CHEMICAL CHARACTERIZATION OF PM_{10} AEROSOL IN URBAN REGION OF INDIAN STEEL CITY, ROURKELA

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Introduction

Air quality is a dynamic and complex environmental phenomenon exhibiting large temporal and spatial variations. Acute air pollution is being faced in urban agglomeration due to rapid economic expansion, increase in population, increased industrial activities and exponential growth in automobiles. Air pollution can threaten the health of human beings, trees, lakes, crops and animals, as well as damage the ozone layer, ecology and property. In an attempt to manage urban air resources, it is necessary to have reliable information on the ambient air quality. To achieve this, a detailed chemical characterization of the particulate matter such as heavy metals, ions, organic carbon and molecular markers needs to be studied.

Methods

The air quality sampling setup has been designed according to the Indian Standard IS 5182 (Part 23): 2006(IS5182, 2006). Sampling locations are shown in Fig 1. The filter papers were calcined at 400 °C for 2 h to remove any organic compounds that may be present on filters (Kong et al., 2010) and then equilibrated in a desiccator before sampling (Karar et al., 2006; Karar and Gupta, 2006). The PM_{10} concentrations were measured gravimetrically by weighing the particulate mass deposited on the quartz microfiber filters and knowing the total volume of air sampled. After gravimetric analysis, a fraction of the exposed filter papers was digested in HNO_3 (nitric acid) and used for trace metal analysis (APHA and AWWA, 2012). Instruments used are summarized in table 1.

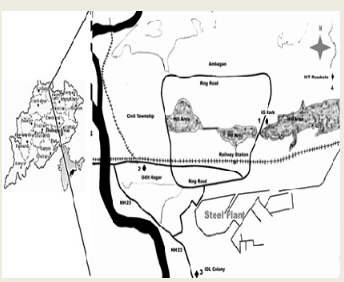

Fig. 1: Sampling site

Table 1: Instruments used

S.No	Instrument	Usage
1	Respirable Dust Sampler (NETEL, NPM-HVS/R)	For monitoring of PM_{10}, TSP and Gaseous pollutants (SO_2, NO_x, NH_3).
2	Muffle Furnace	For baking of filter papers
3	Desiccator	For equilibration of filter papers
4	Balance (Sartorius CPA 124S)	For weighing of filter papers and chemicals
5	Fume Hood (REICO)	For acid digestion of filter papers, dust and soil samples
6	Ultra Sonication Bath (Labman LMUC-2)	For extraction of water soluble ions
7	UV-Visible Spectrophotometer (Perkin Elmer Lambda 35)	For chemical analysis
8	Atomic Absorption Spectrophotometer (Perkin Elmer AAnalyst 200)	For analysis of cations and elements
9	Total organic carbon analyzer (Shimadzu TOC-V CPH/CPN)	For analysis of TOC, IC and TC
10	Carbon monoxide meter (HT-1000)	For monitoring CO
11	Fluoride Electrodes (Thermo Scientific Orion 9409BN Half-Cell Fluoride and Orion 9609BNWP Combination)	For the analysis of F^-

Extraction for Trace Metals

After gravimetric analysis, a fraction of the exposed filter papers were digested in HNO_3 (nitric acid) and used for trace metal analysis (APHA and AWWA, 2012). For trace metal analysis, 40 punch holes (each of 0.20 cm^2) of the exposed fiber filters with an area of 8 cm^2 were acid digested.

Extraction for Ions

For determination of water soluble ionic species, 40 punch holes (each of 0.20 cm^2) of the exposed fibre filter papers with an area of 8 cm^2 were sonicated three times in 20 ml of double distilled water for 30 min in an ultra-sonic bath (Labman LMUC-2).

Analysis of Carbon Species

The total carbon (TC) and total organic carbon (TOC) contents of PM_{10} and TSP samples have been determined by using a SHIMADZU TOC-V CPH/CPN Analyzer.

Results

The 8h (9am to 5pm) average values of PM_{10} obtained during January 2011 to December 2012 are in the range of 80.88µg/m³ to 225.93µg/m³. The chemical characterization of PM_{10} mass showed an abundance (up to 55%) of crustal elements (Al, Fe, Mg and K) followed by 35% of carbon compounds (TOC, IC, TC), 8% of anions (Cl^-, SO_4^{2-}, F^- and PO_4^{3-}) and 2% of other trace elements (Zn, Cr, Cu, Ni, Pb, Hg and As).

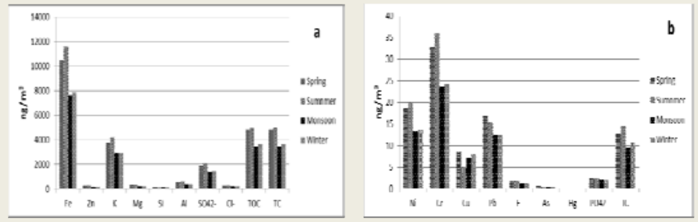

Fig 2: Seasonal variations of chemical species of PM_{10}

Copper is not precipitated and washed by the rain in a big proportion because it may be present in finer fraction of respirable size and stay in the atmosphere inspite of pluvial precipitation.

Correlation Analysis

Spearman rank correlation analysis has been performed between measured aerosol and its metallic and anionic species to investigate the relationships between them using software IBM SPSS 20. The results of spearman rank correlation study between chemical constituents of PM_{10} (table 2) shows that correlation between Ni-Cu, Ni-Pb, Fe-F^-, Cr-K, Cu-F^-,Al-Pb, Mg-SO_4^{2-} and Si-Al are statistically significant.

Table 2: Correlation analysis

	PM_{10}	Fe	Ni	Cr	Zn	K	Cu	Pb	Mg	Si	Al	As	Hg	Cl^-	PO_4^{2-}	F^-	SO_4^{-2}
PM_{10}	1.00	0.08	0.08	0.09	-0.06	-0.01	0.07	-0.18	0.08	0.11	-0.28**	-0.03	0.098	-0.063	0.095	0.125	0.044
Fe		1.000	-0.320**	0.131	-0.103	0.124	-0.093	0.057	0.013	0.115	-0.030	0.095	0.089	-0.030	-0.105	0.267**	0.142
Ni			1.000	0.029	-0.015	0.000	-0.262**	-0.213*	-0.161	0.011	0.095	-0.105	-0.030	0.095	0.082	0.098	-0.063
Cr				1.000	0.007	0.213*	0.019	0.089	-0.006	0.005	-0.105	-0.015	0.095	-0.105	0.013	-0.014	-0.123
Zn					1.000	-0.102	0.086	0.104	0.067	-0.190	-0.015	0.156	-0.105	-0.015	-0.161	-0.023	0.012
K						1.000	-0.020	-0.024	0.216*	0.017	0.156	-0.017	-0.015	0.156	-0.006	-0.069	-0.008
Cu							1.000	-0.081	0.007	0.008	-0.017	0.098	0.156	-0.017	0.067	0.253**	-0.004
Pb								1.000	-0.157	-0.058	0.247**	-0.014	-0.017	0.095	0.098	-0.158	-0.058
Mg									1.000	-0.154	-0.168	-0.023	0.098	-0.105	-0.014	-0.081	-0.251**
Si										1.000	0.256**	-0.069	-0.014	0.098	-0.023	-0.019	0.188
Al											1.000	0.089	-0.023	-0.014	-0.069	-0.083	-0.125
As												1.000	-0.069	-0.023	0.089	0.095	0.089
Hg													1.000	-0.069	0.095	-0.105	0.095
Cl^-														1.000	-0.105	0.089	-0.105
PO_4^{2-}															1.000	0.089	0.089
F^-																1.000	0.191
SO_4^{-2}																	1.000

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Conclusions

The seasonal variation of PM observed that all the chemical constituents of particulate matter have followed a trend i.e., summer > spring > winter > monsoon. Spearman rank correlation analysis between PM_{10} and its chemical constituents helped in identifying the elements with common sources and different sources that further helped in sources apportionment process. Diesel exhaust is the second largest contributor to PM_{10} aerosol (25.67%) which indicates the dominance of vehicular transport in the contribution of PM_{10} aerosol.

References