



Statistical Approach to Study the Ambient Air Quality Parameters in Bileipada, Keonjhar, Odisha, India

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Abstract

Monitoring and assessment of ambient air quality within a definite interval of time is the only way to find out the existing atmospheric conditions and the source of emissions. The monitoring of different parameters such as PM₁₀, PM_{2.5}, SO₂ and NO₂ were carried out for a period of three years covering all seasons starting from March, 2013 to Feb' 2016. The total collection and monitoring methods were executed as per the standard methods of CPCB. For better analysis one-way and two-way analysis of variance (ANOVA) test has been applied to different monitored results based on different monitoring stations and seasons. In two-way ANOVA test for stations, the F values computed as 34.028, 35.362, 34.113 and 29.090 for PM₁₀, PM_{2.5}, SO₂ and NO₂ respectively are found to be highly significant (at P<0.01). Further due to variations in seasons the F were values computed to be 280.290 (PM₁₀), 225.626 (PM_{2.5}), 306.569 (SO₂) and 100.281 (NO₂) which indicate that there is a significant variation in different parameters. This study can provide a platform to new researcher in the field of air quality monitoring in other areas.

Keywords: Ambient Air Quality; Air Pollutants; ANOVA; DMRT

1. Introduction

Now a day it is the top most priority to focused more on the environmental issues related to air pollution and its effect to the nearby areas as well as to the habitation [1-3]. Both natural and manmade sources contributed different types of air pollutants to the atmosphere in a maximum extent [4-6]. Many researches have been carried out in different areas of the world and the outcome from the research has been implemented to fight against air pollution [7-9]. Because of the industrialization activities in developing countries, air pollution emerged as an important issue which directly impact the atmosphere and disturbed the ecological cycle of the area [10-11]. To eradicate the problems more technical research has been carried out with the reference to different air pollutants based upon regional differences and their characteristics [12-16]. For better assessment many study carried out with the help of mathematical tool to calculate the air quality index which helps to find out the existing atmospheric conditions [17-22]. With the help of AQI values, one can be able to take mitigate measures against the sources of pollution and control over level of air pollution [23-25]. To find out the atmospheric effects to the peripheral environment of the industrial and mining complexes due to air pollution, air quality dispersion modeling has been made with the help of advanced gaussian model [26-27].

2. Materials & Methods

2.1. Study area

Bileipada, the study area is located at 22° 3' 43.2216" latitude and 85° 28' 31.0368" longitude in Keonjhar district of Odisha state is surrounded with plenty of industrial and mines complexes (Fig.1). To carried out a detailed study with respect to find out the air quality status, eight monitoring stations were established as per the guidelines by CPCB, Government of India and data has been collected for three years i.e. from March' 2013 to Feb' 2016. Table 1 shows the details of ambient air quality monitoring stations in the study area.

2.2. Sampling methodology

Parameters such as PM₁₀, PM_{2.5}, SO₂ and NO₂ has been analyzed as per the standard guidelines stipulated by CPCB, Govt. of India (CPCB, West and Gaeke, 1956; Jacob and Hochheiser, 1958). Details of parameters monitored with analysis methods were given in Table 2.

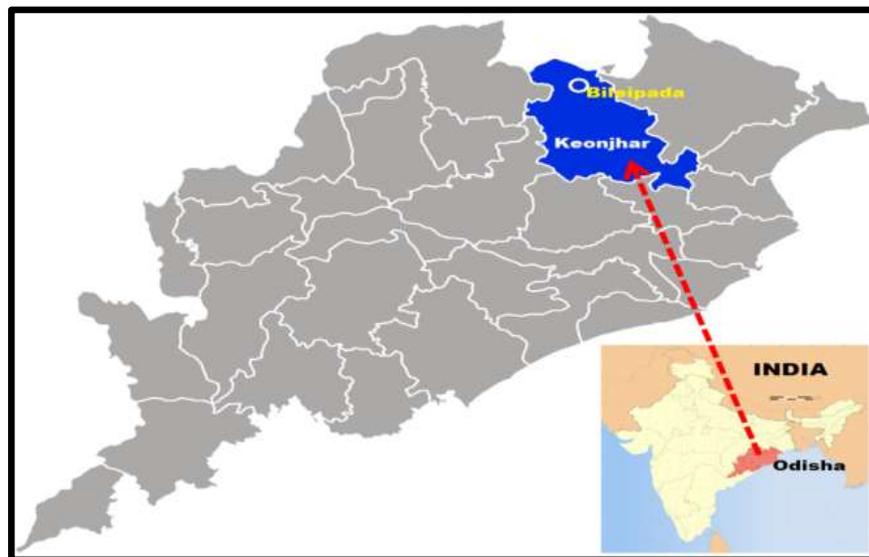


Fig.1: Study area

Table 1: Details of Ambient Air Quality Monitoring Stations.

Sampling Stations (SS)	Latitude	Longitude	Direction
SS-1	22.093694	85.478722	NNE
SS-2	22.085722	85.480638	E
SS-3	22.079527	85.478583	SE
SS-4	22.084944	85.469944	S
SS-5	22.116555	85.468611	N
SS-6	22.078083	85.497416	E
SS-7	22.073000	85.455638	SW
SS-8	22.086944	85.473333	WNW

Table 2: Details of Experimental Methods and formula used for Ambient Air Monitoring.

Parameter	Experimental method	Formula Used	Remarks
PM ₁₀	Gravimetric	$C_{PM_{10}} \mu\text{g}/\text{m}^3 = (W_f - W_i) \times 10^6 / V$	W _f : Initial weight of filter in g W _i : Initial weight of filter in g
PM _{2.5}	Gravimetric	$C_{PM_{2.5}} \mu\text{g}/\text{m}^3 = (W_f - W_i) \times 10^6 / V$	10 ⁶ : Conversion of g to μg V: Volume of air sampled, m ³
SO ₂	Impinger collection, West and Gaeke 1956	$C(\text{SO}_2 \mu\text{g}/\text{m}^3) = [(A_s - A_b) \times CF \times V_s] / V_a \times V_t$	A _s : Absorbance of sample A _b : Absorbance of reagent blank CF: Calibration factor
NO ₂	Impinger collection, Jacobs and Hochheiser 1958	$C(\text{NO}_2 \mu\text{g}/\text{m}^3) = [(A_s - A_b) \times CF \times V_s] / V_a \times V_t \times 0.82$	V _s : Volume of air sampled, m ³ V _a : Volume of sample, ml V _t : Volume of aliquot taken for analysis, ml 0.82: Sampling Efficiency

3. Results and Discussion

Table 3 shows the average concentrations of different ambient air quality parameters with reference to stations based on different season i.e. summer, monsoon and winter. The data has been monitored for consecutive three years starting from March' 2013 and ends on Feb' 2016.

For better interpretation of the monitored results for consecutive three years, statistical analysis has been carried out by using different test (one way and two way analysis of variance) for different parameters with respect to different stations and seasons. After application of two way ANOVA to different stations, the F values computed as 34.028, 35.362, 34.113 and 29.090 for PM₁₀, PM_{2.5}, SO₂ and NO₂ respectively due to stations which found

highly significant (at P<0.01). Further to this F values computed due to variation in seasons were 280.290, 225.626, 306.569 and 100.281 for the above mentioned parameters respective implicates a remarkable variation in different parameters due to variations in seasons (Table 4)

Table 3: Average Concentrations ($\mu\text{g}/\text{m}^3$) of different parameters based on different Season

Sampling Stations (SS)	Avg. concentrations ($\mu\text{g}/\text{m}^3$)											
	Summer 2013-14				Summer 2014-15				Summer 2015-16			
	PM ₁₀	PM _{2.5}	SO ₂	NO ₂	PM ₁₀	PM _{2.5}	SO ₂	NO ₂	PM ₁₀	PM _{2.5}	SO ₂	NO ₂
SS-1	72.4	31.9	10.7	12.9	79.7	41.1	14.7	18.8	138.8	69.5	17.8	21.1
SS-2	78.9	37.2	11.3	13.8	102.6	48.7	18.6	22.8	156.5	77.6	22.7	25.5
SS-3	73.1	34.4	10.9	13.5	98.7	47.2	16.1	21.2	154.6	76.4	21.3	23.7
SS-4	64.6	29.3	9.8	11.8	72.4	35.8	12.2	16.4	111.4	54.1	16.1	18.3
SS-5	66.7	32.5	11.4	13.7	78.8	36.2	12.7	17.3	130.6	68.2	17.9	20.2
SS-6	58.3	23.3	9.9	12.4	67.8	33.5	11.8	18.5	104.7	51.3	15.8	19.1
SS-7	55.9	19.6	8.2	11.1	60.8	30.0	9.3	13.2	63.5	29.5	9.9	11.8
SS-8	68.6	31.9	12.6	14.9	61.3	32.8	11.0	17.2	64.8	30.1	10.8	12.8
	Monsoon 2013-14				Monsoon 2014-15				Monsoon 2015-16			
SS-1	43.6	19.2	8.1	10.6	47.4	20.9	8.4	12.6	66.7	33.3	13.5	15.9
SS-2	49.4	23.1	8.4	11.2	56.6	29.5	10.1	14.3	69.5	34.1	13.4	15.8
SS-3	40.6	18.7	8.6	11.6	52.8	22.5	8.9	12.9	82.6	45.2	14.2	16.5
SS-4	37.5	18.4	7.9	10.8	48.8	24.0	8.4	11.8	57.1	27.1	10.8	12.9
SS-5	35.8	15.6	7.5	10.2	41.4	21.5	8.9	12.3	72.2	37.4	11.8	14.2
SS-6	33.1	15.5	6.4	8.9	40.4	18.3	8.1	11.9	62.1	29.9	11.1	13.3
SS-7	31.5	14.7	7.1	9.7	42.3	17.3	8.1	12.0	45.9	21.3	9.5	12.2
SS-8	42.9	19.9	7.6	10.1	39.3	18.7	7.9	11.6	41.4	20.1	8.8	10.8
	Winter 2013-14				Winter 2014-15				Winter 2015-16			
SS-1	85.2	38.4	13.8	12.9	88.1	43.8	18.2	16.8	145.3	70.4	18.8	17.6
SS-2	86.9	42.2	14.6	13.5	99.9	50.2	20.6	18.8	164.5	82.5	22.3	21.7
SS-3	80.4	37.1	14.4	13.2	94.5	50.2	18.8	17.9	166.6	84.3	21.1	20.3
SS-4	66.1	29.3	11.6	10.5	74.0	37.7	13.6	12.1	112.7	56.1	17.6	15.9
SS-5	69.9	30.7	12.9	11.4	86.7	44.3	18.2	16.3	152.8	75.3	20.3	19.5
SS-6	64.4	27.1	13.1	11.8	79.9	40.3	18.5	16.0	110.2	54.5	17.7	16.4
SS-7	59.8	18.9	10.4	9.7	66.5	32.5	12.7	11.4	67.7	31.7	11.6	10.8
SS-8	74.7	32.8	11.9	10.9	68.9	35.3	14.9	13.1	69.6	32.1	12.4	11.7

Table 4: Two Way ANOVA Test for different Parameters with Respect to Stations and Seasons

Parameters	Source	SS	df	MS	F
PM ₁₀	Station	154096.758	7	22013.823	34.028**
	Season	362655.638	2	181327.819	280.290**
	Station x Season	29743.188	14	2124.513	3.284**
	Error	543421.518	840	646.930	
	Total	1089917.101	863		
PM _{2.5}	Station	46535.047	7	6647.864	35.362**
	Season	84833.238	2	42416.619	225.626**
	Station x Season	8449.764	14	603.555	3.210**
	Error	157916.215	840	187.995	
	Total	297734.264	863		
SO ₂	Station	2752.051	7	393.150	34.113**
	Season	7066.285	2	3533.142	306.569**
	Station x Season	628.365	14	44.883	3.894**
	Error	9680.812	840	11.525	
	Total	20127.513	863		
NO ₂	Station	2837.123	7	405.303	29.090**
	Season	2794.384	2	1397.192	100.281**
	Station x Season	584.485	14	41.749	2.996**
	Error	11703.497	840	13.933	
	Total	17919.490	863		

(** is Significant at P<0.01)

Table 5: One Way ANOVA Test for different Parameters with respect to Seasons

Parameters	Source of Variations	SS	df	MS	F
PM ₁₀	Between Seasons	362655.638	2	181327.819	214.673**
	Within Seasons	727261.463	861	844.671	
	Total	1089917.101			

PM _{2.5}	Between Seasons	84833.238	2	42416.619	171.538**
	Within Seasons	212901.026	861	247.272	
	Total	297734.264			
SO ₂	Between Seasons	7066.285	2	3533.142	232.906**
	Within Seasons	13061.229	861	15.170	
	Total	20127.513			
NO ₂	Between Seasons	2794.384	2	1397.192	79.535**
	Within Seasons	15125.105	861	17.567	
	Total	17919.490			

(** is Significant at P<0.01)

Similarly after application of one way ANOVA test on different parameters based on different seasons, the F values were obtained to be 214.673, 171.538, 232.906 and 79.535 for PM₁₀, PM_{2.5}, SO₂ and NO₂ respectively which were found significant given in Table 5.

Duncan’s Multiple Range Test (DMRT) has been applied in order to express the similarities or any difference in mean values for different parameters with respect to one or more seasons. Table 6 shows the season wise mean with SD for different parameters. Fig. 2 expresses the graphical representation of variations of different concentrations of parameters based on seasons.

Due to variation in different stations one way ANOVA has been applied where the F values calculated to be 20.136, 22.654, 19.368 and 23.003 for PM₁₀, PM_{2.5}, SO₂ and NO₂ respectively shown in Table 7.

Similarly DMRT has been applied in order to express the similarities or any difference in mean values for different parameters with respect to one or more stations for more pin-pointed results. The station wise mean with standard deviation for different parameters are given in Table 8. The variations with respect to stations are shown in Fig.3 for better understanding.

Table 6: Season Wise Mean Values (µg/m³) with Standard Deviation (SD) for different Air Quality Parameters

Season	Mean concentrations (µg/m ³) with Standard Deviation			
	PM ₁₀	PM _{2.5}	SO ₂	NO ₂
Summer	86.897 ±32.005	41.747 ±17.152	13.486 ±4.264	16.743 ±4.464
Monsoon	49.594 ±21.309	23.593 ±11.565	9.313 ±3.218	12.258 ±3.369
Winter	93.150 ±34.590	44.897 ±18.818	15.833 ±4.351	14.581 ±4.856

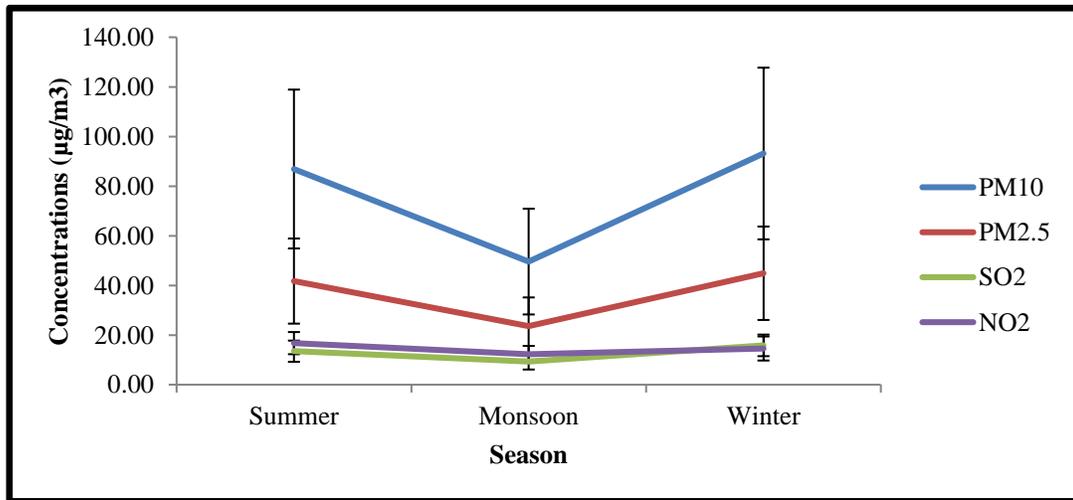


Fig.2: Season wise mean with standard deviation for different parameters

Table 7: One Way ANOVA Test for Different Parameters with respect to Stations

Parameters	Source of Variations	SS	df	MS	F
PM ₁₀	Between Stations	154096.758	7	22013.823	20.136**
	Within Stations	935820.344	856	1093.248	
	Total	1089917.101	863		
PM _{2.5}	Between Stations	46535.047	7	6647.864	22.654**
	Within Stations	251199.217	856	293.457	
	Total	297734.264	863		
SO ₂	Between Stations	2752.051	7	393.150	19.368**
	Within Stations	17375.462	856	20.298	
	Total	20127.513	863		

NO ₂	Between Stations	2837.123	7	405.303	23.003**
	Within Stations	15082.367	856	17.620	
	Total	17919.490	863		

(** is Significant at P<0.01)

Table 8: Station Wise Mean Values (µg/m³) with Standard Deviation (SD) for Different Air Quality Parameters

Sampling Stations (SS)	Mean concentrations (µg/m ³) with Standard Deviation			
	PM ₁₀	PM _{2.5}	SO ₂	NO ₂
SS-1	81.523 ±37.624	39.013 ±19.387	13.413 ±4.523	15.075 ±4.227
SS-2	91.576 ±42.685	45.101 ±21.917	15.207 ±5.791	16.872 ±5.397
SS-3	89.592 ±43.279	44.230 ±22.813	14.474 ±5.262	16.271 ±5.083
SS-4	68.701 ±26.876	33.256 ±13.803	11.730 ±3.812	13.090 ±3.428
SS-5	78.136 ±40.998	38.463 ±21.334	13.121 ±4.898	14.609 ±4.471
SS-6	66.347 ±26.813	31.405 ±13.996	12.143 ±4.796	13.826 ±4.265
SS-7	53.202 ±15.401	23.218 ±8.207	9.551 ±2.746	11.258 ±2.643
SS-8	57.084 ±16.617	27.177 ±7.882	10.596 ±3.411	12.226 ±3.348

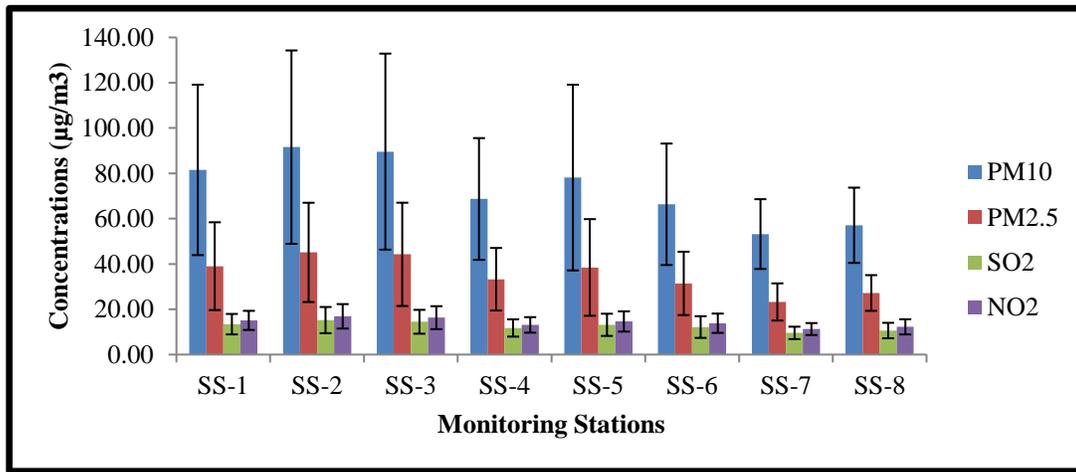


Fig. 3: Station wise mean with standard deviation for different parameters

Table 9: One Way ANOVA for Different Air Quality Parameters Due to Stations and Seasons Interaction

Parameters	Source of Variations	SS	df	MS	F
PM ₁₀	Between Station x Season	546495.584	23	23760.678	36.728**
	Within Station x Season	543421.518	840	646.930	
	Total	1089917.101	863		
PM _{2.5}	Between Station x Season	139818.049	23	6079.046	32.336**
	Within Station x Season	157916.215	840	187.995	
	Total	297734.264	863		
SO ₂	Between Station x Season	10446.701	23	454.204	39.411**
	Within Station x Season	9680.812	840	11.525	
	Total	20127.513	863		
NO ₂	Between Station x Season	6215.992	23	270.261	19.398**
	Within Station x Season	11703.497	840	13.933	
	Total	17919.490	863		

(** is Significant at P<0.01)

F values were found to be 36.728, 32.336, 39.411 and 19.398 for PM₁₀, PM_{2.5}, SO₂ and NO₂ respectively based on interactions of

stations and seasons after the applications of one way ANOVA test (Table 9).

4. Conclusion

From the research work and after application of statistical analysis the result gives a broad idea about the air quality status of the study area based on different stations with respect to seasons. Where the seasonal variation are concerned it has been computed that the PM₁₀ concentrations were observed in winter season i.e. 93.150±34.590 µg/m³ followed by summer season i.e. 86.897±32.005 µg/m³ then monsoon season i.e. 49.594±21.309 µg/m³. The same trend has been found in all other three parameters such as PM_{2.5}, SO₂ and NO₂. In the station wise analysis it has been observed that SS-1, SS-2 and SS-3 were found to be maximum concentrations of all pollutants like PM₁₀, PM_{2.5}, SO₂ and NO₂, this is might be due to maximum exposure to the transportation activities and nearby industrial activities. The same types of research work may help to the other researchers to study the ambient air quality in a broader way to find the exact pollution status as well as mitigation measures and environment management plan to ensure a better healthy atmosphere.

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