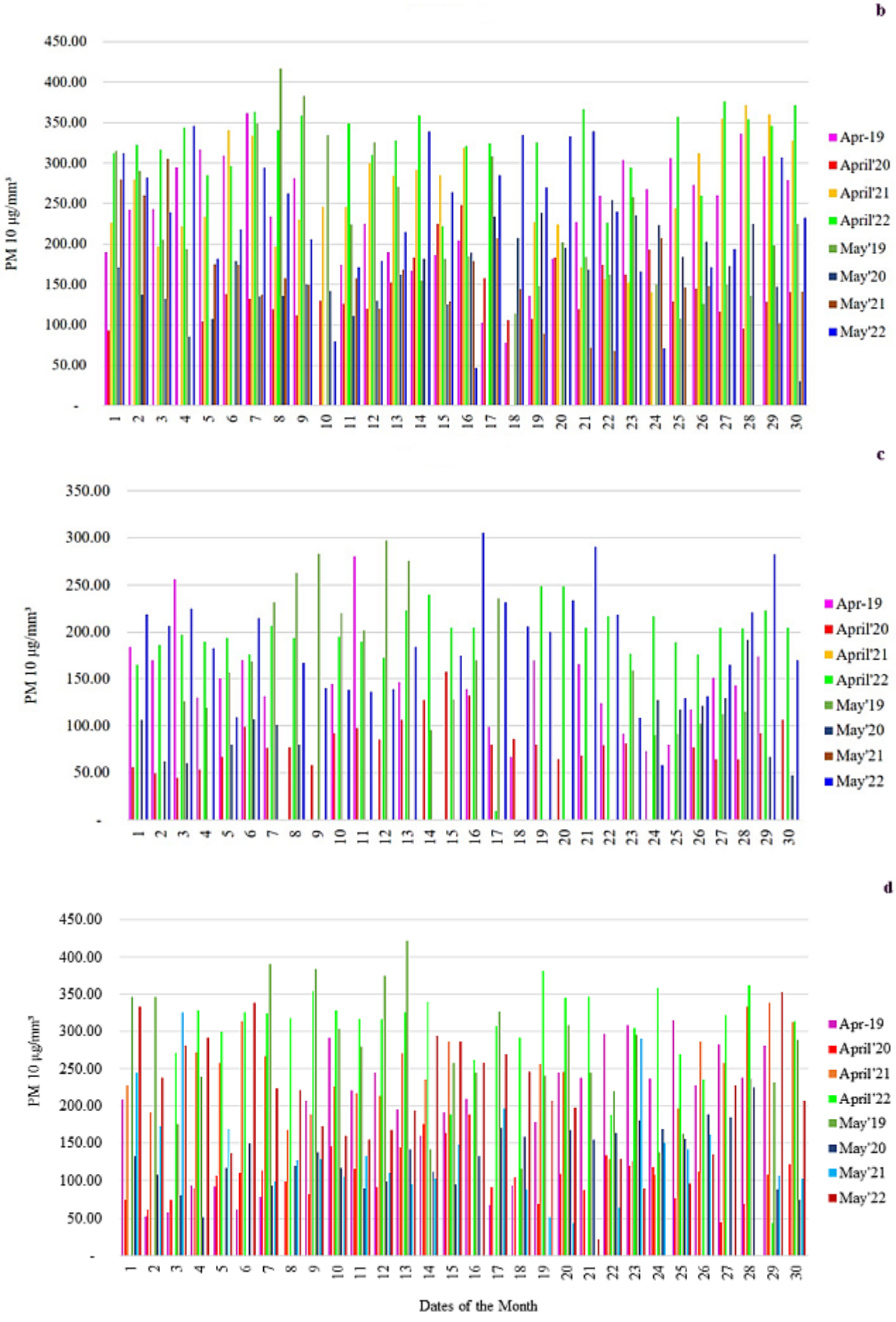


Figure 2. PM_{10} µg/m^3 of air in the April and May months for the years 2019-2022. a - Alipur, b -Bawana, c- Lodhi road, d- Dwarka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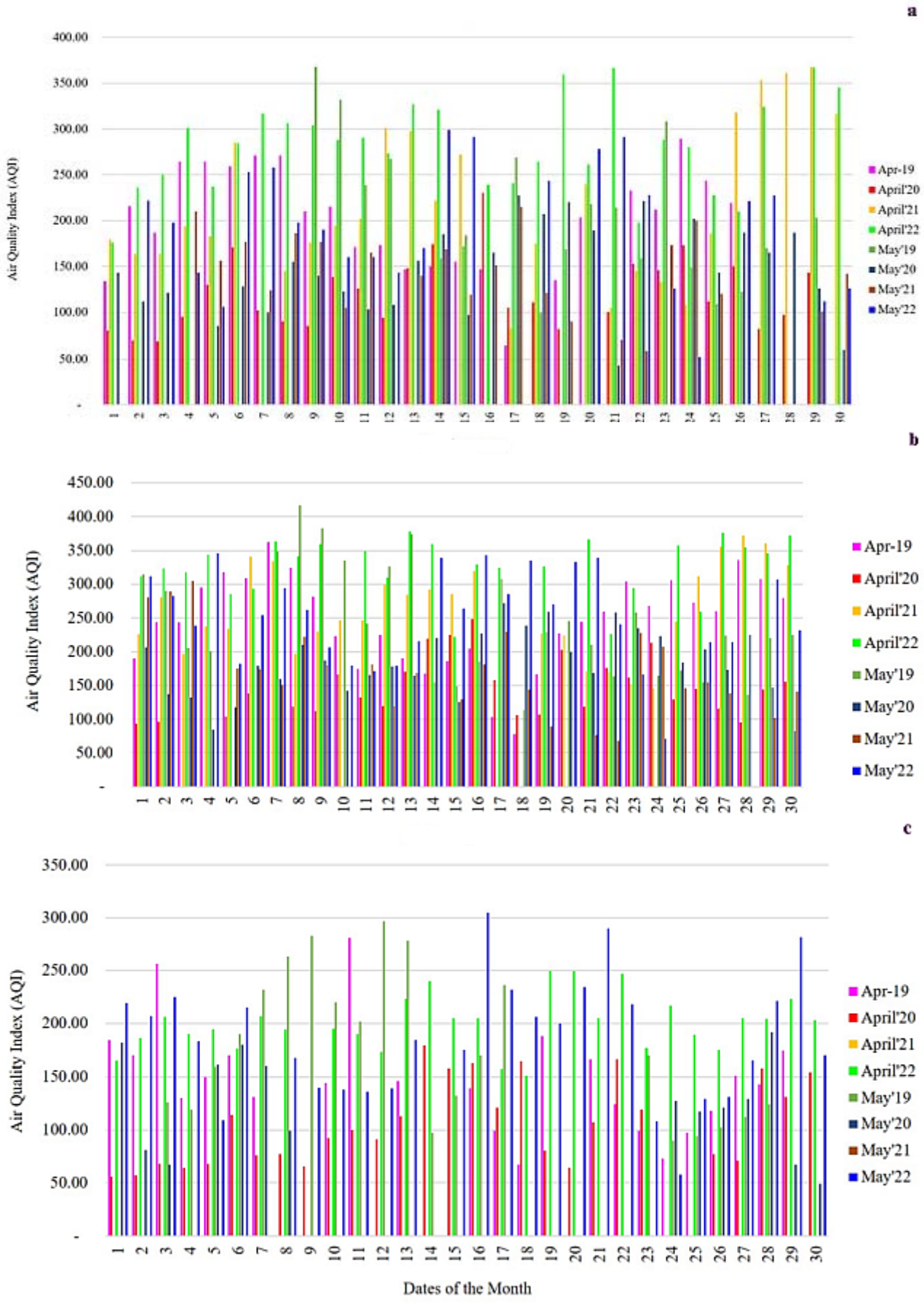
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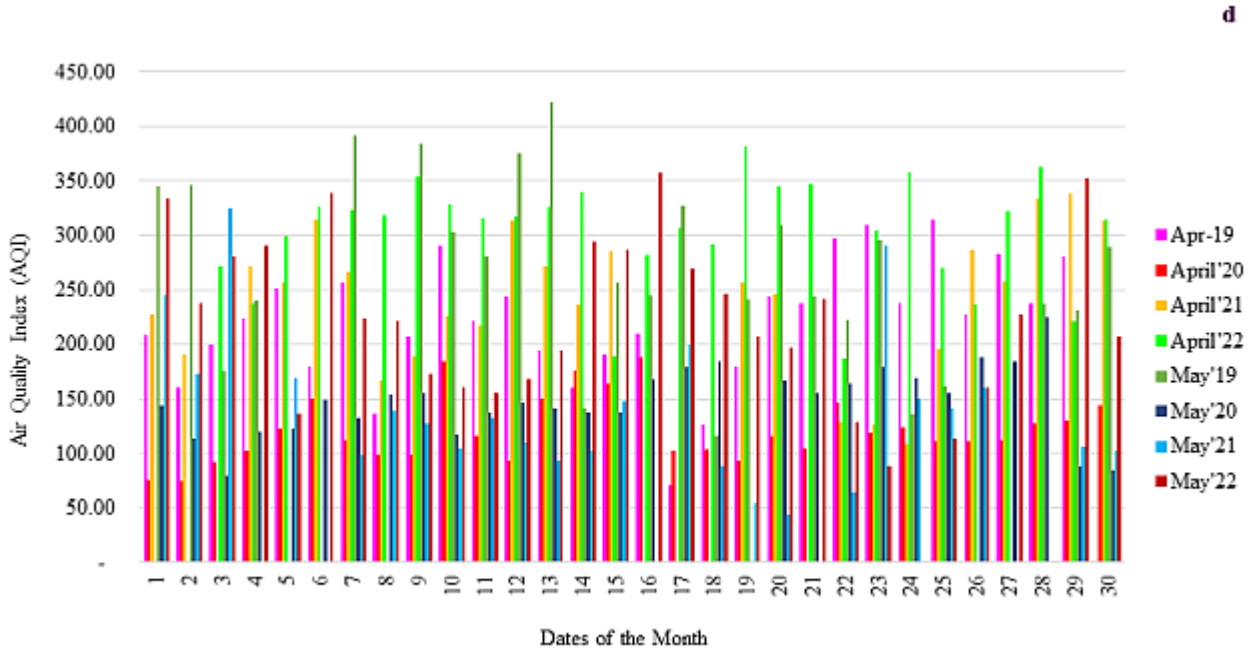

Figure 3. AQI during the April and May months for the years 2019-2022. a - Alipur, b -Bawana, c- Lodhi road, d- Dwarka

Table 1. Range of AQI, PM_{10} (µg/m^3) of air and $PM_{2.5}$ (µg/m^3) of air determining the air quality and associated health impacts

Air Quality	AQI range	PM_{10}	$PM_{2.5}$	Associated Health Impacts
Good	0-50	0-50	0-30	Minimal Impact
Satisfactory	51-100	51-100	31-60	May cause minor breathing discomfort to sensitive people
Moderate	101-200	101-250	61-90	May cause breathing discomfort to people with lung disease such as asthma, and discomfort to people with heart disease, children and older adults
Poor	201-300	251-350	91-120	May cause breathing discomfort to people on prolonged exposure, and discomfort to people with heart disease
Very Poor	301-400	351-430	121-250	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart disease
Severe	401-500	430+	250+	May cause respiratory impact even on healthy people, and serious health impacts on people with lung/heart disease. The health impacts may be experienced even during light physical activity.

Source https://pib.gov.in/newsite/printrelease.aspx?relid=110654

Table 2. Number of days showing poor, very poor and severe AQI levels in different regions for the years 2019 to 2022

AQI	Regions	No. of days with AQI levels in different regions			
		Apr- May-19	Apr- May-20	Apr- May-21	Apr- May-22
200-300	Alipur	19	6	7	25
Poor	Bawana	24	17	19	19
	Dwarka	29	1	13	21
	Lodhi road	11	0	No data	26
300-400	Alipur	4	0	5	11
Very Poor	Bawana	15	0	10	27
	Dwarka	10	0	6	23
	Lodhi road	0	0	0	1
>400	Alipur	0	0	0	0
Severe	Bawana	1	0	0	0
	Dwarka	0	0	0	0
	Lodhi road	0	0	0	0

into fine bronchioles and alveoli and coarse particulate matter ($PM_{10}\mu m$) does not go beyond the upper respiratory tract (Pope 2000, Brook et al. 2004). Major sources of suspended particulate matter are the anthropogenic activities which may be from agricultural work, industries, traffic on roads, thermal power plants, incineration, demolition/construction activities, and by coal used as fuel for domestic purposes (Popescu and Ionel 2010, https://app.cpcbccr.com/AQI_India).

COVID-19 lockdown Phases, 1 to 4 which extended from the periods, 24 March-14 April, 15 April-3 May, 4-17 May, 18-31 May of the year 2020 and from 5 April-15 June in 2021(https://en.wikipedia.org/wiki/COVID-19_lockdown_in_India#Lockdown_in_2021) have caused the serious reduction in air pollution status across the globe (Chen et al. 2020, Muhammad et al. 2020, Venter et al. 2020, Grzybowski et al. 2021, Lovric et al. 2021). During the lockdown period there were traffic restrictions and closure of factories, industries and commercial activities though household emissions may have increased as most of the time people remained indoors. Though a significant portion of PM is generated from a variety of the anthropogenic activities but non-anthropogenic activities like dust blown by wind, changing temperature and wild fires also contribute or aggravate the situation.

During the lockdown period numbers of restrictions were imposed on road traffic as well as on commercial and industrial activities. Since Bawana is an industrial area with about 16000 functional factories, both $PM_{2.5}$ and PM_{10} pollutant levels remained elevated in the area. Changes in the meteorological conditions like the increasing temperature in the months of April and May with hot winds and localised dust storms in some areas might have aggravated the condition of pollution.

The quality of air was better in the years 2020 and 2021, but is extremely bad in 2022 in Bawana as observed from the collected data. It may be due to the increased working hours in factories and small scale industries to cope up with the financial losses of the owners during lockdown and to the finish the targets of more demand. Most of the factory workers with low income had migrated earlier during lockdown to their villages are back and are residing nearby. They use kerosene, wood and coal mostly as fuel for domestic activities. The illegal use of unlisted fuel for running the factories, inspite of the fact that the government is making every effort to encourage people to use green and clean fuel by providing subsidy to the factories for shifting to piped natural gas (PNG). Bawana has 1500 Mega Watt power plant (https://www.power-technology.com/marketdata/pragati-iii-bawana-power-station-india), the largest gas plant in

Northern India and second largest in the country but the actual situation of its power generation and distribution is different from what was presumed.

The pollution levels of Dwarka is attributed to the number of anthropogenic activities like the major construction project of Dwarka expressway, and many unchecked activities on sites of construction, including the housing societies. The illegal burning of open waste was also reported in Dwarka which added to the pollution woes. The situation of polluted air levels is also reflected in the bar graphs (Figs. 1, 2, 3, Table 2) where it shows the AQI was better during the lockdown periods of 2020 than of 2021 and became worse in 2022.

The data shows that the quality of air in the Alipur region was not good in 2019 and became bad in 2021, worsened in 2022 but was better in the lockdown period of 2020-2021. The lockdown restrictions had improved the air quality though extensive construction in 2022 made the condition worse. The major work of National Highway is undergoing at fast pace and the burning of biomass in nearby agricultural fields as well as frequent waste burning in Bhalaswa landfill sites have contributed to the poor quality of air in Alipur region. The emissions from the farmhouses in the vicinity of the Alipur have also added to the pollution of air.

The air quality for the Lodhi road area was poor (AQI 200-300) but not very poor (300-400) as observed in all the other three regions, in the month of April and May 22, and the data for the year 2021 is not available. The vehicular emissions increased in post lockdown periods as many government offices located in the area were opened to work with full capacity. The high temperature, road dust, dry loose soil and dust storms may have contributed to poor air quality.

Air pollution is one of the environmental problems which poses a great risk to human health. By decreasing the levels of the air pollution, the countries can bring down the cases of cardiac and pulmonary illness, stroke, lung cancer, etc.The main cause of occurrence of some human diseases is the particulate matter in the air, as high $PM_{2.5}$ leads to bronchitis, asthma and other respiratory ailments which requires immediate hospitalisations, whereas PM_{10} may worsen the pre-existing heart and lung problems. The levels of the particulate matter and exposure time together have more deteriorating effect on human health. Long-term exposure to PM causes more cardiovascular damage and increases mortality rate, but short-term exposure increases the cardiovascular problems during periods of high pollution (Ridker et al. 2000; Anderson et al. 2012, Martinelli et al. 2013, McGuinn et al. 2017, Liang et al. 2020). The particles deposited in the lungs translocate to extra-pulmonary sites, resulting in systemic inflammation causing cardiovascular problems (van Eeden et al. 2005, Bai et al 2007, Brook et al. 2010, Martinelli et al. 2013, Du et al. 2016). This condition is mediated through increased levels of inflammatory cytokines, IL-6, TNF-Ü, and C-reactive protein (CRP) in blood. High levels of both IL-6 and CRP are related to the development of acute myocardial infarction (Ridker et al. 2000). When exposed to PM above the normal range, changes occur in blood coagulation, the levels of fibrinogen and activation of platelets which also affects the coronary arteries (Ruckerl et al. 2006, Bai et al. 2007).

In 2019, 99% of the people worldwide were living in places where guidelines for the levels of air quality as recommended by WHO were not followed. The outdoor air pollution caused nearly 4.2 million premature deaths all over the world both in the urban and rural areas in 2016 (https://www.who.in/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health). Nearly 91% of premature deaths were reported in the countries belonging to poor and middle-income group, and the highest number was in the regions of South-East Asia and Western Pacific (https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health). It is important to take care of our air and check pollution especially in the pandemic time when the whole world is struck with the devastating Corona Virus. People who have survived COVID-19 and are still battling with its long-term effects of post-COVID syndrome are facing problems of respiration, tiredness, hair loss, irritated eyes, dry skin, etc. Poor air quality will increase the healing time of the damaged lung. Due to high levels of pollution, people who have recovered from severe COVID are still at risk as they may acquire more damage to the lung and its condition may worsen over time.

The study suggests that special care should be taken of the areas of Bawana, Alipur and Dwarka as

in these areas extensive anthropogenic activities have deteriorated air quality though the type of the activities differ in each region. The main reason for air pollution in Bawana is factory emissions, and for the Alipur region, the construction on the highway and its agricultural activities, but for the Dwarka, it is by the variety of construction activities. Lodhi road area is having less pollution stress as anthropogenic activities detrimental to air quality are not to a great extent.

CONCLUSION

The study suggests that the reasons for increasing air pollution in the localized region may differ for each area. The anthropogenic factors if controlled and monitored may significantly improve air quality. There is a need to maintain a balance between developmental activities and the health of air and consequently that of the residents of the area. The outdoor polluted air also affects the quality of indoor air, and even if the susceptible people are warned to stay indoors, they will still face health issues. The attention should also be given to the ultrafine suspended particles which are very small in size and are more toxic biologically but their levels are not monitored and displayed by CPCB stations. Steps should be taken to switch to clean power and fuel where solar energy and natural gas can be tapped for its use. Government should enforce a ban on use of coal as fuel for any purpose and need to fix strict norms of emission from coal-based thermal power plants. A heavy fine should be imposed for the burning of any type of solid waste in localized regions and in landfill sites. The restrictions like 'No construction" once a week should be practiced along with the frequent mechanized cleaning of roads. There is need to explore novel environmental friendly methods of pollution control to create a balance between urban development, air quality and human health.

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Conflict of Interest: The authors declare no conflict of interest.

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