

A Data Driven ARIMA Study of Air Quality Trends and Forecasts of an Urban Agglomeration

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ABSTRACT

The increasing level of pollutants in ambient air has deteriorated the air quality of Ghaziabad at an alarming rate. It is important for the common people, allergist and patients with respiratory symptoms, to have a current knowledge of adverse respiratory effects that can occur from air pollution and the potential health effects and how they might affect their health. This brought us to focus our study on air quality in Ghaziabad region. The prediction of future air quality has been carried out by analysing the AQI daily city level using data analysis techniques. Detailed analysis from 2018-2024 of AQI daily city level has been analysed in this paper by taking year 2020 as base, the year of lock down. Study shows a decline in annual averages AQI in post covid years, reflecting an improvement due to mitigation measures. In addition to descriptive and regression-based trend analysis, an AutoRegressive Integrated Moving Average (ARIMA) model was employed to capture temporal dependencies and seasonal variations in AQI values. The ARIMA-based time-series analysis enables short-term forecasting and provides a more robust understanding of air quality dynamics. The study reveals a declining trend in annual average AQI levels in the post-COVID years, indicating an overall improvement in air quality, likely attributable to mitigation measures and regulatory interventions.

Keywords: AQI (Air Quality Index), PM (Particulate Matter) dehydrogenase.

1. INTRODUCTION

Air is an imperceptible medium enveloping the Earth, supplying breathable oxygen and playing a crucial role in sustaining life on the planet. However, over time, the pristine air is progressively becoming tainted due to the rise in air pollution. Air pollution refers to the presence of one or more substances at concentrations exceeding their standard levels (SO₂, ozone, NO_x, CO, PM, SVOC, PM10 and PM2.5, which may adversely affect humans, animals, and plants. The issue of air pollution is becoming increasingly severe. Rising pollutant levels in the air are resulting in severe health disorders. It directly impacts millions of individuals experiencing shortness of breath, ocular irritation, chronic respiratory disorders, pneumonia, acute asthma, among other conditions.[1] [2]. Research indicates that ozone exposure is linked to a heightened

risk of asthma development in children participating in outdoor sports in California. Ozone is known to exacerbate airway inflammation and responsiveness, as well as enhance the airway's reaction to inhaled allergens [3],[4]. Exposure to nitrogen oxides has been linked to a rise in respiratory infections and wheezing, and can exacerbate the effects of inhaled allergens [5]. High concentrations of sulphur dioxide (SO₂), with or without physical exertion, act as a respiratory irritant, inducing airflow restrictions. Certain studies have linked SO₂, sulphates, and acid aerosols to heightened emergency visits and hospitalizations for asthma [6-8]. Air pollution in Ghaziabad is majorly due to industrial, commercial, constructional, regional, agricultural and due to natural reason. It is caused by several major sources operating simultaneously. One of the primary contributors is industrial exhaust, as emissions of harmful gases such as

sulphur dioxide (SO₂) and nitrogen oxides (NO_x) originate from industrial areas.

According to the Economics and Statistics Division, State Planning Institute, Planning Department, Uttar Pradesh, registered working factories in Ghaziabad constitute about 11.75% of the total working factories in the state, making industrial activity a significant source of air pollution. Vehicular emissions also play a dominant role in deteriorating air quality due to increasing traffic congestion and rapid growth in the number of vehicles. As per data from the Planning Department, Uttar Pradesh, during 2023–2024, the state had a total of 45,651,640 registered vehicles, of which motorcycles and scooters accounted for 36,376,800 vehicles, representing 79.68% of the total. The continuous rise in the motor vehicle burden in Ghaziabad, as reflected in Tables 1 and 2, has made vehicular emissions a major contributor to air pollution [9]. Additionally, the burning of agricultural stubble in Punjab and Haryana significantly affects air quality in Ghaziabad, as farmers burn rice crop residue to quickly prepare their fields for the rabi wheat crop, releasing large amounts of smoke and pollutants that travel to the region [9]. Continuous construction and demolition activities further contribute to elevated levels of airborne particulate matter, making the air hazardous to breathe [9]. Other indirect factors worsening air quality include overpopulation, resuspended road dust, and smoke generated from firecrackers during Diwali, all of which collectively intensify the air pollution problem in Ghaziabad [9].

Table 1. Motor vehicles on road in uttar pradesh (UP)

Category	vehicles	2021-22	2022-23	2023-24
(A)	State Transport			
1	Buses [#]	11315	10560	12015
2	Trucks	88	42	33
3	Taxies	64	79	76
	Total (A)	11467	10681	12124
(B)	Others [!]			
1	Buses	104817	107274	121715
2	Trucks	999825	1061329	1143865
3	Taxies	694270	693764	704561
4	Cars	3751846	4092111	4461744
5	Motor Cycles	31781143	34012072	36376800
6	Tractors	1741509	1858094	1993428
7	Others	156808	89329	112155
	Total B	39230218	41913973	44914268
(C)	E-Powered/Battery operated			
1	Two-Wheeler	20745	45646	82140
2	Three-Wheeler	407	898	6132
3	E-Rikshaw	268677	415919	649100
	Total C	289829	462463	737372
	Grand Total(B+C)	39520047	42376436	45651640

[#]including undertaking buses, [!]Vehicles other than UPSRTC. Source: Statistical Diary UP 2024(Economics and Statistics Division State Planning Institute, Planning Department, UP

2. STUDY AREA

Ghaziabad, officially referred to as the Ghaziabad Municipal Corporation, is strategically situated at the entrance to Uttar Pradesh, India. Ghaziabad is a significant city in the National Capital Region (NCR), bordering the national capital, New Delhi. The District of Ghaziabad is located in the center of the Ganga-Yamuna Doab. To the north, it is bordered by the District of Meerut; to the south, it is bordered by the Districts of Bulandshahr and Gautam Budh Nagar; to the southwest, it is adjacent to the National Capital Delhi; and to the east, it is bordered by the District of Jyotiba Phule Nagar. As per the 2011 Census, Ghaziabad is a densely populated city with a population of 1.729 million, with density of population of Ghaziabad (per sq. km) was 3674, encompassing an area of 210 square kilometers under municipal jurisdiction (Ghaziabad Nagar Nigam), and experiences significant population influx from other cities in Uttar Pradesh. As per census 2011 the population of Ghaziabad was comprising 1.99% of total population of Uttar Pradesh. In recent years, rapid industrialization and urbanization have had a detrimental impact on the environment.

Table 2. Motor vehicles registered during the year in UP

	vehicles	2021-22	2022-23	2023-24
(A)				
1	Buses	1596	10562	10320
2	Trucks	64636	106858	103990
4	Cars	250948	437943	404953
5	Motor Cycles	2124374	2319612	2512654
6	Tractors	108423	131069	133042
7	Others	84020	70483	92840
	Total A	2633997	3076527	3257799
(B)				
	E-Powered/Battery operated			
1	Two-Wheeler	9312	25607	34525
2	Three-Wheeler	112	622	5139
3	E-Rikshaw	67397	149331	218777
	Total C	76821	175560	258441
	Grand Total(A+B)	2710818	3252087	3516240

[#]including undertaking buses, [!]Vehicles other than UPSRTC, Source: Statistical Diary UP 2024(Economics and Statistics Division State Planning Institute, Planning Department, UP
<https://updes.up.nic.in>

Ghaziabad's weather can be described as a mix of seasons warm and pleasant spring (February to April) with occasional dust storms; hot and humid summer (May to June) with temperatures reaching up to 450 °C; monsoon (late June to September) with occasional thunderstorms and strong winds; post-monsoon (late September to early October) with cool breeze and clear skies, high level of air

pollution in festive season (Diwali) and due to burning of crops (late October to mid-November); and cold and foggy winter (late November to early February) with temperatures dropping to below 100 °C. While the emissions quantum is one reason for high air pollution levels in Ghaziabad, seasonal meteorology also plays a dominant role in exacerbating pollution levels.

The winter peaks and monsoonal troughs in air quality exhibit a significant correlation with variations in wind speeds, temperature, and mixing heights. The height of the mixing layer (inversion), serving as an indicator of vertical emission mixing, is at its minimum during winter months and further decreases at night, leading to reduced air volumes for mixing and dispersing emissions. Simultaneously, the winter months experience a significant increase in emissions from the combustion of Parali in adjacent states, as well as biomass and waste, utilized for heating to mitigate declining air and surface temperatures (below 10 °C). The spring and summer months feature mixing layer heights exceeding 1000 m and elevated wind speeds, facilitating improved dispersion of emissions in both horizontal and vertical dimensions, resulting in reduced ambient pollution levels.

Ghaziabad frequently appears on the list of cities that fail to adhere to national ambient air quality standards. Furthermore, it has been listed among the world's most polluted cities on several occasions [10]. India has a PM background concentration that is five to ten times greater than the US and European limits [11]. As a result, the concentrations at which they recommend a break in India have been modified [12]. The extremely high levels of PM₁₀ in particular and particulate matter in general are blamed for the noncompliance. For example, from 2013 to 2018, the average annual PM concentration was continuously higher than 250 µg m⁻³ (AQI poor); It also encompasses the monsoon period, during which particulate matter levels are low, while air quality typically deteriorates in winter due to adverse conditions for pollutant dispersion, such as temperature inversion [13]. The PM_{2.5} levels follow closely with the concentration of PM₁₀, as these often emanate from similar sources [14]. The average PM_{2.5} levels (in µg/m³) studied over different time periods (1998–1999, 2000–2009, 2010–2019, and 2020–2021) in the Delhi-NCR region, shows migration of Ghaziabad from orange/yellow zone (~60–80 µg/m³) in 1998-99 to maroon, hazardously polluted (~125–160 µg/m³) in 2020-21 [15,16].

The rate of urbanization in Ghaziabad is a proxy for an increase in the demand for transportation, electricity for residential and industrial needs, garbage and solid

waste management, the construction of residential and commercial estates, and state infrastructure development in the form of expressways, highways, arterial roads, and pavements. The majority of energy requirements are satisfied through the combustion of coal, gasoline, diesel, and natural gas. The ambient pollution levels have increased as a consequence of the combustion and dust-producing activities.

3. DATA AND METHODS

The data (AQI Ghaziabad “daily city level”) has been collected from CPCB [<https://cpcb.nic.in>][20]. The dataset contains two attributes: Date, daily city level AQI of Ghaziabad for a particular year. The ‘Date’ attribute describes Date of “the daily city level AQI of Ghaziabad”. The data has been taken from 2018 to 2024 for critical analysis and for future prediction of ‘Ghaziabad’. The air quality index (AQI) is defined as ratios of the measured concentration of the atmospheric pollutants to their standard prescribe values [17,18]. Mathematically, the AQI can be

$$AQI = \frac{1}{3} \left[\left(\frac{PM_{2.5}}{sPM_{2.5}} \right) + \frac{SO_2}{sSO_2} + \frac{NO_2}{sNO_2} \right] \times 100 \dots\dots\dots Eq. (1)$$

The sPM_{2.5}, sSO₂, sNO₂ are ambient air quality standards as given by the Central Pollution Control Board of India (CPCB) and PM_{2.5}, SO₂ and NO₂ represent the actual observational values of pollutants [19]. The AQI data (daily city level) for all the years (2018-2024) was taken from the CPCB website. The high AQI values represent a higher level of atmospheric pollutants at the monitoring site. In the present study, multiple analytical approaches have been adopted to examine air quality trends and forecast future conditions. Descriptive analysis has been used to analyze the basic characteristics of the data, with the year 2020 taken as the base year to understand variations and patterns in AQI across subsequent years. Predictive analysis has then been applied to estimate future air quality levels using past data, as predictive analytics employs statistical and machine-learning techniques to infer unknown future outcomes from historical trends. In this context, the annual average AQI values of subsequent years were plotted, and a machine-learning approach in the form of a linear regression line was used to identify and project the future trend of air quality. In addition, an ARIMA (AutoRegressive Integrated Moving Average) model was employed as a time-series forecasting technique to capture temporal dependencies, trends, and seasonality present in the AQI data. The ARIMA model enhances the robustness of predictions by accounting for autocorrelation in the data, thereby providing a more



Figure1. Ghaziabad city map. Source: <https://indiahousing.com/ghaziabad/map.gif>

reliable and comprehensive forecast of future air quality trends when combined with descriptive and regression-based predictive analyses.

4. RESULTS AND DISCUSSIONS

The Figure 2 shows a comparison of Air Quality Index (AQI) data between two years—2018 (blue line) and 2020 (green line)—plotted as a 7-day moving average throughout the year. It is obvious from the Fig. 2 that 2018 shows Consistently higher AQI values throughout the year, indicating poorer air quality. In the beginning of the year, both years show high AQI values, with 2018 notably worse than 2020 but in Post Monsoon Season (September–October) both years show a sharp increase in AQI starting in September. The rise is steeper and higher in 2018, but 2020 catches up by October, likely due to stubble burning and festive pollution. By the End of the year (November–December) AQI levels converge in both years, showing consistently high pollution (AQI ~ 350–450), likely due to Diwali celebrations, stubble burning, and winter stagnation. This suggests that seasonal pollution sources remained active in both years. In year 2018 total number of days having AQI more than or equal to 400 were 51 while in year they reduced to 25 only.

Fig 3 shows a comparison of Air Quality Index (AQI) data between two years—2019 (red line) and 2020 (green line)—plotted as a 7-day moving average throughout the year. AQI in 2020 is consistently lower than in 2019 for most of the year. This reflects improved air quality in 2020, especially during the first half of the year. In early year, AQI in 2019 remains high (above 300), indicating poor to very poor air quality. 2020 also starts at a high level, but begins to drop sharply in March, going

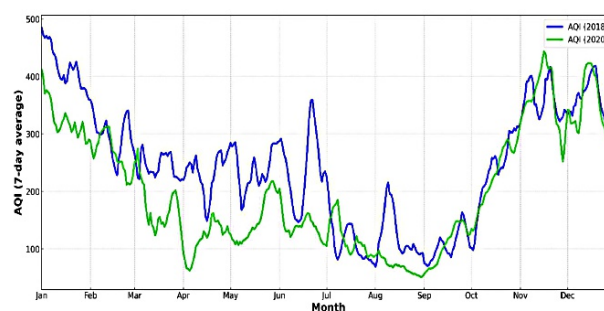


Figure 2. Comparison of Air Quality Index (AQI) data of 2018 (blue line) and 2020 (green line)—plotted as a 7-day moving average throughout the year.

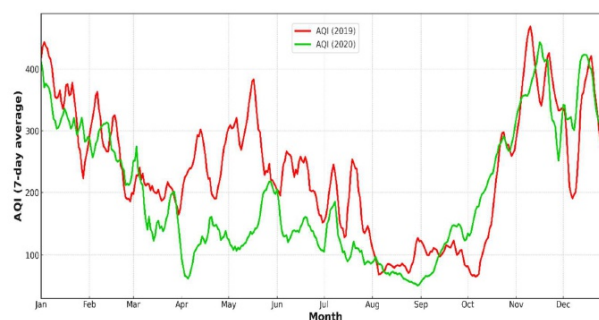


Figure 3. Comparison of Air Quality Index (AQI) data of 2019 (red line) and 2020 (green line)—plotted as a 7-day moving average throughout the year.

below 150 by April due to Lock Down. In Mid-Year (April–August) 2020 shows significantly better air quality, with AQI dropping as low as 75–125 (moderate to satisfactory). In contrast, 2019 AQI remains elevated, fluctuating between 150–275. Winter season (November–December) Both years have high AQI (~350–400+), indicating severe pollution in winter due to Temperature inversion, Trapped emissions, Increased biomass/wood burning. As compared to 2020 having 25 days of 400 AQI,

year 2019 encounters 38 days.

Fig 4 shows a comparison of Air Quality Index (AQI) data between two years—2021 (blue line) and 2020 (green line)—plotted as a 7-day moving average throughout the year. From the graph, January to June, AQI in 2020 is consistently lower than in 2021. This was due to lockdowns and restricted activities during the early phase of the COVID-19 pandemic in 2020, which led to reduced emissions. The lowest AQI values occur from April to July in both years, indicating better air quality during the summer and monsoon months. 2020 reaches AQI values below 100 during April–May, indicating "Good to Satisfactory" air quality levels. Post-Monsoon: From September onward, AQI begins to rise steeply in both years, peaking in October–November. This rise is likely linked to stubble burning, festival pollution (like Diwali), and winter weather which traps pollutants. The pollution reaches at its peak in late October to early November. Both years show AQI peaks reaching above 400, indicating "Severe" pollution levels. In late October, 2020 shows a sharper and slightly higher AQI spike compared to 2021, suggesting worse pollution episodes during that period.

Fig. 5 shows the 7-day average AQI (Air Quality Index) values for the years 2020 (green line) and 2022 (yellow line) across the days of the year. AQI was generally higher in early months for both years. From January to mid-February both years show elevated AQI levels, with 2022 showing higher peaks (~350) compared to 2020 (~320). This indicates poor air quality in the winter months, possibly due to low wind speeds and temperature inversions. We see noticeable improvement in AQI from March to July 2022, while improving, maintains higher AQI levels (mostly above 150), suggesting less improvement in air quality. AQI deterioration begins in August and peaks in October–November. Both years show a sharp rise in AQI from August onwards, peaking in October–November. 2020 shows more extreme spikes, with values reaching above 400, indicating severe air pollution. 2022 also peaks, but with slightly lower maximums, indicating slightly less severe air pollution. Post-monsoon season sees the worst AQI, October to November consistently shows the worst air quality in both years, due to stubble burning, Diwali firecrackers, and weather conditions that trap pollutants. Thus 2020 shows more variability and extremes—sharper declines and higher peaks throughout the year but 2022 shows a decline in AQI in winter season as comparison to 2020.

Fig.6 shows the 7-day average AQI (Air Quality Index) values for the years 2020 (green line) and 2023 (Magenta line) across the days of the year. In the beginning

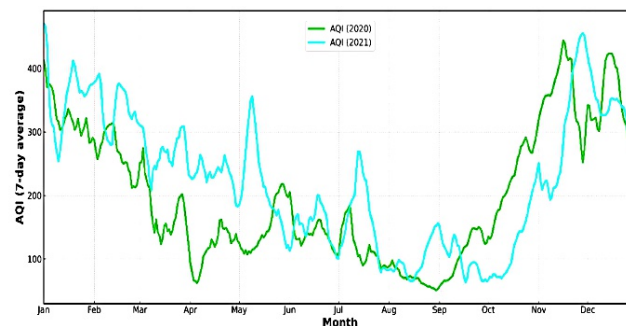


Figure 4. Comparison of Air Quality Index (AQI) data of 2021 (blue line) and 2020 (green line)—plotted as a 7-day moving average throughout the year.

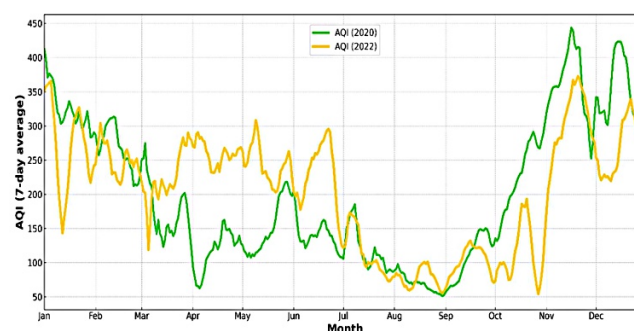


Figure 5. Comparison of Air Quality Index (AQI) data of 2022 (yellow line) and 2020 (green line)—plotted as a 7-day moving average throughout the year.

of the year January–February, AQI values are high in both years, with 2020 showing values slightly above 300, while 2023 shows a steeper decline from ~320 to ~200. Very poor air quality during winter months is likely due to stagnant air, heating emissions, and vehicular pollution. From March to July 2020 shows a significant drop in AQI, falling to values around 100 or even lower (good to moderate range). In contrast, 2023 maintains higher AQI levels in this period, fluctuating between 150 to 250, indicating moderate to poor air quality. In Monsoon season July–August both years shows low AQI. Post monsoon season sees rapid rise in AQI for both years from September onward. 2020 sees more extreme peaks, with AQI values crossing 400 (hazardous levels), especially in October–November while 2023 follows a similar trend but with slightly lower peaks, indicating less severe pollution but still unhealthy.

Figure 7 shows the 7-day average AQI (Air Quality Index) values for the years 2020 (green line) and 2024 (Black line) across the days of the year. The graph follows the same pattern as in earlier graphs for the beginning of the year i.e. Both years start with high AQI levels (250–350), indicating very poor air quality in January–February though 2024 initially shows a slight dip in late January, but otherwise maintains a high level similar to 2020. This is typical of winter pollution due to low

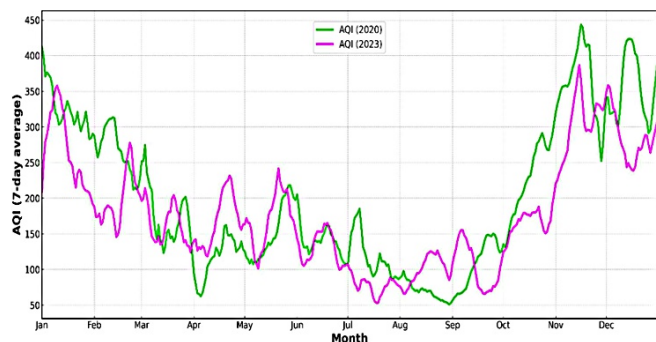


Figure 6. Comparison of Air Quality Index (AQI) data of 2023 (Magenta line) and 2020 (green line)—plotted as a 7-day moving average throughout the year.

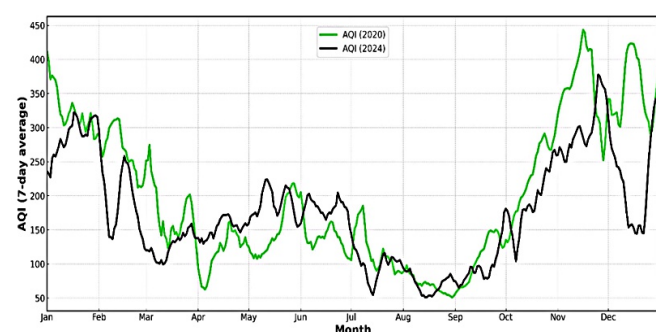


Figure 7. Comparison of Air Quality Index (AQI) data of 2024 (black line) and 2020 (green line)—plotted as a 7-day moving average throughout the year.

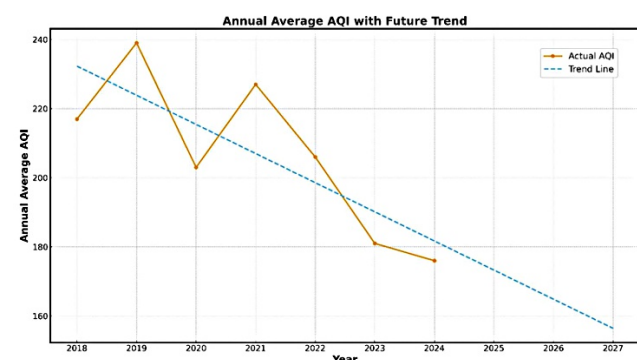


Figure 8. Annual average AQI of each year with trend line.

dispersion, vehicular emissions, and domestic heating. From March to July 2024 remains higher and flatter, mostly between 150–200, indicating persistent moderate to poor air quality. The contrast with 2020 reflects reduced human activity during 2020 (lockdowns) versus fully resumed urban activities in 2024. In monsoon season, both year show a dip in AQI during the monsoon months, due to rain and wind dispersing pollutants. 2020 shows slightly better levels, touching ~75, while 2024 hovers around 100–130. Post monsoon season September to November year 2020 sees severe Deterioration. 2020 AQI spikes sharply from September onward, peaking above 400 in October–November (hazardous level). 2024 also shows a rise, but peaks are lower, around 300–350, indicating very poor air

to weather shifts, interventions, or lower emissions. 2020, however, maintains high pollution levels in December (~350+). For future forecasting, annual average AQI of each year is plotted in Fig 8. In Fig. [8] Red line shows the actual annual average AQI of years (from 2018 to 2024) and blue line shows trend. It is obvious from the study that though the post monsoon and winter season suffers a severe air pollution in Ghaziabad but annual average AQI shows a decline trend. which clearly shows that in comparison to post 2020 annual AQI of Ghaziabad shows a improvement.

ARIMA-Based Time Series Modeling and Forecasting of AQI

To capture the temporal dependence and forecast future air quality trends in Ghaziabad, an Autoregressive Integrated Moving Average (ARIMA) model was applied to the daily AQI time series data spanning multiple years. Prior to model fitting, the dataset—originally stored in a wide Excel format with separate year-wise columns—was transformed into a long-format time series. Each observation was mapped to a specific calendar date, reindexed to daily frequency, and chronologically ordered to ensure consistency for time series analysis. The cleaned dataset was then visualized to examine overall variability, seasonal behavior, and long-term patterns in AQI values. Fig 9 presents the time series plot of daily AQI values from 2018 to 2024. The plot highlights strong seasonal fluctuations, with recurring peaks during post-monsoon and winter months and comparatively lower AQI levels during the monsoon period.

The residual variance ($\sigma^2 \approx 2639.76$) reflects average deviation from fitted values. Residual diagnostics (Fig.11 and 12) show random fluctuations around zero with no significant autocorrelation, confirmed by the Ljung–Box test ($p = 0.66$). Although the Jarque–Bera test indicates non-normality and heteroskedasticity is present, such deviations are common in environmental datasets. Fig. 13 compares observed AQI values with ARIMA forecasts, demonstrating close alignment and validating the model's effectiveness. Overall, the ARIMA model complements descriptive and regression analyses by capturing short-term variability and seasonal behaviour, supporting robust air quality forecasting.

Autocorrelation and partial autocorrelation analyses were conducted to identify suitable ARIMA parameters. The ACF and PACF plots (Fig 10) indicate autoregressive dominance, leading to the selection of an ARIMA (5,1,0) model. The SARIMAX summary output (Table 3) shows that all autoregressive coefficients are statistically significant ($p < 0.001$) and negative, implying

that current AQI values are inversely influenced by AQI levels from the previous five days.

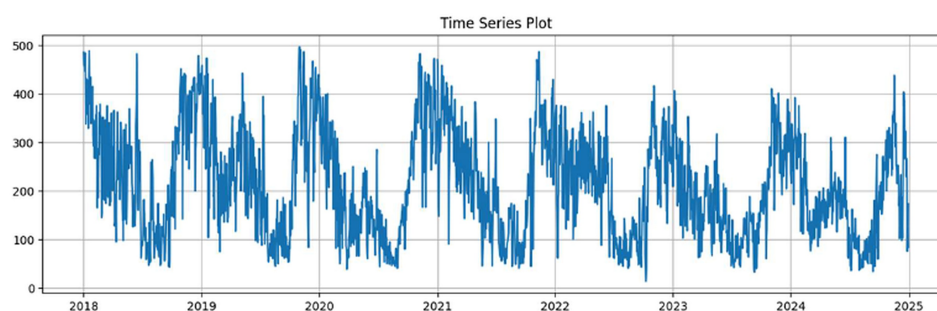


Figure 9. Time series plot of daily AQI values for Ghaziabad (2018–

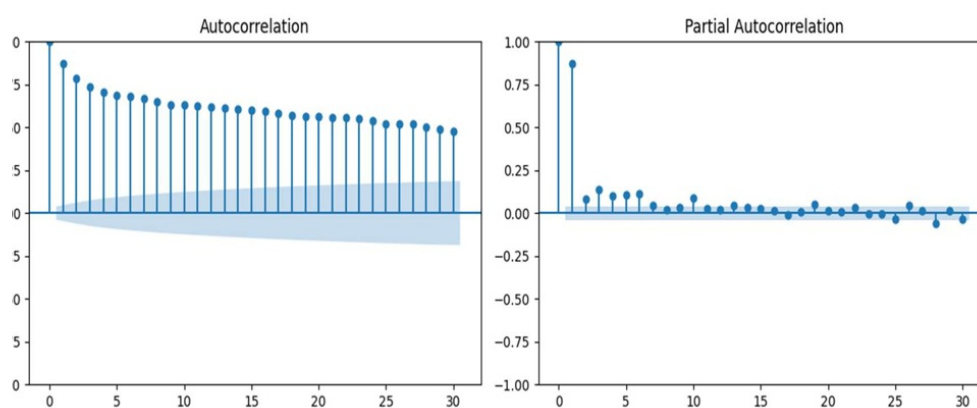


Figure 10. Autocorrelation (ACF) and Partial Autocorrelation (PACF) plots of AQI time series.

5. CONCLUSION

Ghaziabad, one of the prominent cities in the National Capital Region (NCR), has frequently been ranked among the most polluted cities, not only at the national level but also globally. The primary objective of the present study is to analyze the Air Quality Index (AQI) of the city over recent years up to 2024 and to identify underlying trends in air quality. Currently, air quality monitoring in Ghaziabad is carried out at four stations, namely Indirapuram, Vasundhara, Loni, and Ghaziabad. To address the growing problem of air pollution, several mitigation measures have been implemented by the government. Notably, significant efforts have been made to curb parali (crop residue) burning in Punjab and Haryana through the provision of subsidies for crop residue management machinery, the establishment of Custom Hiring Centres for affordable access to equipment, and the promotion of the Pusa decomposer for natural stubble decomposition. In addition, awareness campaigns, crop diversification initiatives, and satellite-based monitoring coupled with penalties have been introduced to discourage stubble burning. These

parali burning, which is reflected in the lower annual average AQI values observed in the post-2020 period compared to pre-2020 levels. At the local level, the Uttar Pradesh Government and Ghaziabad authorities have undertaken several measures to mitigate air pollution, including the deployment of fog guns, regular water sprinkling in dust-prone areas, covering of construction sites with green sheets, public awareness programs, and the implementation of the Graded Response Action Plan (GRAP). However, adverse climatic conditions in the NCR—such as low wind speeds, low humidity, and limited precipitation—often restrict pollutant dispersion, causing Ghaziabad to experience severe pollution episodes and function as a pollution hotspot. Despite these challenges, the observed downward trend in AQI suggests that air quality may continue to improve if current mitigation measures remain consistently enforced. While the linear trend analysis provides useful insight into the long-term direction of change in air quality, it is based on a limited dataset of annual averages. To overcome this limitation, the study incorporates an AutoRegressive Integrated Moving Average (ARIMA) model using daily AQI data, which

Table 3. SARIMAX summary

Dep. Variable		Value	No. Observations		2555	
Model		ARIMA (5, 1, 0)	Log Likelihood		-13682.968	
Ljung-Box (L1) (Q)		0.19	AIC		27377.935	
Prob(Q)		0.66	BIC		27413.008	
Heteroskedasticity(H)		0.56	HQIC		27390.654	
Covariance Type		OPG (outer product of gradient)	Jarque-Bera(JB)		568.50	
Prob(H)(two-sided)		0.00	Prob (JB)		0.00	
Kurtosis		5.14	Skew		-0.43	
	coef	std err	z	P> z	[0.025	0.975]
ar.L1	-0.2271	0.017	-13.259	0.000	-0.261	-0.193
ar.L2	-0.2560	0.018	-14.468	0.000	-0.291	-0.221
ar.L3	-0.1963	0.018	-10.879	0.000	-0.232	-0.161
ar.L4	-0.1606	0.018	-8.911	0.000	-0.196	-0.125
ar.L5	-0.1349	0.018	-7.355	0.000	-0.171	-0.099
Sigma2	2639.7597	53.163	49.654	0.000	2535.562	

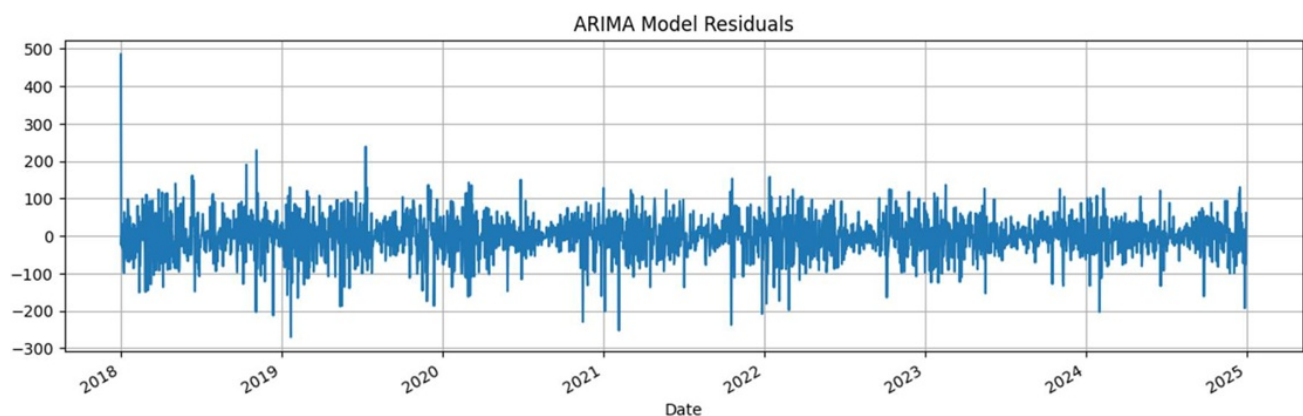


Figure 11. Residuals of the fitted ARIMA (5,1,0) model.

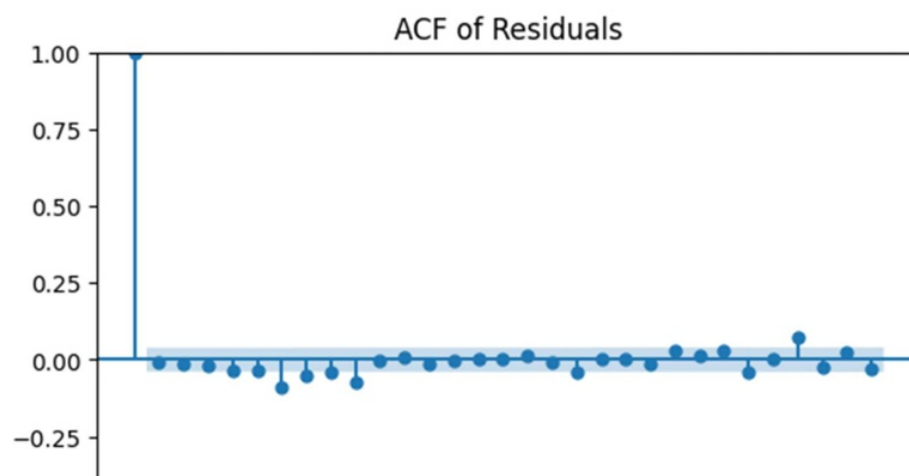


Figure 12. Autocorrelation function (ACF) of ARIMA model residuals.

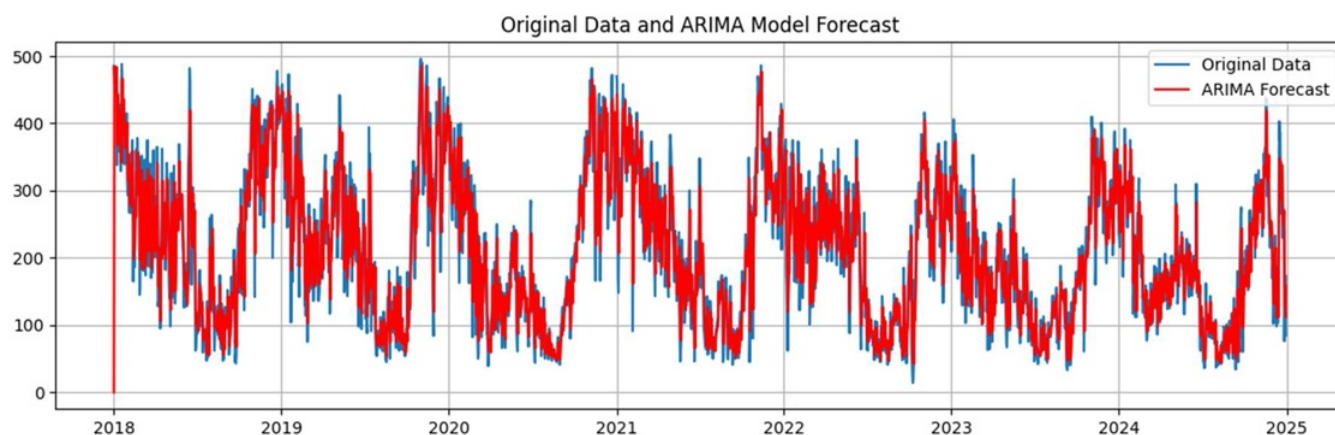


Figure. 13. Comparison of observed AQI values and ARIMA model forecast.

captures short-term fluctuations, temporal dependencies, and seasonal variations more effectively. The ARIMA-based time-series analysis enhances forecasting accuracy and provides a more robust framework for assessing future air quality trends, thereby supporting informed policy formulation and sustainable urban air quality management.

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