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Spatial Temporal Analysis of Air Quality and their Relation to Meteorological Parameters, in India

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Abstract
Air pollution has become a significant global issue, with India ranking 8th in the world for hazardous air quality based on the latest 2022 report. (World Air Quality Report 2023). The growing urban sprawl and human-induced environmental activities have led to a decline in air quality. The Air Quality Index assesses the level of pollution in the air at a particular region. It is a fundamental right for individuals to be informed about the quality of the air they breathe for their well-being. This study aims to examine air pollution levels and trends across various geographical locations in India using data provided by the Central Pollution Control Board under the Ministry of Environment, Forest, and Climate Change in India. The study focuses on analyzing the annual growth of pollutants such as SO2, NO2, PM10, and PM2.5 from 2016 to 2021, collected from monitoring stations in 28 states across 256 locations. The research evaluates the impact of different particulate matter concentrations and showcases the spatial variation of air pollutants between 2016 and 2021. Results indicate a significant decrease in air pollution levels during lockdown periods compared to pre-lockdown periods. On an average (over all cities), more than 24% decrease has been observed for all the AQI of the pollutants. Additionally, a comparative analysis reveals correlations between meteorological factors and air quality, showing that temperature, relative humidity, and wind speed are negatively correlated with AQI, while surface pressure is positively correlated. Temporal analysis was also conducted to examine the relationship between air pollutant concentrations and meteorological parameters.

Keywords: *Air quality index; Air pollutants; Spatial temporal; Meteorological parameters; Correlation and regression analysis.*

1. Introduction

Air pollution poses a grave concern impacting the lives of billions worldwide annually. The World Health Organization (WHO) states that over a quarter of global deaths may directly result from pollution. In 2015, Asia recorded its highest pollution levels, attributing to 35% of deaths globally due to air pollution. The World Health Organization's list of the ten most polluted cities reveals that nine are situated in India, with Delhi holding the sixth position. The pollution concentrations are collected from Pollution Control Board(CPCB) under the Ministry of Environment, Forest, and Climate [1] Change in India (https://cpcb.nic.in/), encompassing states like Andhra Pradesh, Bihar, Chandigarh, Chhattisgarh, Delhi, Gujarat, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, West Bengal, and Odisha, where their Air Quality Index (AQI) values are observed. Air pollution stems from a variety of human activities and natural occurrences, including industrial emissions, vehicle exhaust, burning of fossil fuels, agricultural practices, wildfires, and volcanic eruptions. [2] These sources release harmful pollutants like particulate matter, nitrogen oxides, sulfur dioxide, and volatile organic compounds into the atmosphere, leading to the deterioration of air quality. The repercussions of air pollution on human health are significant, with exposure to pollutants such as particulate matter (PM10, PM2.5), ozone(O_3), Sulphur dioxide (SO_2), and nitrogen oxides (NO_2)

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resulting in respiratory issues, exacerbation of conditions like asthma, and heightened risks of lung diseases. Prolonged exposure is associated with cardiovascular ailments, diminished lung function, and premature mortality. Furthermore, air pollution can contribute to the formation of smog, causing irritation to the eyes and respiratory system

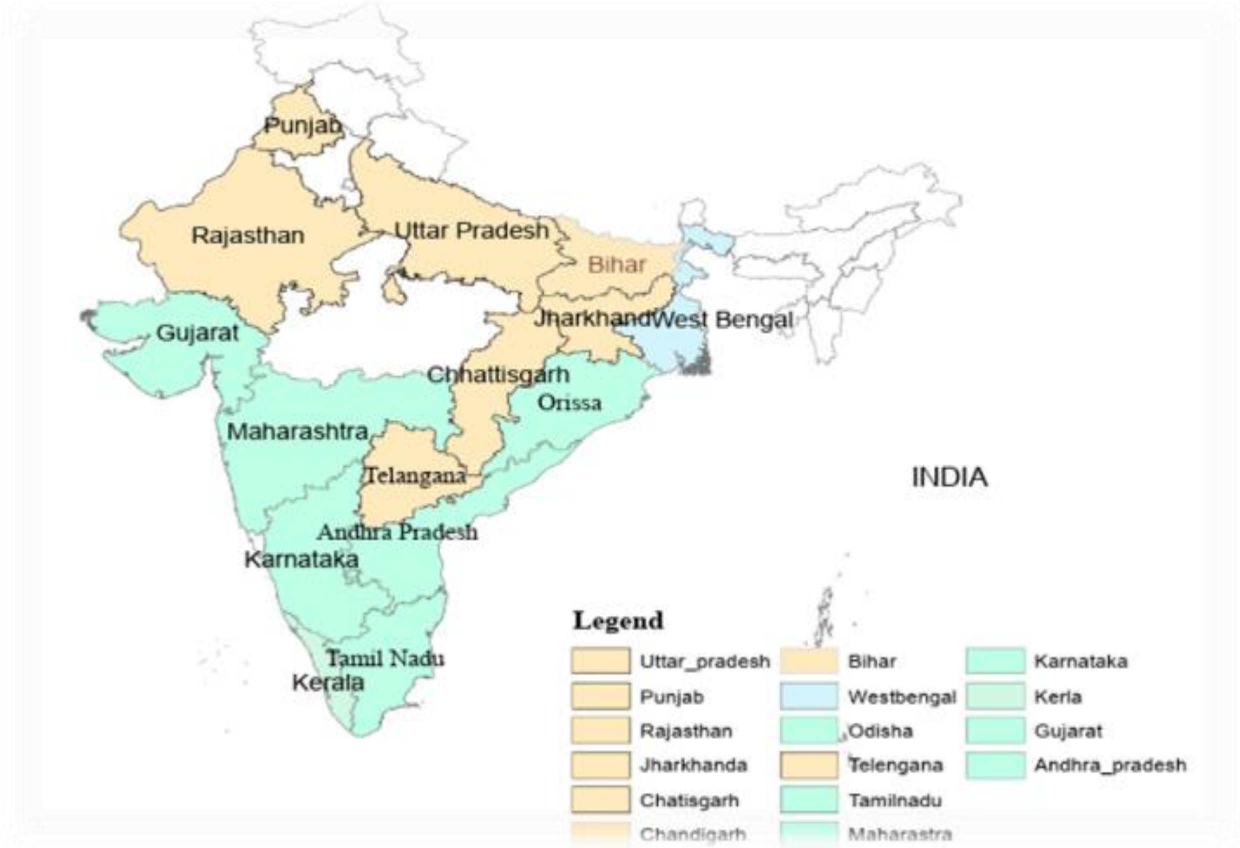

Figure 1 **Arcgis Map of Study Areas**

Above figure 1 showing the different states that have taken for study. coastal regions are the regions which contains mostly water body like sea, river etc.

2. Materials and Methods

2.1 Study Area

The study area encompasses the map of India, spanning numerous states and locations. India, currently one of the fastest-developing countries in Asia, stretches between 8°4′ North and 37°6′ North latitudes, and 68°7′ East and 97°25′ East longitudes. It spans 3214 km from north to south and 2933 km from east to west. [3] With a population of approximately 141.72 crores as of 2022, India holds the top rank globally. Figure 1 delineates the various states focused on in the study. Situated in South Asia, India is the seventh-largest country globally by land area and the second-most populous. Renowned for its rich history, diverse culture, and vibrant traditions, India is divided into 28 states and 8 Union Territories, each with its unique identity. The 28 states in India include Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttara hand, and West Bengal. Additionally, there are 8 union territories, namely Andaman and Nicobar Islands, Chandigarh, Dadra and Nagar Haveli and Daman and Diu, Lakshadweep, Delhi, Puducherry, Jammu and Kashmir, and Ladakh. Each state is characterized by

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its industrial or non-industrial nature, coastal or non-coastal location, and tier classification. India's cities serve as vibrant hubs of commerce, culture, and opportunity. To comprehend and navigate this diverse urban landscape, the Indian government has classified cities into four tiers: Tier I, II, III, and IV. These classifications serve as valuable indicators for factors such as population size, infrastructure development, economic growth, and quality of life. The tier classifications serve multiple purposes. Firstly, they aid in administrative efficiency by enabling governments to manage and govern cities more effectively, facilitating resource allocation, policy implementation, and decision-making. Secondly, they assist in economic assessment by evaluating a city's economic strength and potential, aiding businesses and investors in identifying lucrative markets and growth opportunities. Thirdly, they contribute to urban planning and infrastructure development by prioritizing resource allocation and ensuring appropriate attention to cities in need of development

2.2 Data Collection

This paper refers the data were collected from the Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCB) of each state on a yearly and monthly basis. Meteorological data was obtained online from NASA's website. Based on previous research findings, four key air pollutant components (PM2.5, PM10, SO2, NO2) and four important meteorological factors were selected for analysis of air quality such as temperature(T), relative humidity (RH), average wind speed (WS), and surface pressure(PS). The ambient air quality across the country was assessed through two main method [4] manual monitoring as part of the National Ambient Air Quality Monitoring Programme (NAMP) and real-time monitoring via the Continuous Ambient Air Quality Monitoring System (CAAQMS). The National Ambient Air Quality Monitoring Programme (NAMP) commenced in 1984 with the establishment of monitoring stations located in Agra and Anpara. Under the National Ambient Air Quality Monitoring Programme (NAMP), the State Pollution Control Boards (SPCBs), Pollution Control Committees (PCCs), National Environmental Engineering Research Institute (NEERI) in ambient air quality monitoring at various stations. NAMP focuses on monitoring several criteria pollutants, including Particulate Matter (PM10), Sulphur Dioxide (SO2), Nitrogen Dioxide (NO2), Carbon Monoxide (CO), Ammonia (NH3), Ozone (O3), PM2.5, Benzo(a)pyrene (B(a)P), Lead (Pub), and Nickel (Ni) at selected locations. The objectives of the National Ambient Air Quality Monitoring Programme (NAMP) include: Evaluating the status and trends of ambient air quality, assessing compliance with prescribed ambient air quality standards, identifying cities where national standards for air quality are not met, Gathering the knowledge and insights required for formulating preventive and corrective measures. Figure 2 shows the Adopted Methodology. The Continuous Ambient Air Quality Monitoring System (CAAQMS) is a specialized setup housed within a temperature-controlled container or room, equipped with various analyzers for monitoring ambient air pollutants in real-time. These CAAQMS stations play a crucial role in generating the daily National Air Quality Index (NAQI) of cities. Currently, the network of Continuous Ambient Air Quality Monitoring Stations (CAAQMS) is expanding across India. Presently, there are 296 CAAQMS stations covering 148 cities in 22 States and 4 Union Territories. Under the Continuous Ambient Air Quality Monitoring System (CAAQMS), various pollutants including Particulate Matter (PM10 & PM2.5), Sulphur Dioxide (SO2), Nitrogen Dioxide (NO2), Ammonia (NH3), Carbon Monoxide (CO), Ozone (O3), and Benzene (C6 H6) are monitored at all locations. Additionally, CAAQM stations are equipped with sensors to measure meteorological parameters such as Wind Speed, Wind Direction, Ambient Temperature, Relative Humidity, Solar Radiation, and Rainfall. But the meteorological datas we have collected from the NASA website as per availability.

2.3 Calculation of Air Quality Index

Various methods are utilized worldwide to calculate air quality values. The Air Quality Index (AQI) is computed for specific locations to assess pollution

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levels, with classification into six categories: good (0-50), satisfactory (51-100), moderate (101-200), poor (201-300), very poor (301-400), and severe (>400) as delineated in Table 1. Table 2 provides the breakpoint concentrations for the four primary pollutants. Daily air quality data is aggregated monthly and annually. Sub-indices for each pollutant concentration are determined, with the final AQI for a location derived from the maximum sub-index calculated. The AQI for each concentration is computed using Equation (1), while the final AQI is determined using Equation (2)

$$AQI_p = \frac{I_H - I_L}{BP_H - BP_L}(C_P - BP_L) + I_L \quad \text{Eq (1)}$$

$$AQI = Max\ (S0_2, NO_2, PM_{2.5}, PM_{10}) \quad (2)$$

Table 1 Applied Tools and Utilization

Tool	Version	Utilised for
ArcGIS	10.7.1	For mapping
Q-GIS	3.36.0	For interpolated spatial mapping
Tableau	2024.1	For temporal analysis
Mendeley	1.19.5	For references

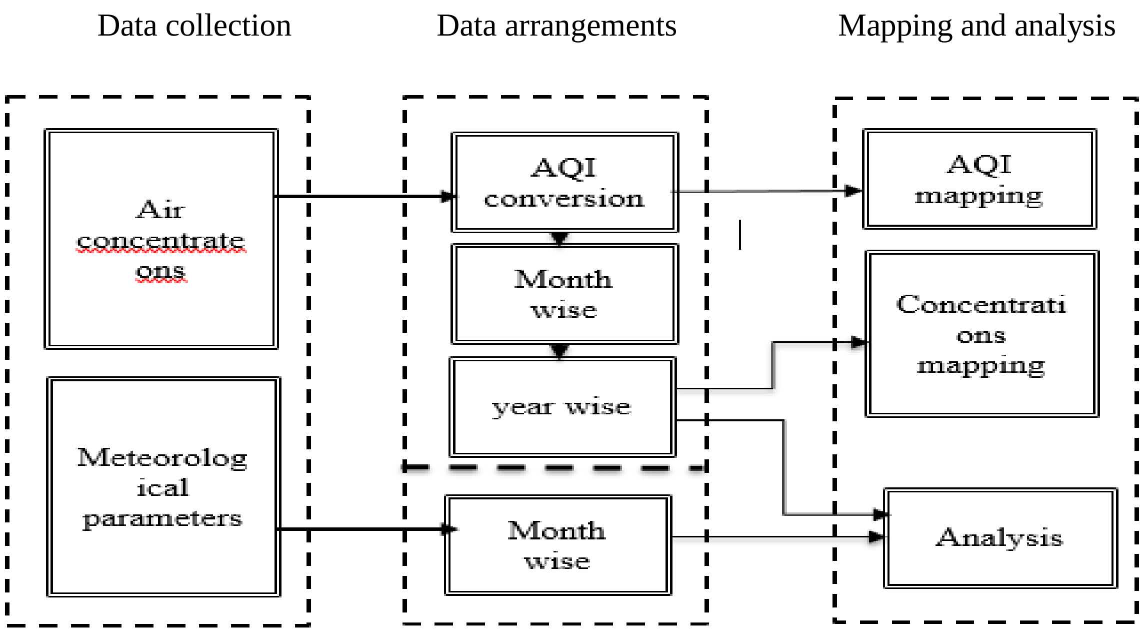

Figure 2 Adopted Methodology for This Study

Table 2 Showing The Ranges Used for Calculations of AQI by Using Concentrations Concentrations

AQI	RANGE OF CONCENTRATION (µg/m3)			
	SO2	NO2	PM 2.5	PM 10
401-500	1600+	400+	250+	250+
301-400	801-1600	281-400	121-250	121-250
201-300	381-800	181-280	91-120	91-120
101-200	81-380	81-180	61-90	61-90
51-100	41-80	41-80	31-60	31-60
0-50	0-40	0-40	0-30	0-30

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Table 3 Showing The Ranges Used for Determination of Pollution Zone

AQI RANGE WITH CATEGORIZATION AND HEALTH AND IMPACT		
AQI VALUE	CATEGORY	IMPACT ON HUMAN HEALTH
0-50	GOOD	Minimal Impact
51-100	SATISFACTORY	Minor Breathing Discomfort To Sensitive People
101-200	MODERATE	Breathing Discomfort To The People With Lung, Heart Disease
201-300	POOR	Breathing Discomfort To People On Prolonged Exposure
301-400	VERY POOR	Respiratory Illness To The People On Prolonged Exposure
>400	SEVERE	Respiratory Effects Even On Healthy People

In the Above Table 3 showing the breakpoint concentration values for each concentration which is used to calculate the individual AQI of concentrations. The concentration value for SO2 is measured as 34 (ug/m3) which is ranging between 0 and 40 (ug/m3) where 0 and 40 (ug/m3) represents the lower and upper breakpoint concentration values respectively. Table 3 shows the ranges of AQI value and their significant impacts on human health by category wise where 0-50 (Good), 51-100(Satisfactory), 101-200(Moderate), 201-300(Poor), 301-400(Very Poor) and >400(Severe).

Table 4 Showing The 5 Year MLR Analysis Between AQI and Air Concentrations

States	Cities	Intercept	Coeff of No_2	Coeff of So_2	Coeff of Pm_{10}	Coeff of $Pm_{2.5}$	Significant
Rajasthan	Kota	23.043	-0.060	0.739	-0.067	-	PM_{10}
	Jaipur	17.53	-0.067	0.745	0.7875	-	PM_{10}
Gujarat	Gandhi Nagar	-162.106	-0.669	0.687	0.501	3.062	$Pm_{2.5}$
Punjab	Ludhiana	2.94E-14	-1.0E-16	1.9E-16	1.0	-2.7E-16	PM_{10}
Maharashtra	Pune	14.545	0.630	0.09	0.432	-	PM_{10}, NO_2
	Mumbai	17.655	0.406	0.06	0.60	-	NO_2, $PM_{2.5}$
Chhattisgarh	Durg	10.947	0.441	0.558	0.488	0.214	PM_{10},NO_2,$PM_{2.5}$, SO_2
	Bilaspur	1.42E-14	-5.33E-17	2.733E-17	1	-	PM_{10}
Andhra Pradesh	Gunter	-1.40E-14	-3.30E-17	1.01E-17	1	-5.30E-17	PM10
Sikkim	Namchi	0.1983	0.023	-0.042	0.99	-	PM10,SO2
Odisha	Angul	0.7430	0.2583	-0.471	0.856	0.242	PM10,PM2.5
	Bhubaneswar	3.5183	0.3709	0	0.7860	0.2391	PM10,PM2.5

2.4 Multi Linear Regression Model (MLR)

Multiple linear regression is utilized to establish a mathematical connection among multiple variables. In essence, MLR investigates how numerous independent variables relate to a single dependent variable. Our study employed MLR to assess the significance Table 4 of data from 2017 to 2022, as well as to analyze the relationship between air quality and meteorological factors. [5] The multiple linear regression model can be described as shown in Equation 3. In the linear equation (Eq.3), where Y represents the AQI value for observation i and x

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denotes the meteorological variables, a stand for the intercept term, bm represents the regression coefficient for meteorological factor m, and ε is the error term.

Table 5 Showing the MLR analysis of AQI with meteorological parameters of combine years

States	Location	Intercepts	Temp coefficient	Surface press. coefficient	Specific humidity coefficient	Wind speed coefficient
Andhra Pradesh	Gunter	-1101.67	-0.52	11.62	0.62	1.90
Punjab	Ludhiana	8522.88	-00.97	82.21	-13.46	-73.41
Chhattisgarh	Durg	-2185.39	0.09	22.84	-0.36	15.16
Sikkim	Namchi	-373.87	0.54	4.64	-0.40	-2.66
Maharashtra	Pune	96.63	-2.14	1.26	-5.56	-0.92

3. Results and Discussion

In 2016 CPCB changes the formula which is mostly used currently not only in India but all over the world. The formula may deviate some extends in different countries but the measured pollution level is nearly same with less error.

1.1 Data Analysis

The data we have collected are analyzed in two ways as spatial and temporal analysis to show the variations.

1.2 Spatial Analysis

Spatial analysis is defined as the process of studying entities by assessing, evaluating and modelling spatial data features such as locations, attributes and their relationships that reveal the geography. We have done the spatial analysis of concentrations from 2016 to 2021 by using the QGIS software (QGIS 3.36.0). From the analysis of concentrations, we analyzed that the North(N) and N-E areas are more polluted than other areas. Figure 3 In the year 2019 fig (5) it shows higher values compared to other years. It also shows that the concentrations decreased in the year 2020 as compared to other previous and post years. Air quality in India's northeast state is worsening and while still much better than pollution hotspots in other parts of the country. So far air pollution is largely seen as a crisis of the Indo Gangetic plains (North Indian plains), [7] particularly in winter when Delhi and several cities in Uttar Pradesh and Haryana find themselves in the lists of the worlds most polluted cities. Air in the northeast States, in the popular imagination, is less befouled due to the region's topography that is less conducive to fossil-fuel led industrialization and geographical isolation. According to the latest report 2021-22 (CPCB) North and East India remained the most polluted regions, with North India experiencing a significant deterioration in air quality compared to the previous winter, while East India showed signs of improvement.

1.3 Temporal Analysis

In our temporal analysis, we examine the correlation between AQI and meteorological factors. We selected four sites, including coastal areas like Bhubaneswar and Pune, and non-coastal regions like Uttar Pradesh and Rajasthan and as a result we concluded that from temporal analysis, [6] it is observed that there is a decrease in AQI as wind speed, temperature, and specific humidity increase. Given that temperature, specific humidity, and wind speed are higher in coastal areas, the AQI tends to be higher in noncoastal regions and lower in coastal regions.

1.4 MLR Analysis of AQI with Meteorological Parameters

Here we have done the MLR analysis of AQI vs Meteorological parameters of month wise average data for combined years from 2016 to 2020, accordingly we got the intercept and coefficient values of corresponding parameters.

$$Y = a + b1X1 + b2X2 + b3X3 + b4x4 + \mathcal{E} \qquad Eq(3)$$

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1.5 Correlation Analysis

The correlational method involves looking for relationships between variables. Correlation coefficients are used to assess the strength and direction of the linear relationships between pairs of variables. Here we have correlated AQI with meteorological parameters and we got the value of r (coefficient of correlation/Pearson coefficient).

Table 6 Pearson Coefficient(R) Values of Different States That Has Taken (Month Wise)

States	Years	r(temp)	r(sp)	r(rh)	r(ws)
Gujarat	2018	-0.35	0.43	-0.5	-0.31
	2019	0.01	0.05	-0.41	-0.11
	2020	NA	NA	NA	NA
	2021	-0.48	0.68	-0.58	-0.51
Punjab	2018	-0.02	0.16	-0.61	-0.53
	2019	-0.47	0.53	-0.3	-0.43
	2020	-0.45	0.52	-0.64	-0.32
	2021	-0.6	0.63	-0.63	-0.01
Andhrapradesh	2018	-0.39	0.36	-0.3	-0.46
	2019	-0.17	0.4	-0.26	-0.33
	2020	NA	NA	NA	NA
	2021	-0.42	-0.65	0.69	-0.06
Chattisgarh	2018	0.26	0.07	-0.3	-0.16
	2019	-0.015	-0.01	0.07	0.19
	2020	-0.19	-0.05	0.11	0.14
	2021	-0.43	0.33	-0.18	-0.23
Rajasthan	2018	-0.38	0.63	-0.83	-0.62
	2019	-0.28	0.7	-0.95	-0.3
	2020	-0.44	0.68	-0.72	-0.51
	2021	-0.44	0.68	-0.72	-0.51

Above table showing the values of Pearson coefficient(r) for different states as given in the table 6. From here we got that the temperature(temp), relative humidity(rh) and wind speed(ws) has a negative correlated(r=-ve) impact on AQI where surface pressure has a positive correlated impact on AQI (r=+ve). Here the data analyzed are between AQI with meteorological parameters in month wise.

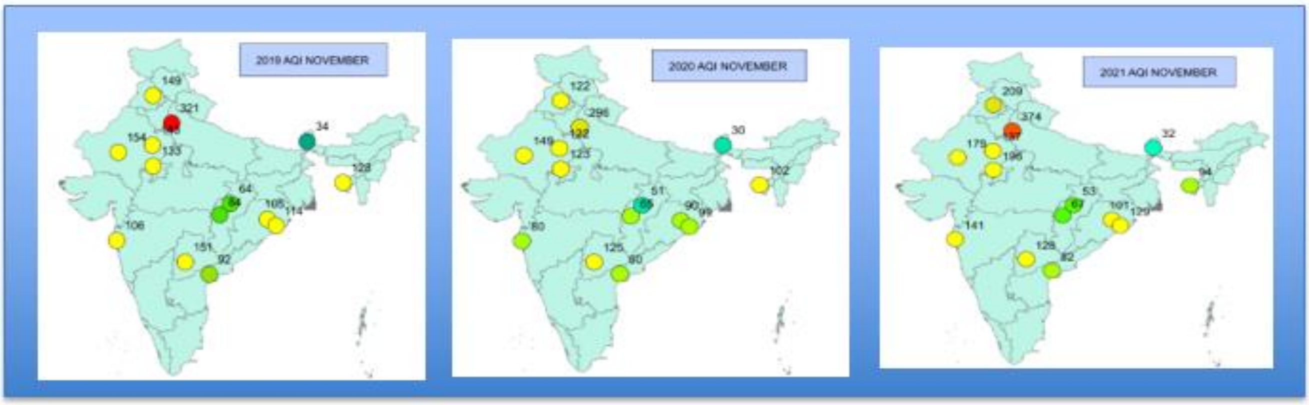

Figure 4 Showing the ArcGIS Mapping of AQI in Year Wise

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Above Figure 4 showing the representation of some AQI value of some different locations for the year 2019,2020 and 2021for the November month. All the data used are averaged to year wise then by using ArcGIS software we mapped the locations according to CPCB standards.

1.6 Spatial Distribution of SO2(Ug/M3)

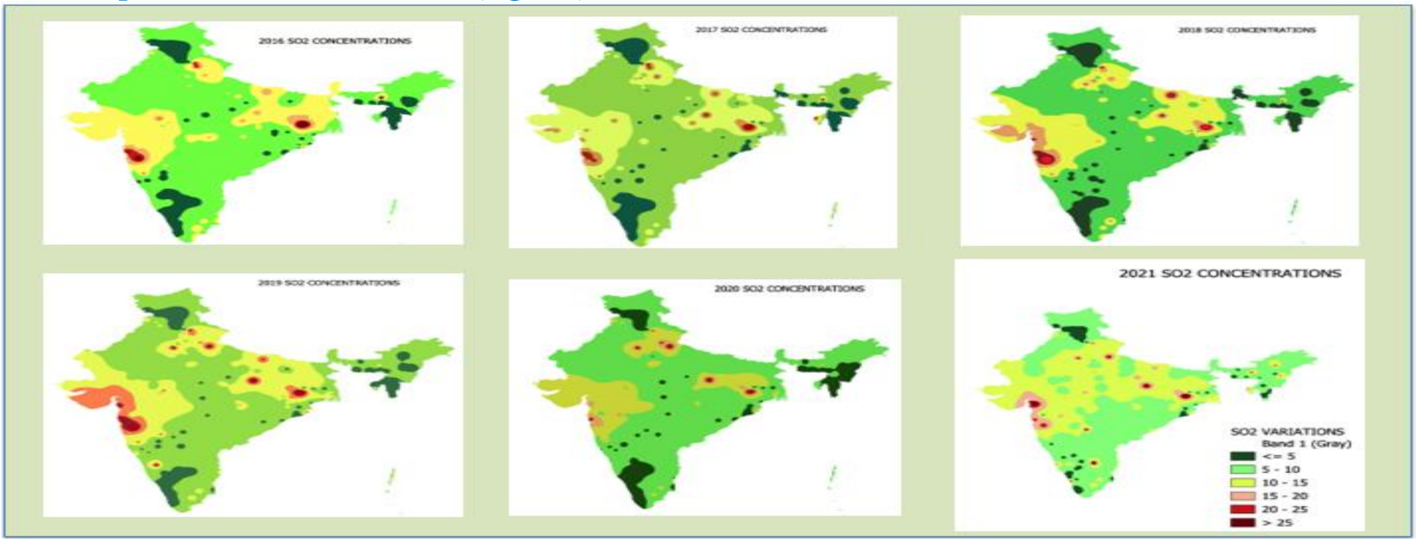

Figure 5 Showing spatial analysis of SO2concentrations in year wise

The spatial distributions of SO2 concentrations (in µg/m³) from 2016 to 2021, as depicted in the Figure 5, reveal varying levels of pollution. The color scheme categorizes concentrations into different ranges: 0-5, 5-10, 10-15, 15-25, and >25, with red indicating the highest concentration in a given location. Analysis of the Figure 6 suggests that the north-western (N-W) and north-eastern (N-E) regions exhibit higher pollution levels compared to other areas. In 2019, notably high values are observed across the monitored locations. However, in 2020, there was a significant decrease in concentrations, which correlates with the global impact of the COVID-19 pandemic. The restrictions imposed during the pandemic likely contributed to the reduction in pollution levels. Subsequently, in 2021, concentrations rebounded, indicating a return to pre-pandemic levels or possibly even higher. The same analysis has done for NO2 concentrations. These observations indicate a potential fluctuation in NO2 concentrations over the years, with specific attention drawn to the higher levels witnessed in 2016 and 2017. The subsequent decline in 2020 followed by an increase in 2021 suggests a dynamic interplay of various factors influencing NO2 emissions and dispersion. It's crucial to delve deeper into the underlying causes behind these trends, considering factors such as industrial activities, vehicular emissions, and meteorological conditions. Additionally, [8] policy interventions and mitigation strategies may need to be revisited and reinforced, particularly in regions with consistently elevated NO2 levels like Delhi, to address air quality concerns effectively. Further analysis incorporating additional datasets, alongside an exploration of contributing factors, could provide valuable insights for informed decision-making aimed at improving air quality and environmental health. Concentration ranges were segmented into <12, 12-24, 24-36, 36-48, 48-60, and >60 µg/m³, each represented by distinct colors in the Figure 7. The same spatial distributions have done for PM10 concentrations (µg/m³) from 2016 to 2021, segmented into distinct concentration ranges. Regions situated to the north exhibit comparatively higher levels of PM10 pollution when compared to other areas. This suggests a spatial concentration pattern, possibly influenced by various local factors such as industrial

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activities, traffic density, and geographical features. There appears to be a decreasing trend in PM10 concentrations over the years under study. This reduction may indicate the effectiveness of pollution control measures or other environmental interventions implemented during this period. PM10 concentrations were categorized into distinct ranges (<50, 50-100, 100-150, 150-200, 200-250, and >250 µg/m³), with each range represented by a specific color in the Figure 8. This segmentation aids in visualizing the severity of pollution levels across different areas. These observations underscore the importance of ongoing efforts to monitor and mitigate air pollution, particularly in regions experiencing elevated PM10 concentrations. Implementing targeted interventions, such as emissions regulations, urban planning strategies, and public awareness campaigns, can contribute to sustained improvements in air quality and public health. Further analysis, incorporating additional data sources and exploring potential drivers of PM10 pollution, can provide deeper insights into the observed trends and inform evidence-based policymaking aimed at protecting the environment and human well-being.

1.7 Temporal Analysis

Temporal analysis is the examination of data and events across various time intervals, such as hours, days, weeks, months, or years. This analytical approach enables the study of patterns, trends, and relationships over time, shedding light on event frequency, consistency, and temporal dependencies.

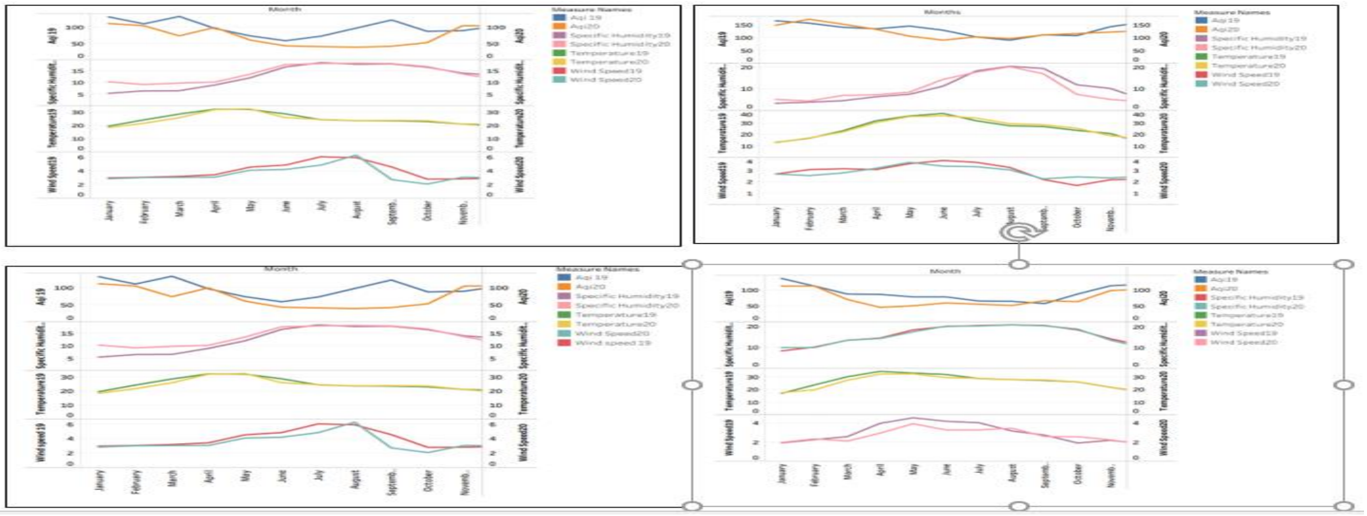

Figure 8 Temporal Variation of AQI and Meteorological Parameters for The Year 2019 And 2020

In our temporal analysis, we investigated the relationship between Air Quality Index (AQI) and meteorological factors across four distinct sites, encompassing both coastal and non-coastal regions. The selected sites include Bhubaneswar and Pune representing coastal areas, and Uttar Pradesh and Rajasthan representing non-coastal regions. Utilizing Tableau Software, we analyzed variations in AQI and meteorological parameters over the years 2019 and 2020. Temperature Impact: We observed a negative correlation between temperature and AQI levels. As temperature increased, AQI tended to decrease. This suggests that higher temperatures may contribute to lower AQI levels. Wind Speed Influence: Similarly, we found a negative correlation between wind speed and AQI. Higher wind speeds were associated with lower AQI levels, indicating that increased wind dispersal might lead to reduced air pollution concentrations. Specific Humidity Dynamics [9] Our analysis also demonstrated a negative correlation between specific humidity and AQI. Higher specific humidity levels correlated with lower AQI values, suggesting that increased humidity may aid in pollutant removal from the atmosphere. Regional Disparities: We observed that coastal regions such as Bhubaneswar and Pune

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exhibited lower AQI levels compared to non-coastal regions like Uttar Pradesh and Rajasthan. This finding aligns with the notion that coastal areas tend to benefit from higher temperatures, wind speeds, and specific humidity levels, which contribute to improved air quality. Overall, our findings suggest that meteorological factors play a significant role in shaping AQI levels, with coastal regions experiencing comparatively lower pollution levels due to favorable meteorological conditions. These insights underscore the importance of considering both geographical and meteorological factors in air quality management strategies tailored to specific regions. By leveraging temporal analysis techniques and visualizations, we can enhance our understanding of the complex interactions between air quality and meteorology, ultimately informing more effective decision-making and intervention strategies to mitigate air pollution.

4. Impact of Air Pollution in Human Health

Exposure to air pollution, whether short- or long-term, poses significant health risks, encompassing a spectrum of diseases such as stroke, chronic obstructive pulmonary disease, and various cancers including those affecting the trachea, bronchi, and lungs. The International Agency for Research on Cancer has identified PM2.5, a common component of air pollution, as a primary contributor to cancer. Recent global assessments have revealed that prolonged exposure to air pollution can impact virtually every organ in the body, exacerbating existing health conditions and complicating overall well-being. Children and adolescents are especially susceptible to the adverse effects of air pollution due to their ongoing physical development and maturing immune systems. Unfortunately, their limited ability to influence air quality policies leaves them particularly vulnerable. Among the pollutants, sulfur dioxide (SO_2), largely emitted from the combustion of fossil fuels and sulfur-containing materials, poses a significant threat. Its presence can harm trees, impede plant growth, and damage delicate ecosystems and water bodies. Moreover, it contributes to respiratory ailments and can worsen pre-existing heart and lung conditions.

Conclusion

In our study, we conducted an extensive analysis examining the intricate relationship between air pollutant concentrations and various meteorological factors such as wind speed, temperature, and humidity. Through multiple regression analysis Table 5, we observed significant findings regarding PM10 values across many areas. Notably, in coastal regions, both PM10 and PM2.5 exhibited significances, with p-values below 0.05 ($p < 0.05$). Conversely, in non-coastal areas, NO_2 demonstrated significance alongside PM10 and PM2.5. Globally, coastal regions are frequently affected by sea-land breeze phenomena, influencing air quality significantly. This phenomenon involves alternating land and sea breezes induced by temperature disparities between land and water surfaces. Our analysis underscores the substantial impact of particulate matters on Air Quality Index (AQI), emphasizing their pivotal role in air pollution dynamics. highlights the persistent air pollution in northern regions, particularly evident in Delhi throughout the year. In 2023, Delhi earned the dubious distinction of being the world's most polluted capital city, according to a report by a Swiss-based air-quality monitoring group. India, including Delhi, ranked as the world's third-most polluted country after Bangladesh and Pakistan, as reported by IQ Air. Air pollution in India stems from various factors, including rapid industrialization and lax enforcement of environmental regulations. Poor industrial practices and inadequate pollution-control measures exacerbate the problem. Additionally, unchecked urban development and construction activities contribute to escalating pollution levels. Delhi's air quality deteriorates significantly during winter due to multiple factors, including the burning of crop residues by farmers in neighboring states, industrial and vehicular emissions, stagnant wind conditions, and firecracker usage during festivals. Consequently, the government has implemented measures such as temporary school closures to mitigate health risks associated with toxic air. Furthermore, Beguserai in northern India and Guwahati in the northeast emerged as the world's most polluted cities, underscoring the widespread

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nature of India's air pollution crisis. Also we got the relation trend between AQI and meteorological parameters from where we got that temperature, humidity and wind speed are negatively correlated withAQI where surface pressure is positively correlated with AQI.

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