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Spatial Analysis of Air Pollution in Bhubaneswar City Using GIS for Sustainable Urban Planning

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Abstract

Territorial dynamics related to air pollution is a significant and growing concern in urban areas. A GIS approach was utilized in applying of French Onyon technique onto air pollution studies to indispensable attempts prevail occurrence and nonoccurrence level for distribution process over Bhubaneswar City, Odisha, India This study summarizes the results of ambient air quality data (from Academic year 2023, collected at six monitoring stations in the city) used to test for seasonal variation among other variables such as yearly maximum–minimum values and levels, annual average concentrations, standard deviation; Air Quality Index (AQI). The results are presented, which show that total suspended particulate matter (SPM), PM₁₀ and PM_{2.5}) Reads were beyond the permissible limits during Pre–monsoons. AQI was calculated at each monitoring station and showed that all places were in the range of polluted. Analysis in GIS provided a spatial estimate of high concentration localities and localized areas based on any individual pollutant. These results showed that traffic network, road conditions, population density and vehicle movement frequency play important roles in the air quality deterioration of study area. This work also shows the power of GIS in air quality assessment and suggests an important note for future sustainable urban planning actions to improve against pollution at Bhubaneswar–City, India.

Keywords: Air Pollution, Air Quality Index (AQI), GIS, Spatial Analysis, Sustainable Urban Planning.

1 Introduction

In India, air pollution has been a stubborn issue for almost 100 years now and its intensity seems to have heightened in the last two or three decades (Gupta et al., 2017). The main factors responsible for this decline are mainly population explosion, unorganized urbanization and industrial growth (Kumar et al., 2017). Bhubaneswar city, the capital of Eastern Indian State Odisha stands out no differently with air pollution growing up as a very aggravating problem pertaining to

almost all part of the city (Behera et al., 2019). The noisy urbanization of Bhubaneswar calls for a great mobilization due to excessive travel by vehicles results in maximum fuel consumption, thereby causing air pollution (Ghose et al., 2017). It is further enhanced by anthropogenic activities followed in construction, industries operations and waste management practices (Sahu et al., 2018).

Urban cities are the most affected by air pollution and a major proportion of the population living in urban areas has to deal with unhealthy quality of air, according to latest report (WHO 2018). Poor air quality is largely the result of high population density, heavy vehicular movement volumes and geographical features that lead to relatively weak transport network configurations in urban areas. Among these, vehicular movement is a major cause of air pollution that generates fine particles (<2.5 μm size), and the gaseous pollutants such as Hydrocarbon (HC), Polyaromatic hydrocarbons (PAHs), Benzene, Volatile organic compounds (VOC) excepting CO₂ emission (CEM, 1980). These pollutants can contribute to respiratory disorders, such as asthma and lung cancer (Pope et al., 2002). This one fact is lyophobic for those relocating to the city; Bhubaneswar has become too urban and over-populated with vehicles that emanate pollution into its pure air. Henceforth, it is very crucial to judge the condition of air pollution in city and comprehend those regions on which immediate attention is needed. The results can be useful to adopt proper measures for air pollution, and a green city.

Air Quality Index (AQI) is the most common scale used to know about how clean or polluted our air is. AQI is a number system designed to report air quality in five different levels: good, moderate, poor, very poor and hazardous (AS EPA, 2019) AQI is calculated using measurements of PM, NO₂, O₃ and CO in the air concentrations. Recently, Geographic Information Systems (GIS) and spatial analysis have attracted much attention regarding the impact of air pollution is focused through which individual's health (new State), as a tremendously chased topic. They generate maps of air pollution levels, showing this information over time and including the many diverse social and environmental aspects at play with air (Jerrett et al., 2017).

Thus it is essential to make plans of such urban planning that are sustainable in order to reduce the damages created from air pollutions in cities like Bhubaneswar. This calls for integrated strategies that look at the social, economic and environmental dimensions of urban development. In such way, cities help to minimize their environmental impact through the use of sustainable urban planning and improving air quality (UN Habitat, 2011) as well life standard.

A great deal of research has addressed and is available on GIS (Geographic Information System) applications in air quality mapping for many urban environments. Kumar et al. A comprehensive study was conducted by Sahoo et al. (2016) on mapping of air quality using GIS based technique and evaluated the economic status due to health problems arising from air pollution in Mumbai, India. GIS is an effective tool in visualizing spatial differences of air quality and its subsequent effects on public health – as was demonstrated by the team (Kumar et al., 2016). The method for the measurement of air pollution, especially Suspended particulate matter has been standardized by The Bureau of Indian Standards BIS in 1973 publication. Air pollutants are the substances which have to be measured using a framework of standard, according to BIS (1973), for achieving uniformity in measurement and accuracy so that data collection is convenient with appropriate analysis.

Bozyazi et al. (1980) studied GIS utilization on air pollution analysis and mapping in Istanbul. Mtiere's research was never completed but it showed the potential of GIS in delineating pollution hot spots and contaminant spatial distribution (Bozyazi et al., 1980). Similarly, Pandey et al. (2013) described the high-level use cases of GIS in air quality monitoring, highlighting its ability to

provide a more accurate and faster environmental evaluation than manual methods just as year because modern-day studies within this field. Lodge (1988) gave the detailing the principles, procedures and equipment used for air sampling has highlighted the significance of methods which provide accurate assessments. It is an essential resource for air quality management professionals and researchers (Lodge, 1988). Merryman et al. (1973) to assess particular techniques for measuring air contaminants that helped in the onset of exact and reliable chemical analysis procedures (Merryman et al., 1973).

Indicative of this was the description highlighted by Mohanty, (1999) in relation to ambient air quality status at Koraput as extrapolated for similar urban environments such as Bhubaneswar. These results reinforce the need for long-term monitoring and pollution control measure (Mohanty, 1999). Kanakiya et al. (2015) explained additionally the orientation of GIS for analysis and mapping of air pollutants in urban areas which could become a bit like an assessment means to identify most important consequences normally used by geographers or geo-statisticians (Kanakiya et al., 2015). West and Gaeke (1956) was the first to devise a method that is now considered fundamental in air quality analysis: fixation of sulfur dioxide followed by colorimetric estimation. The incorporation of such approaches in wider GIS technology can dramatically improve the accuracy and depth of our air quality evaluations.

Finally, according to the literature reviewed in this paper, GIS is considered important for spatial air pollution as well as being information useful during sustainable urban planning. The studies identified in this review describe how GIS can be used to map pollution, visualize patterns and hotspots of pollution exposure, inform policy making processes on air quality as well as its relations to public health. This study aims to evaluate the status of air quality; land use and pollution in Bhubaneswar city using GIS spatial analysis. The aim of this study is to evaluate the spatial distribution of air pollution in Bhubaneswar city, pinpoint hot spots with high levels of pollutant emissions and clarify associations between pollutants concentrations on one hand and environmental as well as socioeconomic factors at a local scale. The results of this study will also help in policy formulation for the urban planners, local authorities and state government to chalk out strategies towards abatement air pollution which should be sustainable development solutions (in case of Bhubaneswar city).

2 Methodology

2.1 Sampling Locations and Air Quality Monitoring

The air quality monitoring was carried out at six selected stations in Bhubaneswar, India. The stations were chosen based on major activity zones, including residential and industrial areas. A brief description of the activities around each monitoring station is provided in Table 1.

Table 1 Description of Sampling Locations

S. No.	Location	Area Type	Code	Surrounding Activities
1	SPCB Office Building, Unit VII	Residential and Commercial	L-01	Vehicular and commercial
2	IRC Village, Nayapali	Residential	L-02	Vehicular, residential, and NH-5 passing nearby
3	Capital Police Station, Unit I	Residential and Commercial	L-03	Vehicular, commercial, and residential
4	Patrapada	Residential	L-04	Vehicular, residential, and NH-5 passing nearby
5	Chandrasekharpur	Industrial	L-05	Industrial, residential, and vehicular
6	Palasuni Water Works	Industrial	L-06	Industrial, residential, and vehicular

2.2 Collection of Air Quality Data

Ambient air quality samples: Dust sampler respirable (RDS) and fine particulate samplers. Respirable particulate matter (<10 μm size) was collected in GF/A filter paper fixed in RDS and $\text{PM}_{2.5}$ particulate samplers. Gas samples were collected using gas sampling technique attachment connected to RDS. One newspaper old fashion paper was collected on a 24-hourly occasion at fortnight intervals in each one station all year round (Lodge, 1988). Table 2 summarized the description of sampling and analytical procedure for ambient air quality monitoring.

Table 2 Methods of Measurement for Different Parameters

S. No.	Parameter	Method of Measurement
1	SO_2 ($\mu\text{g}/\text{m}^3$)	Improved West and Gaeke method (West and Gaeke, 1956)
2	NO_x ($\mu\text{g}/\text{m}^3$)	Modified Jacob and Hochheiser method (Merryman et al., 1973)
3	SPM ($\mu\text{g}/\text{m}^3$)	Gravimetric (BIS, 5182, 1973)
4	PM_{10} ($\mu\text{g}/\text{m}^3$)	Gravimetric (BIS, 5182, 1973)
5	$\text{PM}_{2.5}$ ($\mu\text{g}/\text{m}^3$)	Gravimetric (BIS, 5182, 1973)
6	O_3 ($\mu\text{g}/\text{m}^3$)	Chemical method
7	NH_3 ($\mu\text{g}/\text{m}^3$)	Indophenol Blue Method

2.3 Standard Deviation

Standard deviation shows the variation of the results in a particular monitoring station by repeating the monitoring process several times under similar conditions. Standard deviation with respect to SPM, PM₁₀, PM_{2.5}, NH₃, O₃, and NO_x were calculated and shown in tables. The standard deviation of other gaseous pollutants like SO₂ is not calculated as the value of this pollutant is very less.

2.4 Air Quality Index (AQI)

Air Quality Index (AQI) is the simplest way of expressing air quality and lot a huge data into very small quantum by retaining all essential information to one value. The AQI value of any area is an indicator in the combination and can be intelligible by common people. The AQI was calculated by taking the geometric mean of air quality ratings for individual parameters monitored. Mathematically, the equations are written as (1) and (2), respectively:

$$Q (\text{Quality ratings}) = 100 * q / q_s \quad (1)$$

Where Q = quality ratings q = observed value q_s = prescribed standard.

$$\text{Air quality Index (AQI)} = \sqrt[n]{Q_1 * Q_2 * Q_3 * \dots * Q_n} \quad (2)$$

Where Q₁, Q₂, Q₃ are the quality ratings of different parameters.

On the basis of the AQI, the air quality categories are defined in Table 3.

Table 3 Air Quality Categories

AQI Value	Air Quality Category
0–50	Good
51–100	Moderate
101–200	Poor
201–300	Very Poor
301–400	Hazardous

2.5 Geographical Information System (GIS)

A GIS is a computer-based tool used for capturing, storing, analyzing, and displaying geographically referenced data. In this study, GIS was used to analyze the spatial distribution of air pollutants in Bhubaneswar. The GIS software used in this study was ArcGIS 10.1.

2.6 Creation of Shape Files and Thiessen Polygons

The uploaded points view file is converted into a shape file, producing polygons of sampling stations. But the data of air quality is considered for a particular place, so to estimate the value taken for polluting agent as average in entire region then we have created Thiessen polygons. Thiessen Polygons assigns the Value to whole polygon, which is similar that it makes very good for analyzing in order compare a variation.

2.7 Creation of Thematic Maps

For the pollutants, thematic maps are plotted. These maps assist in checking the change of a pollutant within three years, hence providing us an understanding as to why it has increased or decreased. This has given a platform to the decision-makers, for them to pinpoint methods of reducing the rising levels of pollutants.

3 Results and Discussion

The seasonal variations of air quality parameters, including SPM, PM₁₀, PM_{2.5}, SO₂, NO_x, O₃, and NH₃, were monitored at six locations in Bhubaneswar during 2023. The annual average values and standard deviations of these parameters are presented in Tables 4.

Table 4 Annual Average Value and Standard Deviation (SD) of Air Pollutants in ($\mu\text{g}/\text{m}^3$) at Bhubaneswar during 2023

S. No.	Location Code	SO ₂ (Range) (Average) (SD)	NO ₂ (Range) (Average) (SD)	NH ₃ (Range) (Average) (SD)	O ₃ (Range) (Average) (SD)	PM ₁₀ (Range) (Average) (SD)	PM _{2.5} (Range) (Average) (SD)
1.	L1	BDL-BDL	21.3- 14.7	43.8 -33.4	25- 34.1	59-195	26-89
		BDL-BDL	16.57	37.24	27.58	108.25	46
		BDL-BDL	1.77	3.74	2.45	48.28	20.91
2.	L2	BDL-BDL	12.4- 22.1	34.8-54	24.7- 31.6	42-183	22-69
		BDL-BDL	14.60	39.84	26.42	92.33	36.08
		BDL-BDL	2.85	5.01	1.79	43.12	15.95
3.	L3	BDL-BDL	14-21.4	37.6 -48.1	25.9 - 28.6	49 -198	23- 84
		BDL-BDL	17.20	43.49	27.33	108.83	43.25
		BDL-BDL	2.33	3.08	0.84	46.32	20.66
4.	L4	BDL-BDL	13.7- 24.5	30.5 -49.6	25.6 - 30.1	43 - 200	21 - 79
		BDL-BDL	17.88	39.17	27.29	115.4	45.25
		BDL-BDL	3.042	5.02	1.43	53.12	19.43
5.	L5	BDL-BDL	14.2- 19.1	41.3-52.9	25.4 - 30.6	49-193	22-100
		BDL-BDL	16.41	45.64	27.95	110.25	45.75
		BDL-BDL	1.60	3.45	1.99	50.32	25.11
6.	L6	BDL-BDL	12.8- 21.4	26.2-52	24.4 - 28.3	52-206	17-80
		BDL-BDL	16.62	37.93	26.61	112.16	41.75
		BDL-BDL	2.55	7.50	1.21	57.50	18.82

The air quality categories based on the Air Quality Index (AQI) are shown in Table 5. The AQI values ranged from 80 to 126, indicating that the air quality in Bhubaneswar was predominantly polluted to heavily polluted.

Table 5 Air Quality Categories Based on Air Quality Index (AQI)

Category	AQI of Ambient Air	Description of Ambient Air Quality
1.	Below 10	Very clean
2.	Between 10 and 25	Clean
3.	Between 25 and 50	Fairly clean
4.	Between 50 and 75	Moderately polluted
5.	Between 75 and 100	Polluted
6.	Between 100 and 125	Heavily polluted
7.	Beyond 125	Severely polluted

The air quality ratings and AQI values for each location are presented in Table 6. The results show that all locations exceeded the national ambient air quality standards for PM₁₀ and PM_{2.5}, with AQI values ranging from 85.62 to 91.12.

Table 6 Air Quality Ratings and Air Quality Index (AQI) With Categories of Different Locations of Bhubaneswar

S. No.	Location Code	SO ₂	NO ₂	O ₃	NH ₃	PM ₁₀	PM _{2.5}	AQI	Category
1.	L1	BDL	16.2	26.85	36.27	88.75	–	85.62	Polluted
2.	L2	BDL	87.36	26.71	41.29	83.87	32.12	80	Polluted
3.	L3	BDL	16.71	27.45	42.02	96.37	35.87	91.12	Polluted
4.	L4	BDL	16.45	27.74	39.02	95.37	37.62	90.25	Polluted
5.	L5	BDL	16.39	27.75	44.67	91.37	35	87.37	Polluted
6.	L6	BDL	16.20	26.68	38.77	97.22	34.25	90.87	Polluted

The concentration of pollutants during the pre-monsoon season (2023) is presented in Table 7. The results show that the AQI values ranged from 108.75 to 126, indicating heavily polluted to severely polluted air quality.

Table 7 Concentration of Pollutants in ($\mu\text{g}/\text{m}^3$) at Bhubaneswar during Pre Monsoon 2023

S. NO	Location Code	Particulate Matter			Gases			AQI	Category
		SO ₂	NO ₂	O ₃	NH ₃	PM ₁₀	PM _{2.5}		
1.	L1	BDL	16.8	27.375	35.65	116.75	–	110.5	Heavily polluted
2.	L2	BDL	162	27.95	42.075	116.5	39.5	108.75	Heavily polluted
3.	L3	BDL	18.35	28.025	40.95	132	43.75	121.5	Heavily polluted
4.	L4	BDL	17.45	27.475	38.05	131.75	50	121.5	Heavily polluted
5.	L5	BDL	17.75	2905	45.225	122.5	43.75	114	Heavily polluted
6.	L6	BDL	18.375	26.65	40.575	138.75	44	126	Severely polluted

The concentration of pollutants during the post-monsoon season (2023) is presented in Table 8. The results show that the AQI values ranged from 51.25 to 60.75, indicating moderately polluted air quality.

Table 8 Concentration of Pollutants in ($\mu\text{g}/\text{m}^3$) at Bhubaneswar during Post Monsoon 2023

S. NO	Location Code	Particulate Matter			Gases			AQI	Category
		SO ₂	NO ₂	O ₃	NH ₃	PM ₁₀	PM _{2.5}		
1.	L1	BDL	15.25	26.35	36.9	60.75	-	60.75	Moderately polluted
2.	L2	BDL	12.72	25.475	40.525	51.25	24.75	51.25	Moderately polluted
3.	L3	BDL	15.07	26.875	43.1	60.75	28	60.75	Moderately polluted
4.	L4	BDL	15.45	28.025	40	59	25.25	59	Moderately polluted
5.	L5	BDL	15.025	26.45	44.125	60.25	26.25	60.75	Moderate polluted
6.	L6	BDL	14.025	26.725	36.975	55.75	24.5	55.75	Moderately polluted

The national ambient air quality standards for various pollutants are presented in Tables 9 and 10. The results show that the monitored values exceeded the national standards for PM₁₀, PM_{2.5}, and NO_x.

Table 9 National Ambient Air Quality Standards(A/A/Q/S) Gazette Notification No. SO 384 (E) Air (PCP) Dated April 11, 1994, EPA-GSR 176 (E) April 2, 1996, SO 955 (E) Air (PCP) November 18, 2009

S. No.	Parameters ($\mu\text{g}/\text{m}^3$)	Time Average	Weighted	Industrial, Residential and Rural Area	Sensitive Area
1.	SO ₂	Annual*		50	20
		24 h**		80	80
2.	NO _x	Annual*		40	30
		24 h**		80	80
3.	PM ₁₀	Annual*		60	60
		24 h**		100	100
4.	PM _{2.5}	Annual*		40	40
		24 h**		60	60
5.	O ₃	8 h**		100	100
		1 h**		180	180
6.	NH ₃	Annual*		100	100
		24 h**		400	400

Note: * Annual arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hr at uniform interval.
 ** 24 hours/8 hourly values should be met 98% of the time in a year. However, 2 % of the time, it may exceed but not on two consecutive days.

Table 10 National Ambient Air Quality Standards(A/A/Q/S) Gazette Notification No. SO 384 (E) Air (PCP)Dated April 11, 1994, EPA-GSR 176 (E) April 2, 1996, SO 955 (E) Air (PCP) October 14, 1998

Pollutants	Time Weighted Average	Industrial	Residential , Rural and other Area	Sensitive Area
SO ₂	Annual*	80.0µ/m ³	60.00µ/m ³	15.00µ/m ³
	24 h**	120.0µ/m ³	80.00µ/m ³	30.00µ/m ³
NO _x	Annual*	80.0µ/m ³	60.00µ/m ³	15.00µ/m ³
	24 h**	120.0µ/m ³	80.00µ/m ³	30.00µ/m ³
SPM	Annual*	360.0µ/m ³	140.00µ/m ³	70.00µ/m ³
	24 h**	500.0µ/m ³	200.00µ/m ³	100.00µ/m ³
RPM	Annual*	120.0µ/m ³	60.00µ/m ³	50.00µ/m ³
	24 h**	150.0µ/m ³	100.00µ/m ³	75.00µ/m ³
Lead (Pb)	Annual*	1.0µ/m ³	0.75µ/m ³	0.50µ/m ³
	24 h**	1.5µ/m ³	1.00µ/m ³	0.75µ/m ³
NH ₃	Annual*	0.1µ/m ³	0.10µ/m ³	0.10µ/m ³
	24 h**	0.4µ/m ³	0.40µ/m ³	0.40µ/m ³
CO	Annual*	5.0µ/m ³	2.00µ/m ³	1.00µ/m ³
	24 h**	10.0µ/m ³	4.00µ/m ³	2.00µ/m ³

Note: * Annual arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hr at uniform interval.

** 24 hours/ 8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.

The standard deviation values for each parameter were calculated to determine the variation in the data. The results show that the maximum standard deviation occurred for PM₁₀ at Palasuni area and minimum standard deviation for PM₁₀ at IRC Village, Nayapally. Similarly, the maximum deviation of PM_{2.5} was observed near Chandrasekharpur area and minimum at IRC Village area. The maximum deviation of NO_x was found at Palasuni area. The maximum deviation of NH₃ was observed at Palasuni water work and minimum at Capital police station. The maximum deviation of O₃ was observed at SPCB, office and minimum at capital police station.

This suggests that Bhubaneswar has high levels of PM and gaseous pollutants in the air which is 2–3 times above National standards. Differences in the data show that air quality differs greatly from one location to another or between seasons. GIS maps are prepared for SO₂, NO₂, NH₃, O₃, PM₁₀, PM_{2.5} and AQI both in pre–monsoon and post–monsoon seasons and represented in Figure 1 and 2 respectively.

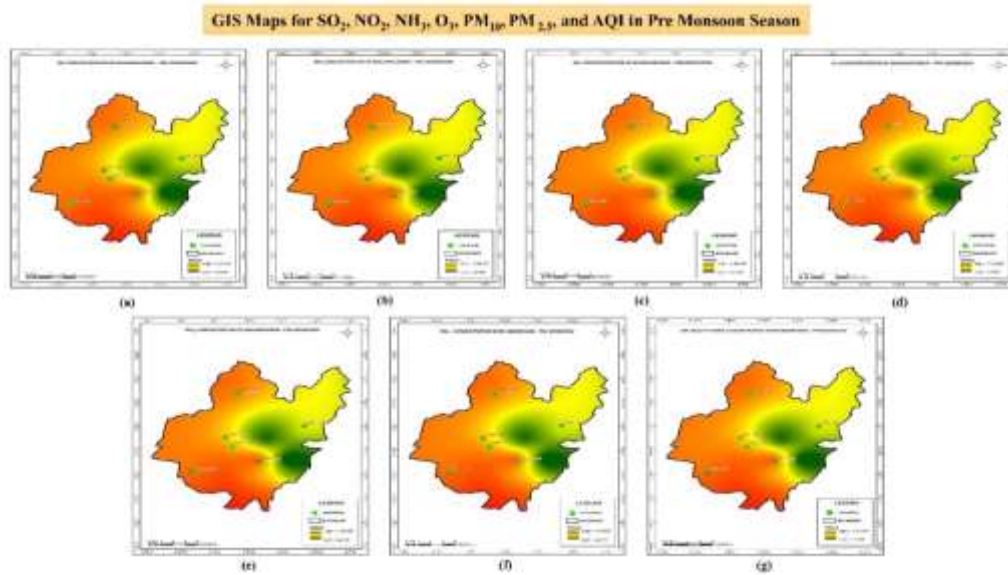


Figure 1 GIS maps in pre-monsoon for (a) SO₂, (b) NO₂, (c) NH₃, (d) O₃, (e) PM₁₀, (f) PM_{2.5} and (g) AQI

The Figure 1 shows the spatial distribution of different pollutants and Air Quality Index (AQI) during Pre-Monsoon Season based on GIS map. The figure includes eight maps: one map for each pollution level, and likely much the rest of AQI. The pollutants included are sulfur dioxide (SO₂), nitrogen dioxide (NO₂), ammonia (NH₃), particulate matter with a diameter less than 10 microns (PM₁₀), and particulate matter with a diameter less than 2.5 microns (PM_{2.5}). Each map is color-coded, with a gradient goes from green (low or healthy levels) to red (very high or unhealthy).

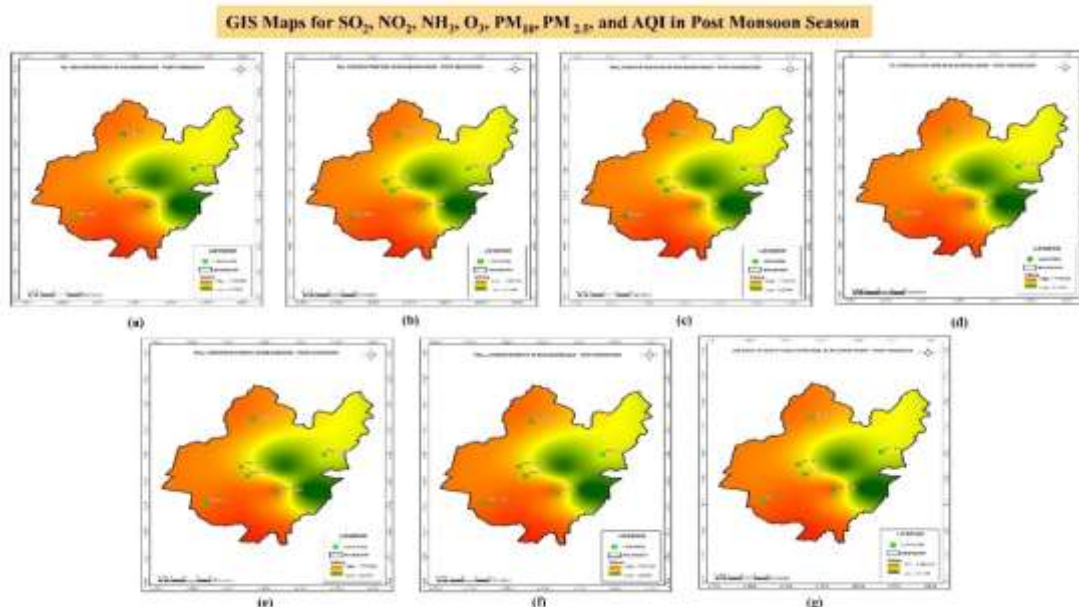


Figure 2 GIS maps in post-monsoon for (a) SO₂, (b) NO₂, (c) NH₃, (d) O₃, (e) PM₁₀, (f) PM_{2.5} and (g) AQI

This spatial distribution of the air quality indices for all pollutants during Post-Monsoon Season were depicted by Geographic Information System (GIS) maps have been presented in Figure 2 with respect to Bhubaneswar city. This chart contains six maps, one for each of the various pollutants and an overall Air Quality Index (AQI). The pollutants of interest were sulfur dioxide (SO₂), nitrogen

dioxide (NO₂), ammonia (NH₃) ozone, particulate matter with a diameter less than 10 micron (PM₁₀) and particulate matter that diameter greater than or equal to 2.5 micron (PM_{2.5}). The color scheme in each map varies between green (low concentrations/better air quality) to red (high concentration/worse air quality).

In Figure 1, we can see the PM₁₀ and PM_{2.5} were recorded at their maximum during the Pre-Monsoon season across all locations in Bhubaneswar. On the contrary, Figure 2 shows that these values were minimum for Post-Monsoon season. It was mostly from the vehicular emissions followed by NO_x being much higher than any other gaseous pollutant observed. At all sites and in the entire season other gaseous pollutants like SO₂, NH₃ and O₃ was below standard values. Results for all locations, the AQI values categorized by air quality category of each season were found with heavy pollution in both Pre-Monsoon Seasons During the Post-Monsoon season, however, all sites exhibited some level of pollution. The AQI of Bhubaneswar city remains in the poor category as a whole.

4 Conclusion

It was observed that the parameters exceed their limit values for all data (AQI) locations Bhubaneswar during Pre-Monsoon but with a minimum increase in Post-Monsoon season within respective limits. This difference may be due to the formation of temperature inversions and the lack of atmospheric dispersion. The reduced values during the monsoon season are likely due to initial rains in which pollutants have been washed out; Bhubaneswar has the AQI under polluted category due to vehicular pollution and unplanned enforcement of traffic control system. To solve this problem, strong pollution control has to be adopted as given below:

- Frequency of tunes (improvised) for all vehicles 28
- Employing of catalytic converters in exhaust systems.
- Periodical monitoring of car pollution levels.
- Strict enforcement of legislation to regulate vehicular air pollution and strict implementation
- Preventing and monitoring fuel adulteration.
- Better road conditions and traffic control systems.
- Advocacy campaigns for vehicular pollution and its disadvantages

Such remedial measures go a long way into improving air quality in the days to come. But if the steps to control vehicular emissions are not implemented locally, air quality in Bhubaneswar may fall further making it a very highly polluted city soon.

Future action: recommend measures to guarantee sustainable air quality enhancement

- Advanced Monitoring Systems — Implement state-of-the-art air quality monitoring systems to deliver real-time data, and facilitate quick action.
- Public Transport: Develop public transport infrastructure in order to decrease the private vehicle circulation.
- Green Initiatives: Encourage green initiatives like urban afforestation and electric vehicles.
- Policy Development: Develop and enforce restrictive measures to curb emissions from industrial processes as well as residential areas
- Research and Innovation: Promote research or innovation in pollution control rs assert that there were no financial or commercial links which could be construed as leading to a conflict of interest during the study. sustainable technologies and urban strategies.
- Community Engagement: Encourage community participation through various programs related to the improvement of air quality

If these steps are taken up Bhubaneswar can jump leaps and bounds in its efforts to clean the air becoming a healthier place for everyone.

Availability of data and materials

The author who is interested will share the datasets created and assessed in this study upon receiving a request.

Conflict of Interest

The authors claim that they had no commercial associations that could be considered as causing a conflict of interest while conducting the research.

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Ethical Approval

None of the authors of this article have carried out any studies involving humans or animals.

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References

- [1] Gupta, A. K., Kumar, R., & Kumar, V. (2017). Air pollution in India: A review. *Journal of Environmental Science and Health, Part C*, 35, 1–13.
- [2] Kumar, P., Kumar, V., & Mahapatra, S. K. (2017). Assessment of air quality in Bhubaneswar, India. *Journal of Environmental Science and Health, Part B*, 52(5), 349–356.
- [3] Behera, S. N., Sharma, M., & Balasubramanian, R. (2019). Air quality assessment in Bhubaneswar, India: A case study. *Atmospheric Pollution Research*, 10(4), 1241–1252.
- [4] Ghose, M. K., Paul, R., & Banerjee, S. K. (2017). Assessment of air pollution in Kolkata, India. *Journal of Environmental Science and Health, Part B*, 52(5), 341–348.
- [5] Sahu, S. K., Behera, S. N., & Sharma, M. (2018). Assessment of air quality in Odisha, India. *Journal of Environmental Science and Health, Part B*, 53(5), 341–348.
- [6] World Health Organization (WHO). (2018). Air pollution. Retrieved from <https://www.who.int/news-room/air-pollution>
- [7] Central Pollution Control Board (CEM). (1980). Air pollution in India. New Delhi: Central Pollution Control Board.
- [8] Pope, C. A., Burnett, R. T., Thun, M. J., Calle, E. E., Krewski, D., Ito, K., & Thurston, G. D. (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *Journal of the American Medical Association*, 287(9), 1132–1141.
- [9] United States Environmental Protection Agency (US EPA). (2019). Air Quality Index (AQI). Retrieved from <https://airnow.gov/index.cfm?action=aqibasics.aqi>
- [10] Jerrett, M., Turner, M. C., Beckerman, B. S., Pope, C. A., van Donkelaar, A., Martin, R. V., ... & Gapstur, S. M. (2017). Spatial analysis of air pollution and mortality in California. *American Journal of Respiratory and Critical Care Medicine*, 196(5), 613–624.
- [11] United Nations Human Settlements Programme (UN Habitat). (2011). Cities and climate change: Global report on human settlements 2011. London: Earthscan.

- [12] Kumar, A., Gupta, I., Brandt, J., Kumar, R., Dikshit, A. K., & Patil, R. S. (2016). Air quality mapping using GIS and Economic evaluation of health impact for Mumbai City, India. *Journal of the Air & Waste Management Association*, 66(5), 470–481.
- [13] BIS. (1973). *Method for Measurement of Air Pollutants, Suspended Particulate Matter (Part-4)*. New Delhi.
- [14] Bozyazi, E., et al. (1980). Analysis and mapping of air Pollution using a GIS approach: A case study of Istanbul.
- [15] Lodge, J. P. (Ed.). (1988). *Methods of Air Sampling and Analysis (3rd ed.)*. Lewis Publishers Inc.
- [16] Merryman, E. L., Spices, C. W., & Levy, A. (1973). Evaluation of Arsenite Modified Jacobs Hochheiser Procedure. *Environmental Science and Technology*, 7(11), 1056–1059.
- [17] Pandey, M., et al. (2013). Analysis & Application of GIS Based Air Quality Monitoring– State of Art. *International Journal of Engineering Research & Technology (IJERT)*, 2(12).
- [18] Mohanty, S. K. (1999). Ambient Air Quality Status in Koraput. *Indian Journal of Environmental Protection*, 19(3), 193–199.
- [19] Kanakiya, R. S., Singh, S. K., & Shah, U. (2015). GIS Application for Spatial and Temporal Analysis of the Air Pollutants in Urban Area. *International Journal of Advanced Remote Sensing and GIS*, 4(1), 1120–1129.
- [20] West, P. W., & Gaeke, G. C. (1956). Fixation of SO₂ as Sulfitomercurate (II) and subsequent Colorimetric Estimation. *Analytical Chemistry*, 28, 1816–1819.