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Research Article

Study of Spatio-temporal analysis of air pollution over Bhubaneswar city, Odisha, India using GIS

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Abstract

Air pollution is today's major problem in our modern society and several factors concur to create unfavorable condition for air pollutant dispersion. The study mainly utilizes the air pollution data collected from central pollution control board (CPCB) monitoring stations across Bhubaneswar. Ambient air quality was monitored with respect to dust particles like suspended particulate matter (SPM), particulate matter of size less than 10μ (PM 10) particulate matter of size less than 2.5μ (pm2.5) gaseous pollutants like sulfur dioxide (SO_2), oxides of Nitrogen (NO_X), Ozone (O_3) and Ammonia (NH_3) at six selected locations of Bhubaneswar for a period of one year (2023) on seasonal basis. The data obtained was further analyzed to assess the seasonal variation, maximum- minimum value, annual average standard deviation and Air Quality Index (AQI). From the analysis it was observed that during winter, the concentration of particulate matter like SPM, PM_{10} and $PM_{2.5}$ remained above the prescribed limit. The concentration of both particulate matter and gaseous pollutants were considered for computation of AQI at each monitoring location. In Bhubaneswar only two locations were in the heavily polluted category, whereas, for locations were in the polluted category and rest two are in moderately polluted category. These findings clearly indicate that traffic network, road conditions, density of population and frequency of vehicle movement are the prominent factors responsible for poor air quality of the study area. GIS is very useful for assessment of air quality. GIS has been used in the present study to map the various pollution data and analyze the area which are most affected by what type of pollutant and subsequent conclusion drawn for making the Bhubaneswar a safe and sustainable area to live in.

***Keywords**: AQI, Air Pollution, GIS, Monitoring*

1. Introduction

Air pollutions is almost a century old challenge in India. However, the last few decades have been severe, the primary cause of which can be attributed to rapid population growth unplanned urbanization and industrialization. Air pollution is a highly intensifying issue in Bhubaneswar city of Odisha, India which is engulfing almost each and every corner of the city mostly due to the human activities like rapid urbanization, increased vehicular activities leading to enormous amount of fuel consumption and all other activities like construction and other anthropogenic activities.

Air pollutions is one of the serious environmental concerns in urban cities where a majority of the population is exposed to poor air quality. Poor air quality in urban areas is due to high population density, frequency of vehicular movement, road conditions, traffic network, etc. Vehicular movement causes air pollution due to emission from auto exhaust containing very fine dust particle of size <2.5 μ and windborne fire road dust. The fine particles (<2.5 μ in size) emitted as smoke can cause respiratory diseases like asthma, lung cancer, etc. Vehicles emit gaseous pollutants like Hydrocarbons (HC) Polyaromatic Hydrocarbons (PAH) Benzene, and Volatile Organic Compounds (VOC) which are carcinogenic in nature. Due to rapid urbanizations, there was a sharp increase in the population and number of vehicles, deteriorating the air quality in both the cities. Therefore, it is imperative to assess the air quality status in both the cities. Based on the findings, measures can be taken to curb the problem of air pollution (CEM,1980).

2.Plan of Study

The air quality monitoring was carried out at six selected stations of Bhubaneswar. The stations were

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selected based on major activity zones like residential areas and industrial area. A brief description of activities around each of the monitoring stations is given in Tables1 and locations of each station in the study area in Figures.

Table 1: Brief Description of the Sampling Locations at Bhubaneswar

S.no	Name of the Location	Area Type	Code	Surrounding Activities
1	**SPCB Office Building, unit VII**	Residencial and Commercial	L-01	Vehicular and Commercia;
2	**IRC Village, Nayapali**	Residencial	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

2.1 Collection of air quality data

The ambient air quality samples were collected by using Respirable Dust Sampler (RDS) and fine particulate sampler. The respirable particulate matter (<10μ in size) was collected with GF/A/ filter paper fitted in RDS, and $PM_{2.5}$ particulate sampler. However, the gaseous samples were collected by gaseous sampling attachment fitted to RDS. The samples were collected on a 24-hourly basis at fortnight intervals in each station throughout the year (Lodge, 1988). A brief description of the sampling and analytical procedure for ambient air quality monitoring is summarized and the details on the method of analysis is shown in Table.

Table 3: Methods of Measurement for Different Parameters

S.no	Parameters	Methods of Measurement
1.	SO μg/m³	Improved West and Gaeke method
2.	NO μg/m³	Modified Jacob and Hochheiser method
3.	SPM μg/m³	Gravimetric
4.	PM_{10} μg/m³	Gravimetric
5.	$PM_{2.5}$ μg/m³	Gravimetric
6.	O_3 μg/m³	Chemical method
7.	NH_3 μg/m³	Indophenol Blue Method

SPM, PM_{10} and $PM_{2.5}$

Ambient air passing through the cyclone of RDS at a flow rate of 1.1-1.4 m³/ minimum where the heavier particles having a size more than 10μ were arrested by the pre weighed cup and the particles of size less than 10μ were collected by GF/A filter paper on an eight hourly basis for 24 hours. Particulate matter of size <2.5 μ was collected by Teflon filter paper of 47mm size in fine particulate samplers. The RSPM, i.e., PM_{10} and Non-Respirable Particulate Matter (NRPM) are calculated by taking the difference between initial and final weights of the filter paper and cup respectively and the total volume of air drawn during sampling. Then sum of RSPM and NRPM gives the SPM value (BIS, 5182,1973).

SO_2 and NO_X

SO_2 and NO_X were collected on four hourly basis for 24 hours by drawing air at a flow rate of 1 min/L through Potassium tetra-chloro-mercurate and sodium hydroxide and sodium arsenite solution (0.1 N) as an absorbent thermocouple. During sampling, the temperature of the impingers was maintained below 15° c by a thermocouple in order to avoid evaporation loss. SO_2 was determined by West- Gaeke Method (West and Gaeke, 1956), in the visible range at 560 nm and NO_X was determined by Jacobs Hochheiser's method (Merryman et al., 1973) in the visible range at 540 nm.

Ammonia (NH_3)

Ammonia was absorbed in 0.1 N of sulfuric acid to form ammonium sulfate. The concentration of ammonia is determined colorimetrically by the chemical reaction of phenol and alkaline sodium hypochlorite to produce indophenol, a blue dye. The reaction was accelerated by the additions of a catalyst, sodium nitroprusside. The absorbance was measured by spectrophotometer at 630 nm.

Ozone (O_3)

Ozone along with other oxidants in air liberates iodine when absorbed in 1% solution of potassium iodide buffered at Ph 6.8± 0.2. Iodine was determined colorimetrically by measuring absorption of Tri iodide at 352 nm.

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, PM_{10} ,PM $_{2.5}$, and NO_X were calculated and shown in Tables. The standard deviation of other gaseous pollutants like SO_2, NH_3 and O_3 were not calculated as the values of these pollutants were very less.

Air Quality Index (AQI)

AQI is the simplest form of expressing air quality of an area by reducing a large quantity of data by keeping all the essential information to a single value. The general public can easily understand the air quality of an area by knowing AQI value of that area (Mohanty, 1999.) AQI was found by taking geometric mean of air quality ratings of individual parameters monitored, the mathematical calculations are expressed below.

Q (Quality ratings) = 100*q/q_3

Where Q= quality ratings
q = observed value
q_3 = prescribed standard

Air quality Index (AQI) = $n\sqrt{Q1}, XQ2, XQ3 \ldots., n$

Where Q_1, Q_2, Q_3 are the quality ratings of different parameters.

On the basis of the AQI, the air quality categories are defined in Table. The quality ratings of different parameters and AQI of study area have been calculated.

2.2 Adding the data to the GIS software

The GIS software used here in this project is ARC GIS. Arc map is used for the further procedure of mapping. The excel sheet of the air quality data with the latitude and longitude details is added to the software and the file is right clicked to give the x-axis for longitudes and Y-axis for the latitudes which creates a point file locating the sampling stations in the form of points feature.

2.3 Creation of a shape files and Thiessen polygons

The added points view file is converted into a shape file forming polygons of sampling stations but the air quality data is taken at a particular place so to consider the value taken for a pollutant for the entire region Thiessen polygon are created which assigns the value to the entire polygon which is near to it making the analysis easy and to compare the variation.

2.4 Creation of Thematic maps

Thematic maps are prepared for the pollutants under study. These maps help in comparing the variation of a pollutant through a period of three years and helps to analyze the reason of increase in value or decrease and giving an opportunity for the decision makers to identify ways in which the increasing pollutants value can be controlled.

3.Results and Discussion

The season wise air quality parameters with respect to SPM, PM_{10}, $PM_{2.5}$, SO_2, NO_X, O_3 and NH_3 for the year 2023 in the six monitoring stations of Bhubaneswar (L1 to L6) are tabulated in tables. The seasonal variation annual. average and standard deviation values for the above parameters are shown in Tables. The new ambient air quality standards for SO_2, NO $_X$, $PM_{,10}$, $PM_{2.5}$, O_3, and $NH_{,3}$ are shown in Table- while SPM as per standard 200 μg/m^3 for residential and industrial area are shown in Table.

Table 4: Annual Average Value and Standard Deviation (SD) Of Air Pollutants in (μg/m3) at Bhubaneswar during 2023

S. No.	Location Code	SO2 (Range) (Average)	NO2 (Range) (Average)	NH3 (Range) (Average)	O3 (Range) (Average)	PM10 (Range) (Average)	PM2.5 (Range) (Average)
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

Table 6: 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

Table 7: 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

Table 9: Concentration of Pollutants in (μg/m3) at Bhubaneswar During Pre-Monsoon 2023

S. No	Location Code	Particulate Matter			**Gases**				
		SO_2	NO_2	O_3	NH_3	PM_{10}	$PM_{2.5}$	AQI	Category
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

Table 10: Concentration of Pollutants in ($\mu g/m^3$) at Bhubaneswar During Post-Monsoon 2023

S. No	Location Code	Particulate Matter			Gases				
		SO_2	NO_2	O_3	NH_3	PM_{10}	$PM_{2.5}$	AQI	Category
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

Table 15: National Ambient Air Quality Standards (NAAQS) 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 (μg/m3)	Time Weighted Average	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 hours 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 16: National Ambient Air Quality Standards (NAAQS) 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

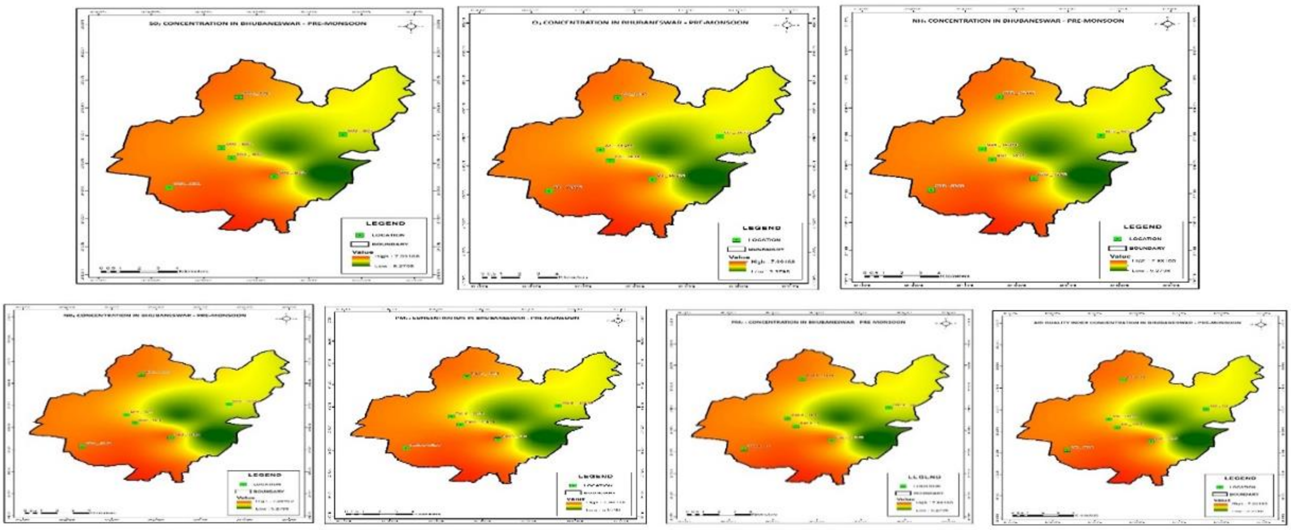
Pollutants	Time Weighted Average	Industrial	Residential, Rural and other Area	Sensitive Area
SO_2	Annual*	$80.0\mu/m^3$	$60.00\mu/m^3$	$15.00\mu/m^3$
	24 h**	$120.0\mu/m^3$	$80.00\mu/m^3$	$30.00\mu/m^3$
NO_X	Annual*	$80.0\mu/m^3$	$60.00\mu/m^3$	$15.00\mu/m^3$
	24 h**	$120.0\mu/m^3$	$80.00\mu/m^3$	$30.00\mu/m^3$
SPM	Annual*	$360.0\mu/m^3$	$140.00\mu/m^3$	$70.00\mu/m^3$
	24 h**	$500.0\mu/m^3$	$200.00\mu/m^3$	$100.00\mu/m^3$
RPM	Annual*	$120.0\mu/m^3$	$60.00\mu/m^3$	$50.00\mu/m^3$
	24 h**	$150.0\mu/m^3$	$100.00\mu/m^3$	$75.00\mu/m^3$

Lead (Pb)	Annual*	1.0μ/m³	0.75μ/m³	0.50μ/m³
	24 h**	1.5μ/m³	1.00μ/m³	0.75μ/m³
NH_3	Annual*	0.1μ/m³	0.10μ/m³	0.10μ/m³
	24 h**	0.4μ/m³	0.40μ/m³	0.40μ/m³
CO	Annual*	5.0μ/m³	2.00μ/m³	1.00μ/m³
	24 h**	10.0μ/m³	4.00μ/m³	2.00μ/m³
Note: * Annual arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hours 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.				

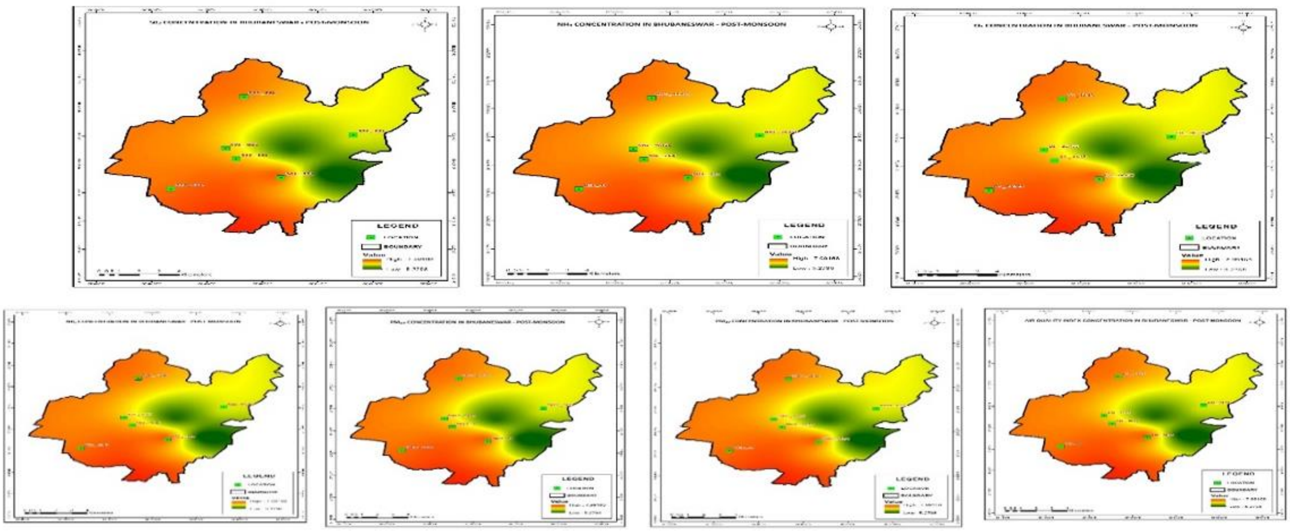
It was observed that maximum standard deviation occurs for both SPM and PM_{10} at Palasuni area and minimum standard deviation for SPM and PM_{10} at IRC village, Nayapally respectively. Similarly, maximum deviation of $PM_{2.5}$ near Chandrasekharpur area and minimum at IRC Village area. For NO_X maximum deviation at Palasuni area at Chandrasekharpur area. The maximum standard deviation indicates that there was a wide variation among data from the mean value. While minimum standard deviation value indicates that all values are nearer to the mean value. Maximum deviation of NH3 was found at Palasuni water work and minimum at Capital police station. Similarly maximum deviation of O3 was observed at SPCB, office and minimum at capital police station.

GIS maps are prepared for SO2, NO2, NH3, O3, PM_{10}, $PM_{2.5}$, and AQI both in pre-monsoon and post-monsoon seasons. And represented through figures.

Pre-Monsoon 2023



Post-Monsoon 2023



It was observed that PM10 and PM 2.5 values in pre-monsoon was maximum, and during post- monsoon it was minimum at all locations in Bhubaneswar

Higher NO_X values were observed when compared to other gaseous pollutants. This was due to vehicular pollution. The other gaseous pollutants like SO_2 , NH_3 and O_3 at all locations in all seasons were below the standard values.

Based on the quality rating of individual parameters, AQI at all locations of Bhubaneswar were calculated and tabulated in Tables 7 and 8 respectively. The AQI values when compared with the air quality categories in Table 6, it was observed that during pre-monsoon season all the locations are heavily polluted, but in post monsoon season all the locations are moderately polluted. Overall AQI of Bhubaneswar city falls under polluted category.

Conclusion

From the observed data and AQI values at different locations in Bhubaneswar it was observed that all parameters are more than the respective values during pre-monsoon and within prescribed limit in post-monsoon season. This may be due to the inversion of temperature and non-dispersion of pollutants in the atmosphere. The minimum values during monsoon may be due to wash –out effect of the pollutants during the first and second rains. It was observed that over all AQI of Bhubaneswar falls under polluted category, mainly due to vehicular pollution and unplanned traffic control system. Efficient pollution control measures with respect to vehicular pollution are to be stringently followed like: (1) Regular tuning of all types of vehicles; (2) Use of catalytical converter in exhaust system; (3) Regular check of the pollution level of the vehicle; (4) Ensuring stringent law to check vehicular pollution and their proper implementation; (5) Checking the adulteration of fuel;(6) Improving the road conditions and traffic control systems; and (7) People should be made aware regarding vehicular pollution and its harmful effects. The remedial measures in controlling air pollution in vehicles will definitely improve the problems in future. However, if nothing tangible is done with respect to vehicular pollution, air quality in Bhubaneswar city will deteriorate further to severely polluted category in the near future.

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