e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

A STUDY ON THE SPATIO-TEMPORAL VARIATIONS IN AIR QUALITY OF KOLKATA CITY FROM 2010-2019

Diptyajit Bhakta[*1], Chandra Sekhar Matli[*2]

[*1]Indian Institute of Technology, Dhanbad-826001, INDIA.

[*2]National Institute of Technology, Warangal, INDIA.

DOI : https://www.doi.org/10.56726/IRJMETS32801

ABSTRACT

This paper evaluates the air quality at different locations in the city of Kolkata, capital of West Bengal, India. Geo-spatial and geographical information techniques were used to estimate the seasonal, monthly and spatial distribution of pollutants from the year 2010-2019. The interpolation technique of GIS is very helpful in establishing a visual change in the AQI values during the years. The data used in this project work is acquired from Central Pollution Control Board (CPCB) and West Bengal Pollution Control Board (WBPCB) web sites. An attempt was made to assess the variations in pollutants concentrations over different seasons of the year. Three pollutants viz. NO_2, SO_2 and particulate matter (PM10) are considered for the study for want of data. Results indicate that particulate matter is the most dominating pollutant, while NO_2 and SO_2 have remained within the permissible limit for major portion of the study period. The results also indicate that the pollutant concentrations are higher in Winter season (November – February), while monsoon (July – October) is the cleanest part. The spatial distribution image of Air Quality Index (AQI) during the winter months from 2010-2019 shows a pattern of deteriorating air quality. The study also suggests that the Dunlop bridge location is the most polluted region out of the four monitoring regions considered during the study, which is perhaps due to dominant industrial activities in that region.

Keywords – Ambient Air Quality, Spatio-temporal Variation, Spatial Distribution, Geographical Information System, Air Quality Index

I. INTRODUCTION

Air quality is one of the most concerning issues worldwide and is also the most arguable point of discussion in the West and many developed countries. Indian cities are also ranked among the most polluted cities in the world (Ravindra, 2016). Recent studies have shown the importance of air quality and the impact of its adverse effects on human health and lifestyle. Reports have shown an estimate of lethal damages caused by air pollution. In today's world rapid rate of urbanization and industrialization is a major factor behind the serious issue of air pollution. Air pollution causes various health issues including heart diseases, diabetes, mental health hazard, and pulmonary diseases. Air pollution is now held accountable for maximum premature deaths per year, and studies have found that air pollution is one of the major causes of human mortality. Bad air quality also affects the quality of life, living standards, and ultimately the economy over that area. The quality of air depends on the season and therefore varies according to the weather conditions prevailing in that area. Various studies have shown an interrelation between air quality and local weather conditions and have also justified the fluctuations of air quality parameters during different months of the year. Many recent summits like Kyoto Protocol, Paris Agreement, Rio Conference 1992 have all failed to bring any remarkable changes till now.

Kolkata like any other metropolitan city in India has seen a trend of exacerbating air quality in the past decade, especially during the winter months. This has very harmful impact on the health of the residents of the city and also in its economy. This can be attributed to rapid urbanization, increased population growth, traffic congestion, poor road quality, etc. Other factors include rapidly changing land use/land cover patterns, diminishing blue and green space over terrestrial landform, qualitative degradation of aquatic and terrestrial ecosystems, and weakened self-regulatory mechanism of ecosystem fail to maintain equilibrium due to higher emissions within a short interval. This has increased the urgent need to evaluate the air quality of the city for better policy and management to reduce the pollution levels. The ArcGIS software has provided an effective platform for generating and analyzing the air quality changes over the years. The GIS provides a flexible, useful, and work-friendly environment for mapping the spatial distribution and analyzing the changes from the map layers. This study discusses in detail about the seasonal variations of air pollutants at four monitoring stations and from 2010-2019. It also discusses the spatial variation of air quality index values during the winter months from 2010-2019 at four different stations and the monthly variation of AQI at the four locations considering three years into evaluation.

STUDY AREA

The city of Kolkata is the capital of the Indian state of West Bengal, and also one of the largest city in the eastern part of India. Kolkata is the 3rd largest metropolitan city with an area extending over 206 km^2 and having an elevation of 9 m above sea level. Kolkata is situated on the eastern bank of the river Hoogly and slopes away to marshy wetlands on the eastern side. The soil is mainly of the alluvial type. The city is home to 4,496,694 people with a population density of likely over 22000 people per km^2. The mean annual temperature of the city is 26.8 °C with monthly mean temperatures varying between 19°C to 30°C. The summer (March - June) months are hot and humid with lower ranges lying at 30°C and upper ranges at 40°C. During the winter, the lower ranges of temperature vary between 9°C - 11°C. May is the hottest month while January is the coldest month of the year. The city gets to see much rainfall attributed due to the Bay of Bengal branch of the monsoon winds; monsoon lasts over four months from July to September. Kolkata gets an annual rainfall of 1850 mm, with maximum rainfall in the months of June, July, August, and September. The month of December gets to see very little rainfall and humidity. The city also gets to see many thunderstorms during the summer months. The duration of winter is very less and lasts for only two-and-half months. The average relative humidity of this area is 69 percent, while the upper ranges lie in the range of 80-85 percent during the monsoon days. The air quality monitoring stations are listed in Table 1 and shown in Fig 1. The serial number in this table coincides with the location of the monitoring station in the map.

Table 1: Air Quality Monitoring Stations

S. No.	Lat	Long	Station Name	Category
1	22.56203	88.40911	Paribesh Bhawan	Commercial/Residential
2	22.54169	88.35443	Minto Park	Commercial
3	22.65403	88.37719	Dunlop Bridge	Industrial
4	22.59102	88.41685	Salt Lake	Residential/Commercial

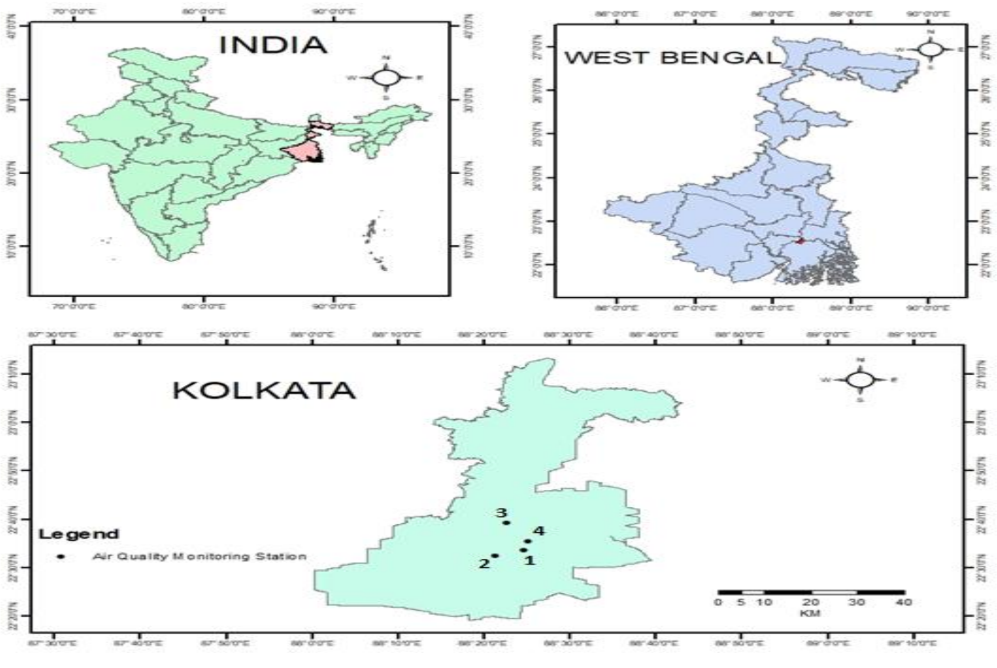

Figure 1. Index Map of the Study Area indicating Monitoring Locations

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

II. DATA COLLECTION AND ANALYSIS

2.1 Spatial Data

The software ArcGIS, designed by ESRI, was used for data processing, analysis, and mapping. The spatial data of the study area is downloaded from Stanford Libraries (https://purl.stanford.edu/br919ym3359) and other data maps of India and West Bengal are created in the GIS Environment. The location of four air quality monitoring stations were marked in the map and the data are interpolated using the ArcGIS software. The data of these four locations are used to map the changes in the study area from 2010-2019. The spatial interpolation of the maps was done using the Inverse Distance Weighted (IDW) interpolation available in the Geostatistical Analyst toolbar of the software. The Inverse Distance Weighted interpolation is typically a local interpolation algorithm. The IDW Interpolation works on the assumption that the unknown value of a point is more governed by a nearer point than by a further one (Fang Huang, 2011). The IDW interpolation works on the basic principle of using a weighted linear combination set of sample points, it counts the two statistical and mathematical methods to create surfaces and calculate the predictions of unmeasured points (Khouni, 2021).

2.2 Ambient Air Quality

In this study, the daily data is collected from four air quality monitoring stations located across the city and analyzed according to the national standards. The stations are manually monitored by West Bengal Pollution Control Board (WBPCB). The concentration levels of Nitrogen dioxide NO_2, Respirable Suspended Particulate matter RSPM or PM10, and Sulphur Dioxide SO_2 are collected from WBPCB and CPCB websites for four locations. The daily data is used to determine seasonal and annual averages. The same process is followed for mapping the spatial distribution, where the average is taken for the readings during the winter months.

2.3 Seasonal Variations

For the study, the whole year is classified into three seasons namely Winter, Summer, and Monsoon. Each season is considered for a duration of four months: Winter (November-February), Summer (March-June), and Monsoon (July-October); as per the meteorological variations. The readings of the pollutants viz. SO2, NO2, PM10, are analyzed for three seasons from 2010-2019 at four locations. The readings for each season are taken as the average of the readings for four months.

2.4 Air Quality Index (AQI)

The Air quality index is a unitless dimensionless standard parameter used to describe the quality of air over an area. The AQI is a single numerical value calculated from the concentrations of individual pollutants. The AQI is calculated using the Eq. (1).

$$\text{AQI} = \frac{1}{n}\left[\frac{\text{Pollutant1}_{\text{Actual}}}{\text{Pollutant1}_{\text{Standard}}} + \frac{\text{Pollutant2}_{\text{Actual}}}{\text{Pollutant2}_{\text{Standard}}} + \cdots n\right] \times 100 \quad \ldots \text{Eq.}(1)$$

The actual subscript refers to the observed values of the pollutants and the standard subscript refer to the standard values set by Central Pollution Control Board, New Delhi. The standard for NO_2 and SO_2 are $80\mu g/m^3$ for annually monitored values, and for PM10 the value is $100\mu g/m^3$ (National Ambient Air Quality Standards, 2009). The AQI values are interpolated and converted into GIS layers to indicate changes for a period of 10 years (2010-2019). The AQI values used for mapping the spatial distribution change is procured from the website of WBPCB.

Table 2: Air Quality Index

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

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

III. RESULTS AND DISCUSSION

3.1 Seasonal & Temporal Variations

The variations of the three pollutant levels viz. SO_2, PM10, NO_2 at four locations during the three seasons for ten years from 2010-2019 are presented in Fig. 2. The results indicate that the annual average concentration of particulate matter during the winter season is higher than the permissible limits prescribed in the NAAQS, CPCB at all four locations and for all the 10 years. The level of particulate matter coincides with the boundary limit in the summer season and also crossing it at times, at three locations (except in Salt Lake). This may be due to the increased vehicular emissions in the commercial and industrial areas. The graphical trend for PM10 shows an increasing concentration in the year 2017 for Paribesh Bhawan, Minto Park, and Dunlop Bridge. The graphs for PM10 show that the Dunlop Bridge location is the most polluting out of all the four stations. This is perhaps due to dominant industrial activities contributing to higher emissions and vehicular emissions. From analyzing the graph for PM10 at the four locations it can be concluded that there is an increasing trend in the level of PM10 for all three seasons and it can be predicted that the coming years can be more polluting if emissions are not regulated.

Concentrations of sulfur dioxide presented in Fig. 2 are well within the permissible limits at all four locations during all three seasons namely summer, winter, and monsoon for 10 years from 2010-2019. In the case of nitrogen dioxide, it can be seen that the concentration levels have exceeded the permissible limit i.e., 80 $\mu g/m^3$ during 2010 at three locations (except Paribesh Bhawan), and it has also exceeded in 2011 in Dunlop Bridge location. Apart from that other instance have been noticed where the levels have coincided with the boundary limit in the case of Dunlop Bridge, Minto Park, and Salt Lake locations. The reason behind the higher level of SO2 may be due to the emissions from power plants, industrial boilers, fossil fuels for heating and cooking purposes (karar, 2008). The SO_2, PM10, and NO_2 levels have always remained high during the winter season in comparison to summer and monsoon, and a similar trend is being seen in all the four locations for 10 years. This can be attributed to the lowering of the inversion layer, light winds during the winter season, and the prevalence of high wind velocity and precipitation during summer and monsoon. The graphs of PM10 at all the locations also show that the concentration level has never crossed the reference level (100$\mu g/m^3$) during the monsoon season in any of the years. This can be attributed to the high amount of precipitation during this time and higher wind velocity. The graphs of NO_2 at three locations, except Paribesh Bhawan, show a decreasing trend in the reduction of emission, this may be due to the recent pollution curbs by the government agencies. From the figure, conclusion can be drawn that the Dunlop Bridge location is the most polluting in terms of all the pollutants and all the seasons for 10 years study period. This is attributed to uncontrolled emissions from various industries, vehicular emissions, re-suspension of dust due to vehicle-generated turbulence, unpaved roads, dust generation from brakes. Similar seasonal variations have been found in studies conducted in Jaipur (Dadhich, 2018) (karar, 2008).

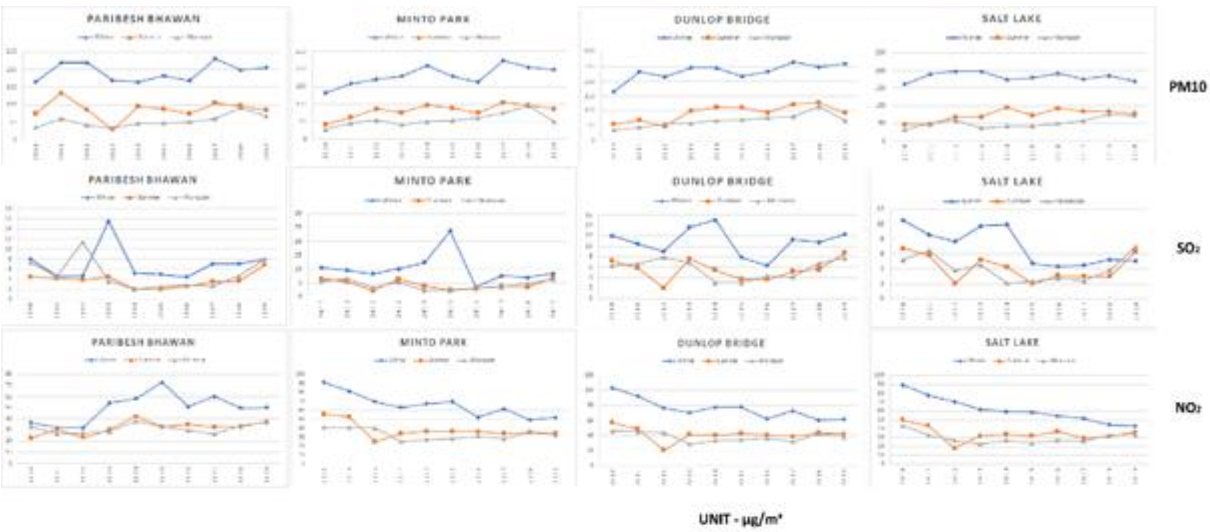

Figure 2: Seasonal and temporal variation of air pollutants during 2010 -19

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

3.2 Spatial Changes in Air Quality

The Air quality data of the study area indicates higher concentration of pollutants during the winter seasons, so the AQI are calculated for winter at the four monitoring stations in Kolkata city. Figure 3 and 4 present the spatial and temporal changes of AQI values in the four monitoring stations during the winter season (2010-2019). AQI values at various locations during the study period range between 100 -200 except for few isolated peaks at Minto Park during 2017-19. From 2012 to 2019 the air quality at the Dunlop bridge monitoring station has remained predominantly in the poor category zone as this location is dominated by industrial and transportation activities.

Spatial distribution of AQI indicates decline in air quality during 2010 to 2019. In the year 2010 the air quality was good category while the air quality deteriorated to poor category in 2019. The figure shows a gradual degradation in air quality over the years. Minto Park which is dominated by industrial and transportation activities the air quality is very poor. The overall deterioration in air quality can be attributed to increasing population density leading to higher traffic and industrial emissions. For want of data, finger printing of the causes of poor air quality is not considered in the scope of the study. Also, extrapolation to arrive at the spatial distribution gives broad information of the trends and the same can be used for control of air quality degradation by suitable mitigation and regulation.

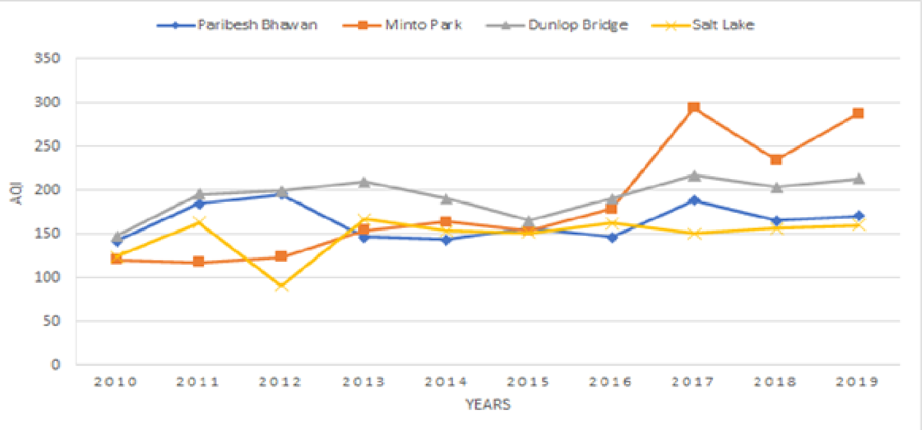

Figure 3: Trends in AQI during the years 2010-2019 (Winter Season)

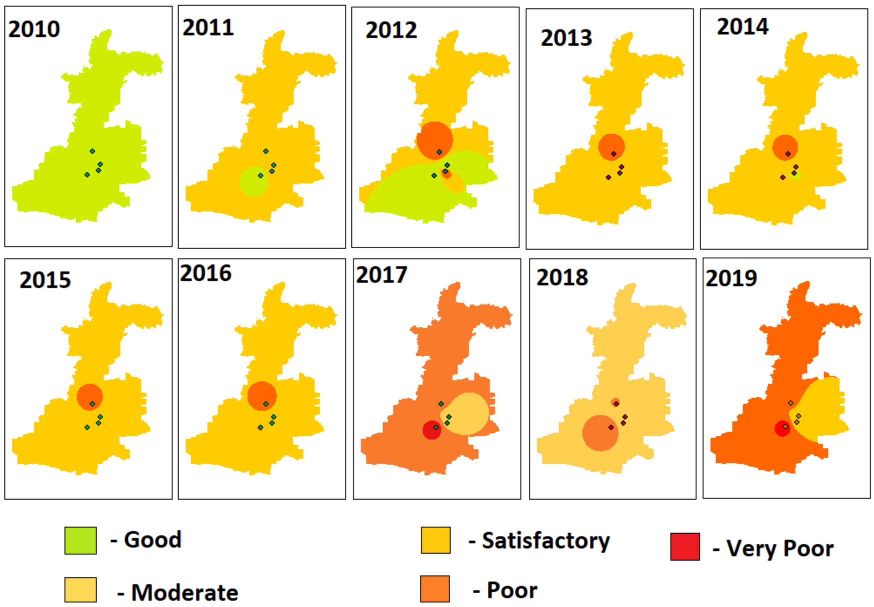

Figure 4: Spatial distribution of AQI values at four monitoring stations from 2010-2019 during winter season.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

The mean, minimum and maximum values of AQI for 2010, 2015 and 2019 are presented in Table 3. The air quality till 2015 can be considered to be satisfactory as most of the maximum values are either close to 200 or less than 200. However, the AQI increased significantly and crossed 200 by the year 2019 indicating poor air quality. This can be attributed to increasing pollution and poor regulation in place to control emission from different activities.

Table 3: AQI in the years 2010, 2015 and 2019 during winter

Years	2010			2015			2019		
Station	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Paribesh Bhawan	142	178	80	156	205	132	171	196	142
Minto Park	120	147	80	153	160	146	287	318	210
Dunlop Bridge	148	90	165	166	219	116	213	259	177
Salt Lake	124	79	190	152	174	111	160	201	119

3.3 **Monthly Variations**

Monthly variations of the AQI for four locations considered for the study are presented in Table 4 and Figure 5. The graph shows a similar trend at the four locations, indicating better air quality during monsoon and summer months. From the results, it can be concluded that the monsoon season (July - October) is the cleanest part of the year while the winter season (November - February) as most polluted with summer lying in between. The graphical trend at all the four locations and for the three years shows that the AQI values are less than 50 during April to September period, indicating good or satisfactory AQI. The reason behind the lower AQI values during the monsoon can be attributed to higher and frequent precipitation in monsoon, resulting in precipitation-driven washout (especially SO_2 and NO_2). In summer months, temperature results in unstable conditions and strong winds leading to higher dispersion of pollutants and hence better air quality. During winter and around-winter months (October and March), stable atmospheric conditions reduce pollutant dispersion and hence poor air quality. The AQI values during the winter season lie in the moderate range (101 - 200), with instances of sometimes lying in the poor range (201-300) as in the year 2019 in Minto Park and very poor (300-400) in 2019 in Dunlop Bridge station.

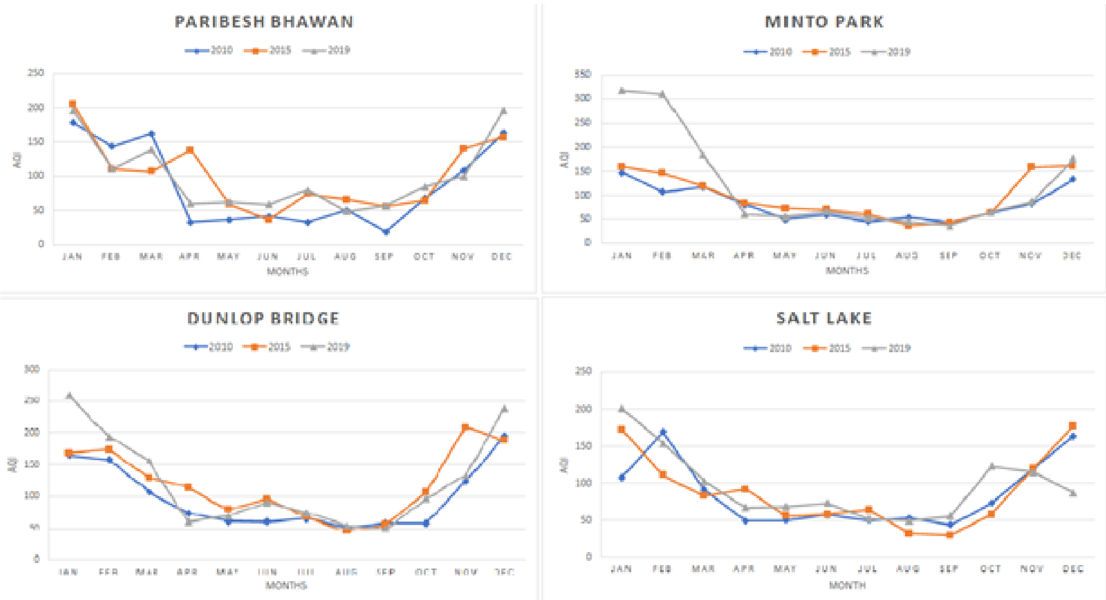

Figure 5: Monthly variation of AQI values at four monitoring stations

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

Table 4: AQI values during the winter season of 2010, 2015 and 2019

Months	2010				2015				2019			
	Paribesh Bhawan	Minto Park	Dunlop Bridge	Salt Lake	Paribesh Bhawan	Minto Park	Dunlop Bridge	Salt Lake	Paribesh Bhawan	Minto Park	Dunlop Bridge	Salt Lake
Jan	178	147	165	108	205	160	168	172	196	318	259	201
Feb	144	107	158	169	110	146	174	111	111	310	194	154
Mar	162	117	107	91	107	118	129	83	139	183	157	103
Apr	33	80	73	49	138	84	114	92	60	60	60	67
May	37	50	61	50	59	72	79	56	63	56	69	68
Jun	42	59	60	58	37	70	96	58	59	66	91	73
Jul	33	45	65	50	74	60	67	64	80	53	73	52
Aug	51	54	51	53	66	37	45	32	49	45	54	49
Sep	19	44	58	44	56	43	55	30	57	37	49	56
Oct	68	64	58	73	65	63	107	58	85	65	97	123
Nov	109	83	123	119	141	159	209	119	100	86	133	115
Dec	163	133	195	164	157	162	188	177	196	176	239	87

IV. CONCLUSIONS

The city of Kolkata appears to have serious air pollution problems in the past decade from 2010-2019. In this study, air quality data pertaining to years 2010 to 2019 is used to assess air quality of Kolkata. AQI was determined and the results are used to evaluate the seasonal variations, spatial distribution, and monthly variations in the city. It was found that Particulate Matter is the major pollutant in the study area. Results of the study indicated poor air quality in winter and better air quality in monsoon and summer months. The monsoon season is the cleanest in terms of all the pollutants over the period of ten years. The spatial distribution map shows a gradual increase in pollution level during the study period which is possibly due to increase in population density resulting in higher traffic and industrial emissions. The Dunlop Bridge location can be classified as the most polluting station of all the four monitoring stations and in all the years. The study also shows that GIS is very effective tool for arriving at the spatial distribution of AQI. The monthly variation graph at all the four stations shows that the monsoon season has good air quality and the winter season has satisfactory air quality. The trends in AQI are consistent during the study period indicating an urgent need to control air quality degradation by implementing suitable migratory methods and regulation. Spatial distribution maps can be handy for the urban planners and policy makers to plan effective strategies for controlling air quality degradation.

V. REFERENCES

[1] Agrawal, G. (2021). Ambient air pollution in selected small cities in India: Observed trends and future challenges.

[2] Dadhich, A. (2018). Assessment of spatio-temporal variations in air quality of Jaipur city, Rajasthan, India. In The Egyptian Journal of Remote Sensing and Space Science (pp. 173-181).

[3] Fang Huang, D. L. (2011). Explorations of the implementation of a parallel IDW interpolation algorithm in a Linux cluster-based parallel GIS. 426-434.

[4] Gautam, S. (2020). Spatio-temporal variation in the concentration of atmospheric particulate matter: A study in fourth largest urban agglomeration in India.

[5] karar, k. A. (2008). Spatio-temporal characteristics of gaseous and particulate pollutants in an urban region of Kolkata, India. 103-118.

[6] Khouni, I. (2021). Use of GIS based Inverse Distance Weighted interpolation to assess surface water quality: Case of Wadi El Bey, Tunisia.

[7] Manob Das, A. D. (2021). Spatio-temporal concentration of atmospheric particulate matter (PM2.5) during pandemic: A study on most polluted cities of indo-gangetic plain.

[8] Morawska, L. (2021). The state of science on severe air pollution episodes: Quantitative and qualitative analysis.

[9] Naqvi, H. R. (2021). Spatio-temporal analysis of air quality and its relationship with major COVID-19 hotspot places in India.

[10] Ravindra, K. (2016). Air pollution trends over Indian megacities and their local-to-global implications. 475-495.