QUALITATIVE ANALYSIS OF AEROSOLS AND AIR QUALITY DURING THE PRE-MONSOON SEASON FOR THE CITIES OF DELHI, MUMBAI, BENGALURU AND CHENNAI OVER THE PAST FIVE YEARS (2018-22) USING MERRA-2 AND GROUND BASED DATA.

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Summary:

Air pollution has emerged as one of the major problems in the major cities of India, especially in the recent decades. The rapid urbanization has played a huge role in this. All four cities of Delhi, Mumbai, Bengaluru and Chennai have a higher aerosol and AQI level than desirable. Air pollution in all four cities needs to be curbed in order to minimize health issues. The nationwide lockdown of 2020 had a significant impact on the air quality of all four cities. Post 2020, air aerosol amounts have increased in all four cities and 2022 had the highest amount. Delhi is the most polluted of all four cities.

Keywords: Air pollution, Aerosol Optical Depth, Air Quality Index

Introduction:

Air quality of an area is largely affected by the amount and time of various aerosols present in the air. Aerosols are solid or liquid particles, dispersed in a gaseous medium. Aerosol optical depth (AOD) is a measure of aerosols distributed in a vertical column [1]. AOD data of an area can be obtained through satellite remote sensing. Air pollution in major cities of India has now become a common problem. Air pollution is also a linked with health issues like the chronic obstructive pulmonary disease [2]. It is important to make the masses understand about the deteriorating air quality, the national Air Quality Index (AQI) is one such tool, that helps in getting an idea of the air quality of an area in one single number [3].

Literature Review:

According to the Indian Meteorological Department the months of March, April and May constitute the pre-monsoon season in India. A recent study has reported an overall increase in AOD over three major zones of India (the Indo-Gangetic Plains, the southern peninsular region, and the desert zone) during the pre-monsoon seasons of 2005-2021 [4].

Delhi in recent years has consistently been among the most polluted cities in the world. It is located in the Indo-Gangetic Plains, an aerosol hotspot [5]. A study indicated that the carbonaceous fractions of the aerosol emissions are linked with the vehicle exhaust, coal smoke and biomass burning in Delhi [6]. Kumar and Joseph [7] observed that vehicular emission (due to fossil fuel combustion) was responsible for increased PM_{10} and $PM_{2.5}$ concentrations in the city of Mumbai.

For the city of Bengaluru Gouda et al. in their March – May 2020 study observed that the strict lockdown had a significant impact on the air pollution level, as they reported a reduction in the level of pollutants as compared to pre-lockdown period.

In case of Chennai, a 2006 study by Jayanthi and Krishnamoorthy found that the inhabitants of the Manali and surrounding villages were affected by respiratory issues that was likely due to the poor air quality in the industry rich areas [9].

The National Air Quality Index was developed the Central Pollution Control Board (CPCB) in order to create awareness among the masses about the air quality of an area. There are six AQI categories, namely Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe. Each of these categories is decided based on ambient concentration values of air pollutants and their likely health impacts (known as health breakpoints). AQ sub-index and health breakpoints are evolved for eight pollutants (PM_{10} , $PM_{2.5}$, NO_2 , SO_2 , CO, O_3 , NH_3 , and Pb) for which short-term (upto 24-hours) National Ambient Air Quality Standards are prescribed. Based on the measured ambient concentrations of a pollutant, sub-index is calculated, which is a linear function of concentration [3].

AQI	Remark	Color Code	Possible Health Impacts
0-50	Good		Minimal impact
51-100	Satisfactory		Minor breathing discomfort to sensitive people
101-200	Moderate		Breathing discomfort to the people with lungs, asthma and heart diseases
201-300	Poor		Breathing discomfort to most people on prolonged exposure
301-400	Very Poor		Respiratory illness on prolonged exposure
401-500	Severe		Affects healthy people and seriously impacts those with existing diseases

Fig. 1 : National Air Quality Index. Source: https://app.cpcbccr.com/AQI_India

Objectives:

Primary objective was to retrieve and present the seasonal mean AOD and the monthly mean AQI data of the pre-monsoon season over the five year study period (2018-22), for the cities of Delhi, Mumbai, Bengaluru and Chennai. An attempt was also made to look at the behavioural (qualitative) correlation between the mean AOD and AQI.

Methods:

The AOD data for the pre-monsoon seasons of the five year study period, was retrieved from NASA's Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) reanalysis model. The dataset had a a spatial resolution of 0.5° x 0.625°. M2TMNXAER, product was used to obtain total extinction Aerosol Optical Thickness (AOT) 550 nm data in form of time-averaged 2-dimensional monthly mean data collections. QGIS software was used to later extract the required data from the 2-d time averaged maps.

The AQI data was obtained from the Sameer application by the Central Pollution Control Board. The data used was obtained from the following monitoring stations: Lodhi Road, Delhi – IMD; Bandra, Mumbai – MPCB; Bandra Kurla complex, Mumbai – IITM; City Railway Station, Bengaluru – KSPCB; Manali, Chennai – CPCB.

CPCB states that the AQI calculation is made in the following manner [10], [11] :

The Sub-indices for individual pollutants at a monitoring location (all eight pollutants may not be monitored at all locations, minimum three are necessary of which one should be either $PM_{2.5}$ or PM_{10}) are calculated using its 24-hourly average concentration value (8-hourly in case of CO and O3) and health breakpoint concentration range. The highest sub-index is the AQI for that location.

The sub-index (I_p) for a given pollutant concentration (C_p), as based on 'linear segmented principle' is calculated as: $I_p = [\{(I_{HI} - I_{LO}) / (B_{HI} - B_{LO})\} * (C_p - B_{LO})] + I_{LO}$
B_{HI} = Breakpoint concentration greater or equal to given concentration
B_{LO} = Breakpoint concentration smaller or equal to given concentration
I_{HI} = AQI value corresponding to B_{HI}
I_{LO} = AQI value corresponding to B_{LO}; subtract one from I_{LO} , if I_{LO} is greater than 50
Finally, AQI = Max (I_p) (where; p = 1, 2, ... , n ; denotes n pollutants)

Study Area:

Study Region	Latitude	Longitude
Delhi	28.70° N	77.10° E
Mumbai	19.08° N	72.88° E
Bengaluru	12.97° N	77.59° E
Chennai	13.08° N	80.27° E

Table 1. Location of the study region. Source: Google Earth

Delhi, the national capital of India is a highly polluted city often ranked among the cities having the worst air quality. Mumbai, is called the financial capital while Bengaluru is called the IT capital of India. Chennai is a cultural and IT hub in South India. Mumbai and Chennai are coastal regions. All four of these major cities have been through rapid urbanisation in the past decades and have high population densities. A lot of deforestation has also occurred in these cities. With increasing population and high number of development activities, the air quality has declined.

Results and Discussion:

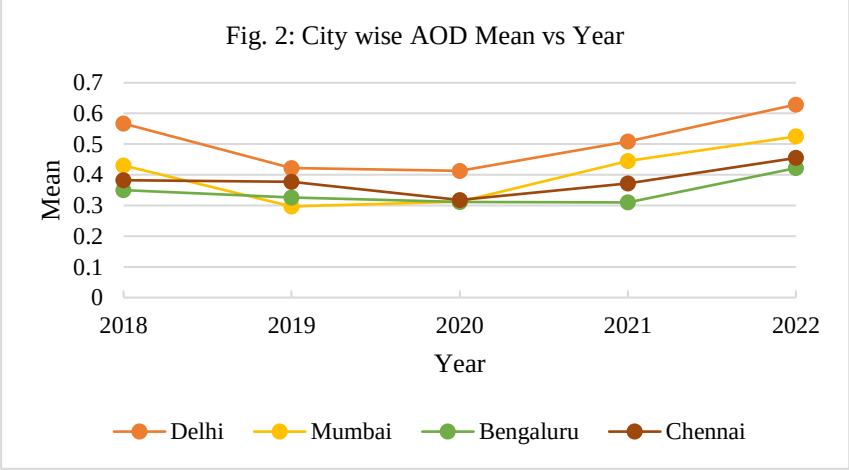


Fig. 2: City wise mean AOD comparison over the 2018-22 period.

The above figure (Fig. 1) shows, for each city, how the mean AOD in the pre-monsoon, has changed in the last five years (2018-22). It is clearly visible that Delhi has the highest AOD level among the four cities in all five years. Also the AOD level seems to have reduced in 2020 for all four cities, this could be due to the Covid-19 lockdown imposed in the months of March, April and May in 2020. Post 2020 the AOD level for the cities of Delhi, Mumbai and Bangalore has risen in 2021 and 2022. Bengaluru on the other hand has shown a slight decline in the 2021 year as well. All four cities have the highest individual AOD values in 2022 on comparing with the previous years.

Year	Month	Mean AQI Delhi (Data Points)	Mean AQI Mumbai (Data Points)	Mean AQI Bengaluru (Data Points)	Mean AQI Chennai (Data Points)
2018	**March**	150 (26)	NA	147 (20)	125 (31)
	April	168 (14)	NA	123 (19)	77 (30)
	May	168 (13)	NA	170 (19)	75 (29)
2019	**March**	129 (17)	120 (30)	146 (15)	138 (31)
	April	158 (12)	93 (29)	139 (22)	77 (28)
	May	176 (23)	86 (31)	124 (20)	145 (18)
2020	**March**	95 (29)	85 (26)	118 (20)	83 (30)
	April	104 (29)	67 (30)	79 (9)	48 (30)
	May	117 (16)	85 (14)	86 (26)	65 (31)
2021	**March**	146 (28)	115 (13)	93 (9)	59 (24)
	April	140 (19)	100 (30)	84.4 (15)	64 (25)
	May	90 (13)	87 (3)	77 (26)	60 (20)
2022	**March**	167 (29)	175 (29)	103 (14)	69 (30)
	April	196 (28)	125 (20)	93 (21)	42 (24)
	May	185 (29)	89 (19)	84 (24)	83 (28)

Table 2: City wise Monthly Mean AQI 5 year data.

Table 2 has the monthly mean data for each city over the five year study period. The number of data points (each data point indicates the AQI of 1 date) have also been indicated in parenthesis as the data availability was not consistent and some values have been calculated with less than 10 data points.

Year	Month	Delhi Prominent Polluter	Mumbai Prominent Polluter	Bengaluru Prominent Polluter	Chennai Prominent Polluter
2018	**March**	PM_{10}	NA	PM_{10}	$PM_{2.5}$
	April	PM_{10}, $PM_{2.5}$	NA	PM_{10}	$PM_{2.5}$
	May	PM_{10}	NA	PM_{10}	$PM_{2.5}$
2019	**March**	PM_{10}, $PM_{2.5}$	PM_{10}	PM_{10}	$PM_{2.5}$
	April	PM_{10}	CO	PM_{10}	$PM_{2.5}$, CO
	May	PM_{10}	CO	PM_{10}	$PM_{2.5}$
2020	**March**	PM_{10}, $PM_{2.5}$	PM_{10}, CO	PM_{10}	$PM_{2.5}$, CO
	April	PM_{10}, $PM_{2.5}$	PM_{10}, SO_2	PM_{10}	$PM_{2.5}$, CO
	May	PM_{10}, $PM_{2.5}$	$PM_{2.5}$, SO_2	PM_{10}	$PM_{2.5}$, CO
2021	**March**	$PM_{2.5}$	PM_{10}, CO	PM_{10}	$PM_{2.5}$, CO
	April	$PM_{2.5}$	PM_{10}	PM_{10}	CO
	May	$PM_{2.5}$	PM_{10}	CO	CO
2022	**March**	PM_{10}, $PM_{2.5}$	$PM_{2.5}$	CO	PM_{10}
	April	PM_{10}	PM_{10}, $PM_{2.5}$	CO	PM_{10}, O_3
	May	PM_{10}	PM_{10}	CO, PM_{10}	PM_{10}, $PM_{2.5}$, CO, O_3

Table 3: City wise, Prominent Polluters for the Monthly Mean AQI 5 year data.

Table 3 above, indicates that PM_{10} has been a prominent polluter in Delhi, Mumbai and Bengaluru since the past few years. PM 2.5 seems to be the prominent polluter in Chennai's case. All cities except Delhi, have also shown prominent presence of CO as well.

Fig. 3a. Delhi Monthly Mean AQI

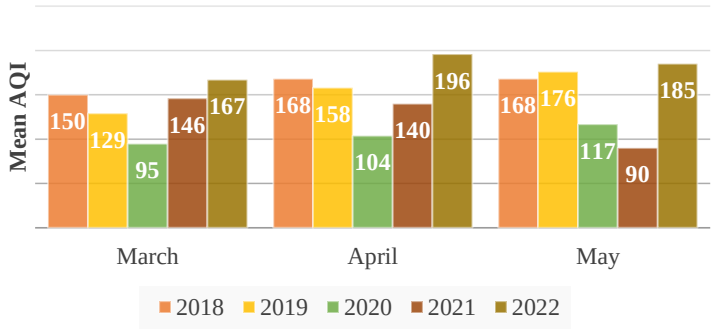


Fig. 3b. Mumbai Monthly Mean AQI

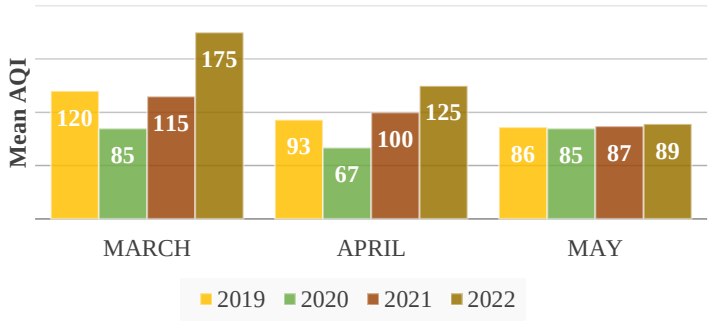


Fig. 3c. Bengaluru Monthly Mean AQI

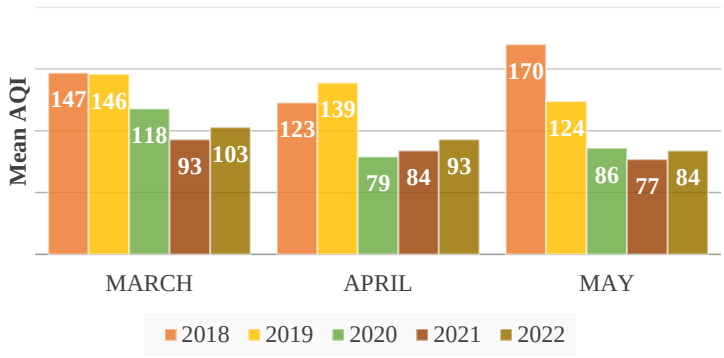


Fig. 3d. Chennai Monthly Mean AQI

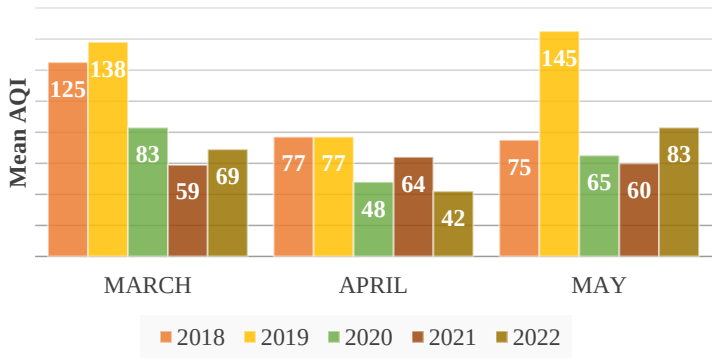
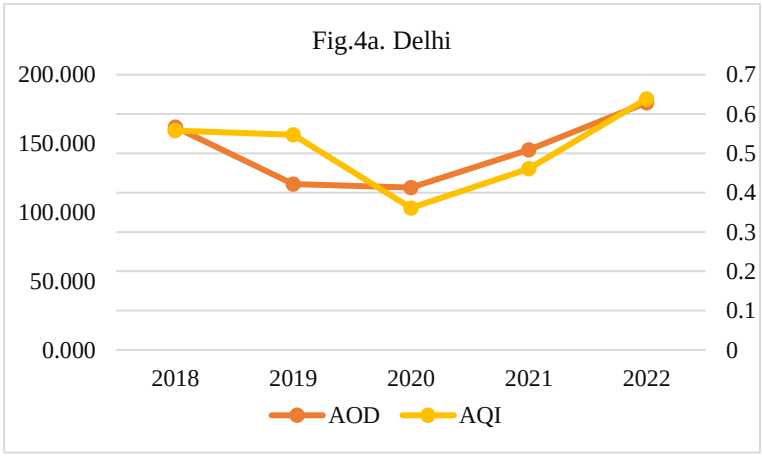
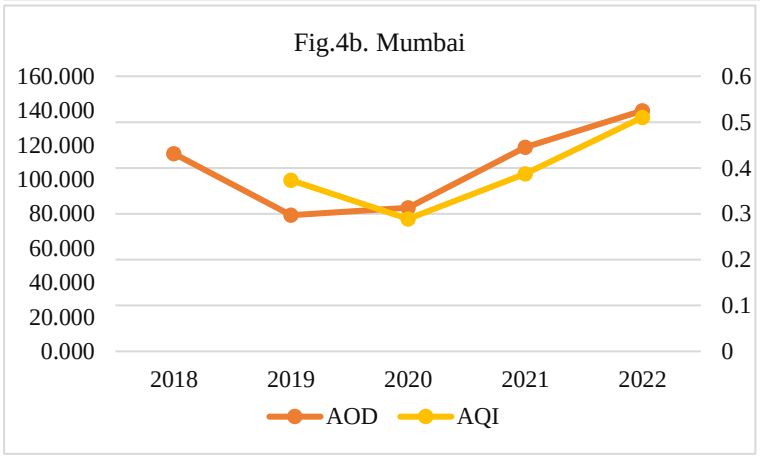
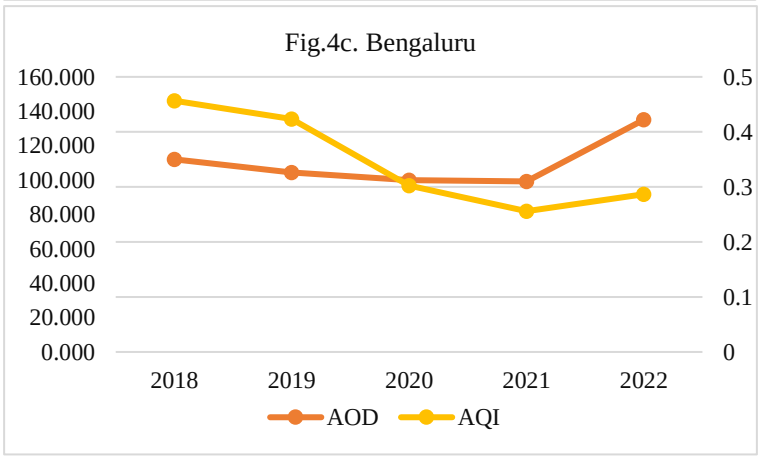


Fig.3 : 5 year Monthly mean AQI data for the 4 cities

Fig.3a. and Fig. 3 b. indicate that Delhi and Mumbai have become more polluted in 2022 compared to previous years. Interestingly, Fig. 3c. and Fig. 3d. show that Bengaluru and Chennai have maintained the lower AQI levels post 2020. All four cities show a less AQI value in the year 2020, possibly due to the nationwide lockdown.







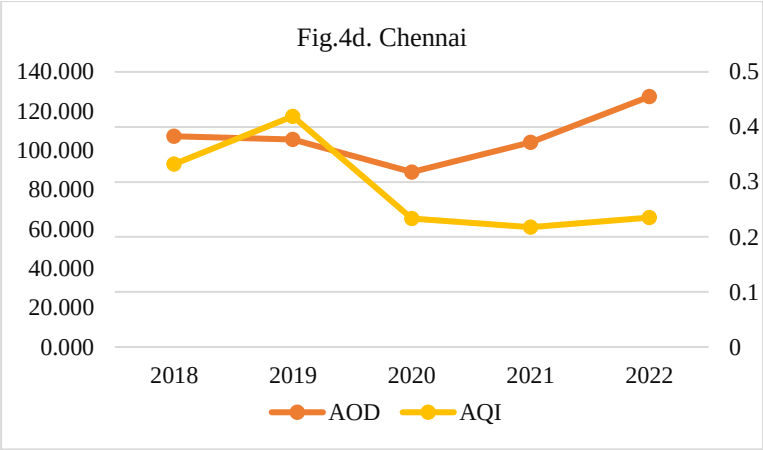


Fig. 4: AOD and AQI, qualitaitve behavioural comparison

Fig. 4 Attempts to compare the AQI and AOD (behavioural) pattern in the 2018-22 period. The AOD and AQI plots show similar behavior (increasing and decreasing together, from one year to the next) in case of Delhi, Mumbai and Bengaluru. Whereas in case Chennai the plots show slight disagreement in case of 2020-21 period.

It seems that strict lockdown had reduced both the vehicle movement and construction activities in these megacities as well as the resulting emissions.

Scope For Further Work:

This work can be improved and expanded upon by considering more number of ground stations. Possibly health data can be retrieved and linked with the air quality.

Conclusions:

1. All cities show a drop in AOD, AQI level in the lockdown period of 2020.
2. Delhi is the most polluted city, the air is almost always above AQI 100.
3. All cities have AQI above 50 almost throughout the study period.
4. AOD and AQI levels have increased significantly in Delhi and Mumbai in 2022.
5. AQI data availability is an issue for certain cities, but a positive effort has been made by CPCB to provide public AQI data.

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