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Assessment of Heavy Metal Concentrations in Ambient Air of Bhubaneswar, India

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A B S T R A C T

A study was carried out to determine the concentration of heavy metals like cadmium, Copper, Nickel, Zinc, Lead, Manganese and Iron present in ambient air of capital city of Odisha, Bhubaneswar. Simultaneously particulate matter like PM_{10} and $PM_{2.5}$ and gaseous pollutants like SO_2, NO_x, O_3, and NH_3 were also monitored on seasonal basis while heavy metals were collected once a year. The obtained results were reflected and compared with the Ambient Air Quality standards prescribed by the Minister of Environment and Forest (MoEF). The concentration of lead at all locations was found to be within the limits i.e. 0.5 µg/m3. Similarly nickel concentration was also detected below the limit i.e. 20 µg/m3. In the ambient air of Bhubaneswar heavy metals like cd is in the range of 0.0036-0.0084, Cu-0.0079-0.0136, Ni-0.0173-0.02554, Zn-0.1213-0.1641, Pb-0.1259-0.2492, Mn-0.10058-0.145, Fe-1.2767-1.7158. From the study it was found that the concentration of heavy metals in the ambient air is low except iron. The seasonal range and annual average of particulate matter as well as gaseous pollutants of all the locations were calculated and compared with the Ambient Air Quality Standards (NAAQMS, 2005).

Introduction

Air pollution is a matter of utmost concern due to its potential to cause significant harm to both human and environmental health. Unregulated industrial expansion and the relentless growth of urban have pushed this problem beyond geographical boundaries and have endured for decades (1). One in every eight individuals succumbs to the effect of air pollution (2), which reveals the gravity of the situation. According to WHO report approximately 91% of the global population reside in urban areas where pollutants level exceed recommendation guidelines. (3). The consequence of air pollution manifest in various forms, with lung disease account for 23% of related fatalities followed by cardiovascular disease (19%), ischemic disease (24%), and stoke (21%) (4). Among the array of air pollutants studied extensively nitrogen oxide, sulfur oxides, stratospheric ozone and atmospheric particulates stand out as they not only pose direct threat to human health but also cause environmental degradation and contribute to climate change. (5).

Air born particulates, including $PM_{2.5}$ and PM_{10} represents a complex merger of tiny solid particles and liquid droplet that remain suspended in the atmosphere, shaped by atmospheric processes (6).$PM_{2.5}$ bound heavy metals variety of sources, primarily stemming from human activities and natural processes. Additionally, vehicular exhaust and construction activities contribute to these pollutants in urban areas. Inhaling $PM_{2.5}$ presents a significant harm to human health because characterized by a surge in these fine particles easily infiltrate the respiratory system, accumulating in the innermost lung regions and potentially causing respiratory issues (7). Recent study emphasized the gravity of this issue, with countries like Bangladesh, India, Pakistan in south Asia facing the problem of air quality (8). Notably the air quality of capital city of Odisha state of India is also deteriorating day by day. Rapid urbanization coupled with population explosion has given rise to an unhealthy environment characterized by a surge in anthropologic emission (9).

An attempt has been made to assess the existing ambient air quality status and to suggest measures for abatement of air pollution. The ambient air quality monitoring was carried out at Bhubaneswar city. The stations were selected on the basis of major activities of the city like residential and industrial. A brief description of the activities around each monitoring station are given in table-1.

Collection of sample and method of analysis

For heavy metal analysis the dust particles are collected over EPM-2000 filter paper of Whatman make on 24 hourly basis in respirable dust sampler. The filter paper is subjected to digestion with nitric acid (500 ml water with 2.5ml cone. $HN0_3$), and evaporated till the volume educes to 30ml. The sample was filtered and the volume was diluted with distilled water and made to 500ml. The sample was then analysed in Atomic Absorption Spectrophotometer to find out different toxic heavy metals. The methods of analysis are given in Table -2 (De, A.K 1994).

Particulate Matter & Gaseous Pollutants

The particulate matter PM_{10} & $PM_{2.5}$ were collected by the help of Respirable dust sampler and fine particulate sampler respectively. Both the instruments are operated simultaneously to find out the PM_{10} & $PM_{2.5}$ under same conditions. PM10 particulate was collected over a GF/A filter paper while $PM_{2.5}$ was collected by Teflon filter paper. The concentration of particulate matter was determined by gravimetric method. The gaseous pollutants like $S0_2$, NO_x, 0_3, NH_3 of the ambient air are absorbed in the absorbing solution taken in the impingers fitted in the respirable dust sampler. Then the samples are analysed by colorimetric method after adding suitable reagent for colour development.

Air quality monitoring was conducted at six selected locations in Bhubaneswar, chosen to represent key activity zones, including residential and industrial areas. Detailed descriptions of the activities surrounding each monitoring station are provided in Table 1

Result and Discussion

The air quality parameters, including Suspended Particulate Matter (SPM), Particulate Matter (PM_{10}), Particulate Matter ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen oxides (NO_X), ozone (O_3), and ammonia (NH_3) concentrations, were analyzed for the year 2023 at six monitoring locations (L1 to L6) across Bhubaneswar. The seasonal variations, as well as the annual average and standard deviation values for these parameters, are summarized in various tables. The results highlight the regional air quality status and provide valuable insight into pollution trends throughout the year.

Table 3 presents the annual average and standard deviation (SD) values for various air pollutants measured across six locations (L1 to L6). The data reveal distinct patterns in pollutant concentrations across the city.

For instance, PM_{10} and $PM_{2.5}$ showed considerable variation in their ranges and averages, with L1 reporting the highest PM_{10} concentration (108.25µg/m³) and L6 exhibiting a lower average $PM_{2.5}$ concentration (41.75µg/m³). The pollutant with the highest variation across locations was NO_2, which ranged from 12.4µg/m³ to 87.36µg/m³.

The concentrations of lead at all locations were found to be within the limits i.e. 0.5µg/m3. Similarly nickel concentration was also detected below the limit i.e. 20 µg/m3. In the ambient air of Bhubaneswar heavy metals like cd is in the range of 0.0036-0.0084, Cu-0.0079-0.0136, Ni-0.0173-0.02554, Zn-0.1213-0.1641, Pb-0.1259-0.2492, Mn-0.10058-0.145, Fe-1.2767-1.7158. From the study it was found that the concentration of heavy metals in the ambient air is low except iron.

Table.1 Brief Description of the Sampling Locations at Bhubaneswar

Sl. No.	Name of the Location	Area Type	Code	Surrounding Activities
1	**SPCB Office Building, Unit VIII**	Residential and Commercial	L-01	Vehicular and Commercial
2	**IRC Village, Nayapali**	Residential	L-02	Vehicular, residential, and NH-5 passing near by
3	**Capital Police Station, Unit I**	Residential and Commercial	L-03	Vehicular, Commercial
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

Samples were collected over 24- hour intervals at fortnightly intervals throughout the year (Lodge, 1988). Table 2 summarizes the methods used for measuring different air quality parameters.

Table.2 Methods of Measurement for Different Parameters

Sl. No.	Parameters	Methods of Measurement
1.	SO $\mu g/m^3$	**-Improved West and Gaeke Method** **-Ultraviolet Fluorescence**
2.	NO $\mu g/m^3$	**- Modified Jacob & Hochheiser Method** **-Gas Phase Chemiluminescence**
3.	SPM $\mu g/m^3$	**-Gravimetric** **-TEOM (Tapered element oscillating microbalances)** **-Beta attenuation**
4.	PM_{10} $\mu g/m^3$	**-Gravimetric** **-TEOM (Tapered element oscillating microbalances)** **-Beta attenuation**
5.	$PM_{2.5}$ $\mu g/m^3$	**-Gravimetric** **-TEOM (Tapered element oscillating microbalances)** **-Beta attenuation**
6.	O_3 $\mu g/m^3$	**-UV Photometric** **-Chemiluminescence** **-Chemical Method**
7.	**NH_3 $\mu g/m^3$**	**-Chemiluminescence** **-Indophenol method**

Table.3 Annual Average Value and Standard Deviation (SD) Of Air Pollutants in (µg/m3) at Bhubaneswar during 2023

Sl. 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	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	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	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	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	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	**2.55**	**7.50**	**1.21**	**57.50**	**18.82**

Table.4 National Ambient Air Quality Standards (A/A/Q/S) Gazette Notification No. SO 384 (E) Air (PCP) dt. 11.04.94, EPA-GSR 176 (E) 02.04.96, S.0.955 (E) Air (PCP) 14.10.98

Pollutants	Time Weighted Average	Industrial	Resident, Rural and Other area	Sensitive Area
$S0_2$	Annual*	80mg/m^3	60 mg/m^3	15 mg/m^3
	24 hours**	120 mg/m^3	80 mg/m^3	30 mg/m^3
NO_x	Annual*	80 mg/m^3	60 mg/m^3	15 mg/m^3
	24 hours**	120 mg/m^3	80 mg/m^3	30 mg/m^3
SPM	Annual*	360 mg/m^3	140 mg/m^3	70 mg/m^3
	24 hours**	500 mg/m^3	200 mg/m^3	100 mg/m^3
RPM	Annual*	120 mg/m^3	60 mg/m^3	50 mg/m^3
	24 hours**	150 mg/m^3	100 mg/m^3	75 mg/m^3
Lead (Pb)	Annual*	1.0 mg/m^3	0.75 mg/m^3	0.50 mg/m^3
	24 hours**	1.5 mg/m^3	1.00 mg/m^3	0.75 mg/m^3
NH_3	Annual*	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3
	24 hours**	0.4 mg/m^3	0.4 mg/m^3	0.4 mg/m^3
CO	Annual*	5.0 mg/m^3	2.0 mg/m^3	1.0 mg/m^3
	24 hours**	10.0 mg/m^3	4.0 mg/m^3	2.0 mg/m^3

• 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.5 National Ambient Air Quality Standards (AM/Q/S) Gazette Notification No. SO 384 (E) Air (PCP) dt. 11.04.94, EPA-GSR 176 (E) 02.04.96, S.O. 955 (E) Air (PCP) 18.11.2009

Sl. No	Parameters	Time Weighted Average	Industrial, Residential, Rural area	Sensitive area
1	SO_2 (µg/m^3)	Annual*	50	20
		24 hours**	80	80
2	NO_x (µg/m^3)	Annual*	40	30
		24 hours**	80	80
3	PM_{10} (µg/m^3)	Annual*	60	60
		24 hours**	100	100
4	$PM_{2.5}$ (µg/m^3)	Annual*	40	40
		24 hours**	60	60
5	O_3 (µg/m^3)	Annual*	100	100
		24 hours**	180	180
6	NH_3 (µg/m^3)	Annual*	100	100
		24 hours**	400	400
7	Lead (µg/m^3)	Annual*	0.5	0.5
		24 hours**	1	1
8	CO (mg/m^3)	Annual*	2	2
		24 hours**	4	4
9	Nickel (Ni) (ng/m^3)	Annual*	20	20

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.6 Heavy Metal Content in Ambient Air of Bhubaneswar City

Sl. No.	Location	Cd (µg/m3)	Cu (µg/m3)	Ni (ng/m3)	Zn (µg/m3)	Pb (µg/m3)	Mn (µg/m3)	Fe (µg/m3)
1	L-01	0.00525	0.012833	0.025417	0.164167	0.249091	0.141583	1.715833
2	L-02	0.003571	0.010333	0.023083	0.151667	0.206364	0.132	1.575
3	L-03	0.005	0.008833	0.02	0.136333	0.18	0.11625	1.480833
4	L-04	0.003714	0.007917	0.017333	0.121333	0.125889	0.100583	1.276667
5	L-05	0.008375	0.013583	0.024583	0.162833	0.229091	0.145	1.691667
6	L-06	0.005143	0.0085	0.017417	0.130833	0.146	0.1065	1.35

In conclusion, the analysis reveals substantial seasonal variation in air quality across Bhubaneswar. Notably, particulate matter (PM_{10} and $PM_{2.5}$) levels were highest during the pre-monsoon season, which can be attributed to reduced rainfall and increased dust emissions. The post-monsoon period saw a marked decrease in particulate levels, likely due to improved dispersion and removal of pollutants by rainfall.

Gaseous pollutants like NO_X were consistently higher across all monitoring locations, reflecting the contribution of vehicular emissions, which are a significant source of NO_X in urban environments. SO_2, NH_3, and O_3 concentrations were generally below the permissible limits, indicating that these pollutants were less of a concern during the study period. The higher deviation observed for NO_X and NH_3 at some locations

(e.g., Palasuni) suggests localized sources of pollution, possibly from traffic and industrial activities. Air Pollution with respect to dust particle is severe during winter due to non dispersion of pollutants. The heavy metals like Cd, Ni, Cu, Zn, Lead, Manganese and Iron are found in the atmosphere mostly come from vehicular emissions. It was observed that ambient air qualities for nickel at all locations are less than the prescribed standard is 20 µg/m3 in study area. It is time that necessary steps have to be taken to improve the ambient air quality. The first steps towards improvement of air quality is to reduce the number of vehicles both petrol and diesel driven , regular tuning of vehicles, use of catalytic converter, regular check-up of pollution level of the vehicles as well as adulteration of fuel, improving road condition and traffic control systems. Steps have to be taken to adopt CNG system in the engine and make it mandatory for all vehicles. This will certainly improve the air quality in future.

Author Contributions

Somen Das: Investigation, formal analysis, writing—original draft. Hemanta Kumar Patra: Validation, methodology, writing—reviewing. Bijaya Kumar Padhi:—Formal analysis, writing—review and editing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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