



A Statistical Approach to a Stationary Environmental Assessment of Air Quality in a Coal Mining Area of Eastern IGP Region, India

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Abstract: We know that conventional coal fuel cycle is among the most destructive activities on the earth which threaten the health, polluting the air and water and land and finally contribute to global warming. Thus, studies related to it, is very important nowadays. Present research work is a small contribution towards this. Our area of study is Dhanbad, located in the eastern part of Indo-Gangetic Plain region in India with latitude and longitude 23.8°N and 86.45°E respectively. The variations in air quality in terms of sulfur dioxide (SO₂), nitrogen dioxide (NO₂) and particulate matter around coal mining region of Jharkhand were evaluated over the period of 2013 and 2014 at five sites during different seasons. Air pollution index (API), calculated on the basis of suspended particulate matter (SPM), SO₂ and NO₂ concentrations were highest near the coal mining area. Discernible variations in hourly, diurnal, monthly and seasonal CO, SO₂ and NO₂ were apparent. Pollutants dispersion and spatial variations were explained by the use of cluster analysis (CA). Multivariate statistical analyses were adopted including; principal component analysis (PCA) to identify the major sources of air pollutants in the area. The major sources contributing to air pollution in mining region were coal mining related activities and active mine fires, and secondarily vehicular emissions, while wind-blown dust through unpaved. The major sources of airborne trace metals identified were mainly coal mining and associated activities, emissions from automobile exhaust and industries, suspended soil dust and earth crust, biomass burning, oil combustion, and fugitive emissions roads also contributed to some extent.

Keywords: Coal mining region, CO, SO₂, NO₂, Air Pollution Index (API).

I. Introduction

One of the leading issues of the today's world is the link between environmental issues and the development processes. It is obvious that the development process will increase the energy demand (Kaygusuz, 2012). Different sources of energy, from fossil fuels to nuclear, pollute the environment in different ways and at different levels (Omer, 2008). Presently, energy is largely produced by burning of fossil fuels such as coal, oil and natural gas (Veziroglu and Sahin, 2008). Among all these energy sources, coal is a crucial resource, most abundantly present, and is also the cheapest source of energy (Franco and Diaz, 2009). Coal provides 29.6% of global primary energy needs, generates 42% of the world's electricity, and global coal consumption has increased by 46% during 2001 to 2010 (World Coal Association, 2011). In order to meet the energy requirement, the overall coal production and coal mining have tremendously increased in India, which ranks third among top ten coal producing countries (World Coal Association, 2011). The mining activities contribute to the problem of air pollution directly or indirectly (Baldauf et al., 2001; Collins et al., 2001). The most important emissions during coal mining and through active mine fires are particulate matter (PM), sulfur dioxide (SO₂), nitrogen dioxide (NO₂) and heavy metals. These air pollutants have bad impact on the human health, flora and fauna and finally deteriorate air quality in and around coal mining areas (Singh et al., 1991). The present study was conducted over a period of two years to quantify the spatial and seasonal variations in air pollutant concentrations around coal mining areas of Jharia coalfield, situated in Dhanbad district of Jharkhand state of India.

II. Materials and Methods

Experimental site

The sampling was done in Dhanbad district of Jharkhand state of India, Tables 1 and 2 summarize pollutants data on Dhanbad City. Dhanbad is a commercial city with high vehicle and motorcycle traffic in its main roads. Dhanbad is designated coal mining area. The experimental site is located near the mining area.

Table 1: Statistical distribution of PM₁₀ trace metals levels (µg/m³) in particulate matter of study area.

Pollutants	Range	Arithmetic Mean	Geometric Mean	Median	SD
PM ₁₀	170-339	258	250	287	64
Pb	0.040-0.318	0.15	0.128	0.128	0.082

Ni	0.0001-0.02	0.01	0.004	0.004	0.006
Cu	0.06-6.32	1.44	0.911	0.834	1.550
Mn	0.079-1.75	0.47	0.316	0.309	0.499
Fe	1.0-28.0	8.90	5.87	4.435	8.115
Zn	0.17-2.26	0.68	0.521	0.473	0.576
Cd	0.04-0.074	0.06	0.058	0.068	0.014
Cr	0.125-0.430	0.32	0.307	0.32	0.094

Table 2: Principal components loadings of the trace metals for the study area Factors.

Factors	Components		
	PC1	PC2	PC3
PM ₁₀	0.458	0.339	0.301a/0.011b
Pb	0.305	0.809	-0.397a/0.063b
Ni	-0.082	0.790	0.018a/0.012b
Cu	-0.066	0.039	0.953a/-0.008b
Mn	0.922	-0.041	-0.241a/0.139b
Fe	0.909	0.099	0.124a/0.080b
Zn	0.632	-0.086	0.722a/0.718b
Cd	-0.285	0.670	0.383a/0.769b
Cr	0.346	0.600	0.039a/0.735b
Eigen Value	2.848	2.024	1.842a/1.676b
% variance	31.64%	22.49%	20.46%a/18.622%b
% Cumulative Variance	31.64%	54.13%	74.60%a/71.341%b

Seasonal variations

Air quality of the area was monitored for three consecutive seasons in 2013 and 2014 at various sites for SO_x, NO_x and Particulate Matter (i.e. PM₁₀ and PM_{2.5}). The seasonal variation in Ambient Air Quality around is compared along with Maximum permissible limit as per Guidelines provided by Central Pollution Control Board new Delhi (CPCB) for National Ambient Air Quality Standard (NAAQS:2009). The results of tested parameters are presented in table-4, 5 and 6 along with statistical data analysis in table-7.

Table 3: Annual correlation matrix for coal mining area.

	SPM	PM ₁₀	Pb	Ni	Cu	Mn	Fe	Zn	Cd	Cr
SPM	1	0.677 ^a	-0.031	0.243	0.086	0.168	0.203	0.263	0.023	-0.048
PM ₁₀		1	0.218	0.279	0.090	0.345	0.365	0.439	0.268	0.054
Pb			1	0.638^a	-0.323	0.306	0.348	-0.128	0.254	0.500
Ni				1	0.092	-0.093	-0.101	0.015	0.258	0.238
Cu					1	-0.296	0.081	0.633 a	0.326	0.116
Mn						1	0.739 a	0.411	-0.339	0.273
Fe							1	0.614 b	-0.065	0.409
Zn								1	-0.066	0.142
Cd									1	0.337
Cr										1

^a Correlation is significant at the 0.01 level

III. Result and Discussion

A large amount of Particulate matter is emitted from coal mines, particularly if the ash content of coal is high (<35%). In the current study PM₁₀ showed significant variation site wise and season wise. Monitoring site A-01 was found in the range of 129µg/M3 in summer, 117µg/M3 in winter and 82µg/M3 in monsoon. Similar trends were observed for A-02 114µg/M3 (S), 74µg/M3 (M), 109µg/M3 (W) and for A-03 119µg/M3 (S), 85µg/M3 (M), 108µg/M3 (W) respectively. However PM₁₀ was at site A-04 was reported 84µg/M3 in summer, 87µg/M3 in winter and 66µg/M3 in monsoon, which is lower from the permissible limit (<100 µg/M3) in all respects. The deviation range of A-01, A-02 and A-03 found to be higher (>100µg/M3) as per given guidelines of CPCBNAAQS: 2009 in summer and winter. During summer season, particulate matter concentrations were found to be higher due to enhanced dispersion of fugitive dust append by coal and ash handling activity. Higher concentrations of particulate matter during winter can be attributed to low temperature and low wind speed that results in lower mixing height and poor dispersion conditions. The lowest concentration was observed during monsoon season, which may be attributed to washout by rainfall and also due to higher relative humidity, which reduces re-suspension of dust.

Statistical Analysis of Data by Pearson Correlation Coefficient (r):

Obtained data were statistically analyzed with Pearson Correlation Matrix to examine the effects of Environmental Pollutants on Ambient Air at site. The analysis was performed for seasonal alteration and overall

annual interactions on different parameters. Correlation coefficient (r) between any two parameters, X-axis & Y-axis is calculated for total 04 parameters such as, ultra fine Particulate Matter (PM_{2.5}), Fine Particulate Matter (PM₁₀), Oxides of Sulphur (SO_x) and Oxides of Nitrogen (NO_x). The degree of line association between any two of the Seasonal parameters measured by Pearson correlation coefficient (r) is presented in form of 4 x 4 correlation matrix. Total 40 correlations were calculated for three different seasons along with annual correlation coefficient, which help us to know the cumulative effect of Emission pollutants on Ambient Air Quality. Out of 24 correlations tabulated for 4 parameters, 20 were recorded significantly positive while other 4 was shown negative (inverse) correlations.

Table 4: Ambient Air Quality Analysis in Dhanbad in summer season.

S.NO.		Parameters	Unit	NAAQC-2009	A-01	A-02	A-03	A-04
Ambient Air Analysis	1	PM ₁₀	µg/M3/24 Hrs.	100	128	114	118	83
	2	PM _{2.5}	µg/M3/24 Hrs.	60	44	79	63	47
	3	Sox	µg/M3/24 Hrs.	80	97	85	87	58
	4	NO _x	µg/M3/24 Hrs.	80	93	86	85	55

Table 5: Ambient Air Quality Analysis in Dhanbad in monsoon season.

S.NO.		Parameters	Unit	NAAQC-2009	A-01	A-02	A-03	A-04
Ambient Air Analysis	1	PM ₁₀	µg/M3/24 Hrs.	100	83	74	86	65
	2	PM _{2.5}	µg/M3/24 Hrs.	60	26	36	47	27
	3	Sox	µg/M3/24 Hrs.	80	59	65	43	39
	4	NO _x	µg/M3/24 Hrs.	80	32	65	41	37

Table 6: Ambient Air Quality Analysis in Dhanbad in winter season

S.NO.		Parameters	Unit	NAAQC-2009	A-01	A-02	A-03	A-04
Ambient Air Analysis	1	PM ₁₀	µg/M3/24 Hrs.	100	116	108	107	86
	2	PM _{2.5}	µg/M3/24 Hrs.	60	35	70	57	32
	3	Sox	µg/M3/24 Hrs.	80	83	73	76	57
	4	NO _x	µg/M3/24 Hrs.	80	88	85	83	61

Table 7: Pearson Correlation Matrix for Different Ambient Air Quality Parameters

	PM ₁₀	PM _{2.5}	SOx	NOx	NOx	SOx	PM _{2.5}	PM ₁₀	PM ₁₀	PM _{2.5}	SOx	NOx	NOx	SOx	PM _{2.5}	PM ₁₀	
PM ₁₀	1							1	1							1	
PM _{2.5}	0.157	1					1	0.609	0.298	1					1	0.580	
SOx	0.952	-0.137	1			1	-0.009	0.011	0.453	0.087	1			1	0.404	0.901	
NOx	0.988	0.282	0.895	1		1	0.833	0.275	-0.197	0.938	-0.046	0.493	1	1	0.908	0.585	
Summer						Monsoon					Winter					Annual Correlation Matrix	

IV. Conclusion

In the present study, the study area covers a substantial portion of Dhanbad region. Trace metals (Fe, Mn, Cu, Zn, Cd, Cr, Pb and Ni) associated with PM₁₀, were characterized at mining area of Dhanbad, India to identify and quantify their major sources. Factor Analysis–Principal Component Analysis, identified dominance of crustal source as 31.64% for mining area. It was supported by correlation study, where, $r=0.677$ ($p<0.01$) for mining area. Local sources such as construction activities, mining, road dust suspension etc. most likely contributed to this factor. Vehicular sources contributed 22.49% ($r=0.638$) for mining area to ambient metals and resuspended dust. The industrial activities contributed 20.46% and ($r=0.614$) for coal mining area. Enrichment factor analysis portrayed anthropogenic emissions of trace metals, Pb, Cd and Cr in coal mining area. The findings of this study may be useful for framing an appropriate strategy for necessary mitigative/preventive measures. Analytical data of the ambient air shows that particulate matter was higher specifically for A-01, A-02 and A-03 in summer and it may be a result of enhanced dispersion of fugitive dust append by coal and ash handling activity. During winter, it can be attributed to low temperature and low wind speed, which lead to lower mixing height and poor dispersion conditions. However, SO_x and NO_x were also

recorded higher but in monsoon attributed to washout by rainfall and because of higher relative humidity that reduces re-suspension of dust. Further, Statistical analysis reveals that the pollutants have significant correlation.

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