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Comparison of Trace Metals Concentration in PM_{10} of Different Locations of Lucknow City, India

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The elevated concentration of Respirable Suspended Particulate Matter, (RSPM, PM_{10}) $\leq$ 10 μm in size, in the ambient air is a major cause of health problem and urban people are affected at risk on exposure. The PM_{10} including fine and ultra fine particles are mainly responsible for cardiovascular as well as respiratory diseases (Sagai et al. 1996; Sasaki and Sakamoto 2005). Current studies have revealed that the mortality and morbidity rate is directly related with the concentration and number of respirable particles in the aerosol (Dockery et al. 1993; Pope et al. 1995; Schwartz et al. 1996; Bérubé et al. 1999; Zhu et al. 2002; Fang et al. 2005).

Technological upgradation and scientific know-how has reduced pollution load, especially the gaseous pollution and mass concentration of particulate matter (PM) in urban area. However, increase in the number of vehicles causes more emission of pollutants, especially of the respirable particles, which are directly related with human health (Morawska et al. 2002). The particulate matter contains trace elements and toxins, which can penetrate deep into the pulmonary interstitial spaces in the lungs due to their higher diffusion coefficients. These fine particles provoke lung inflammation and are responsible for cardiovascular diseases (Seaton et al. 1995) and are potentially toxic to human health because of their large surface areas, which are coated with different chemical constituents and carcinogens (Mckenzie et al. 2005).

There is an increasing concern about the composition of atmospheric particulates because co-pollutants such as organic and inorganic substances including metals are the precursors to fine particulate matter formed in the atmosphere (Querol et al. 2001). Metal content in airborne urban PM has great influence on the human health and the concentration of different metals in RSPM, whether it is from automobile exhaust or street dust, is a matter of scientific study.

Lucknow, the capital of Uttar Pradesh, situated in northern India with a population of 22.45 lakhs, (2001census) lies between 26^0 52'N Latitude and 80^0 56'E Longitude at 128 m above sea level. The minimum & maximum ambient temperature and relative humidity during the study period ranged between 19.3 - 29.3°C & 34.0 - 44.7°C and 10.0 - 53.0% & 37.0 - 91.0% respectively. Vehicular

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traffic is the major source of particulate matter in the urban air of Lucknow city. The total vehicles were 7,49,830 (all categories) as on 31st March 2005. The growth is 10.38% over the last year.

Keeping in view the above, monitoring of ambient air quality was conducted to study the status of RSPM level of Lucknow city. The concentration of 11 trace elements concentration were also estimated, to find out the metal level in inhalable dust particles in RSPM during the month of May 2005. Different metals data were subjected to statistical analysis to find out the multiple relationships with each other, using the Newman Keuls Multiple Comparison Test, ANOVA and correlation matrix.

MATERIALS AND METHODS

Four residential, 5 commercial and 1 industrial area were selected for monitoring to correspond to entire coverage of Lucknow City. Monitoring of RSPM was carried out using Respirable Dust Sampler (Model-415, Envirotech, New Delhi) at a flow of 1.0- 1.2 m^3/min for 24 hrs. Preweighed cellulose filters, Whatman (EPM–2000) of 20 x 25 cm size were used and reweighed after sampling in order to determine the mass of the particles collected. The concentration of the particulate matter in ambient air was then computed on the net mass collected divided by the volume of air sampled.

Thirty-three circles of 1" diameter (10 locations +1 control) were punched out in triplet from the sampled filter paper and digested with concentrated nitric acid on hot plate till white fumes arose and reduced to 2-3 ml. The content was filtered through Whatman Filter No. 42 and final volume made-up to 25 ml by double distilled water. The filtrate was examined for the concentration of Fe, Cr, Cu, Ni, Cd, Pb, Zn, Co, Mn, Ca and Mg by Varian Spectra AA-250 Plus.

RESULTS AND DISCUSSION

Mean concentrations of total trace metals in each location (between locations) and each metal concentration within locations has been shown in Table 1 and 2 and their graphical representation in Fig. 1 and 2 respectively.

Mean concentrations of metals were found to be maximum at Aminabad (423.98 ng/m^3) and minimum at Amausi (169.57 ng/m^3). Similarly, mean concentration of Fe (1242.10 ng/m^3) was observed maximum and Cd (6.36 ng/m^3) the minimum. The hierachy of metals between and with locations was arranged in descending order of their mean concentration below.

Location: Aminabad > Indira nagar > Charbagh > Hussainganj > Alambagh > Aliganj > Gomti nagar > Chowk > Vikash nagar > Amausi and

Metals: Fe>Ca>Cu>Pb>Zn>Mg>Mn>Cr>Co>Ni>Cd

Table 1. Summary of total trace metals concentrations (ng/m^3) – between locations.

Locations	Metals (ng/m^3)		
	Min.	Max.	Mean± SE (n=11)
Aliganj	3.00	1265.55	232.13±121.25
Vikash nagar	2.91	1118.93	179.00±104.00
Indira nagar	0.93	1619.58	297.37±164.85
Gomti nagar	5.63	1004.93	218.44±112.14
Hussainganj	4.42	1372.00	254.49±136.70
Charbagh	2.93	1652.62	280.81±152.82
Alambagh	0.43	1432.96	253.79±147.25
Chowk	5.33	1260.30	210.54±120.03
Aminabad	3.71	2406.50	423.98±238.70
Amausi	1.44	976.54	169.57±91.54

Table 2. Summary of individual trace metals concentrations (ng/m^3) – within locations.

Variables	Min.	Max.	Mean±SE (n=10)
Fe	489.49	2406.50	1242.10±188.97
Cr	0.43	29.24	12.77±2.77
Cu	51.59	379.78	161.67±32.47
Ni	2.91	22.51	7.93±2.02
Cd	2.91	11.15	6.36±0.5
Pb	48.19	320.30	159.40±36.42
Zn	38.00	121.66	73.41±8.56
Co	0.93	29.13	12.08±3.06
Mn	1.44	59.31	18.77±5.40
Ca	706.45	1511.15	1023.56±75.98
Mg	11.34	86.44	54.09±7.71

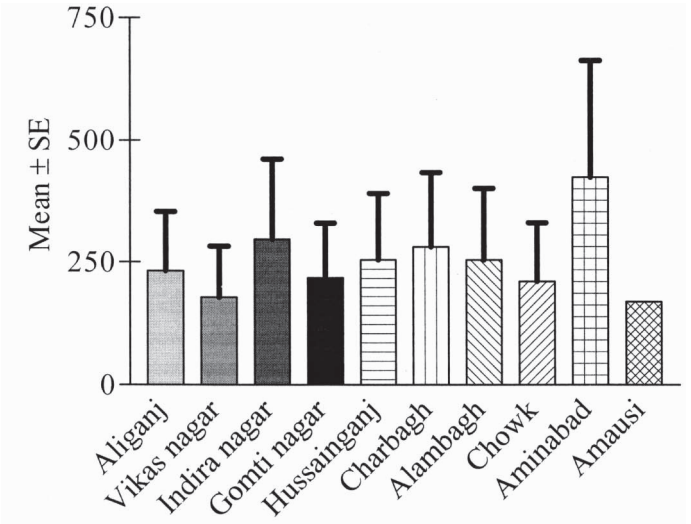

Figure 1. Average of total trace metals concentrations (ng/m^3)

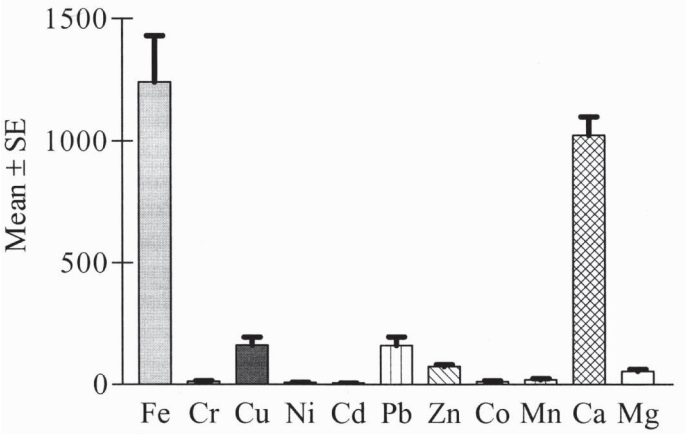

Figure 2. Average of each trace metal concentration (ng/m^3)

It is concluded that, in May 2005, PM_{10} of Lucknow, was most dominated by Fe and least by the Cd and Aminabad was found the most affected and Amausi was the least affected.

Heterogeneous variation was observed in the concentration of trace metals so we transformed (log_{10}) the data. The transformed data was then submitted to statistical analysis.

Equality of mean differences in trace metals concentration, between and within locations was carried out by two-way analysis of variance (ANOVA without replication). No significant ($F=1.91$, $p>0.05$) difference was observed between locations but within location it differed significantly ($F=68.21$, $p<0.01$). To find out which pair of metals differed in their mean level, pair wise comparison was done by Newman Keuls multiple range test (Table 3) and the obtained result summarized as

$$Fe=Ca > Cu=Pb=Zn=Mg > Mn=Cr=Co=Ni=Cd$$

or

$$Fe=Ca \neq Cu=Pb=Zn=Mg \neq Mn=Cr=Co=Ni=Cd$$

Trace metals are clustered in 3 groups, namely, group 1(Fe, Ca), group 2 (Cu, Pb, Zn, Mg) and group 3 (Mn, Cr, Co, Ni, Cd). These groups differ significantly ($p<0.01$) with each other but metals within groups are equal, they did not differ significantly ($P>0.05$).

Table 3. Newman Keuls multiple comparison test

Metals	Fe	Cr	Cu	Ni	Cd	Pb	Zn	Co	Mn	Ca	Mg
Fe	-										
Cr	**	-									
Cu	**	**	-								
Ni	**	ns	**	-							
Cd	**	ns	**	ns	-						
Pb	**	**	ns	**	**	-					
Zn	**	**	ns	**	**	ns	-				
Co	**	ns	**	ns	ns	**	**	-			
Mn	**	ns	**	ns	ns	**	**	ns	-		
Ca	ns	**	**	**	**	**	**	**	**	-	
Mg	**	**	*	**	**	*	ns	**	**	**	-

ns = not significant ($p>0.05$), * = significant ($p<0.05$), ** = significant ($p<0.01$)

Inter correlation among metals is shown in Table 4. Correlation of metals, Fe with Mn ($r=0.89$, $p<0.01$) and Mg ($r=0.77$, $p<0.01$); Cr with Cu ($r=0.67$, $p<0.05$) and Zn ($r=0.70$, $p<0.05$), Cu with Ni ($r=0.75$, $p<0.01$), Pb ($r=-0.62$, $p<0.05$) and Mn ($r=0.62$, $p<0.05$); Ni with Pb ($r=-0.70$, $p<0.05$); Cd with Pb ($r=0.60$, $p<0.05$); Pb with Ca ($r=-0.56$, $p<0.05$); Mn with Ca ($r=0.598$, $p<0.05$) and Mg ($r=0.57$,

$p<0.05$) were found significant. Significant, Positive (*"direct correlation"*) and negative (*"inverse correlation"*) association of metals has its own relevance and may be useful when correlating it with PM_{10} as well as in finding out the sources.

Correlation of PM_{10} with metals, Fe ($r=0.71$, $p<0.05$), Mn ($r=0.66$, $p<0.05$) and Mg ($r=0.71$, $p<0.05$) were found positive and significant. This means increase or decease in the concentration of Fe, Mn and Mg may increase or decrease the concentrations of PM_{10}. In other words concentrations of trace metals, Fe, Mn and Mg are dominating the concentrations of PM_{10}. Interestingly, these 3 metals belongs to separate groups (cluster), Fe and Mn having higher mean in their group 1 and 3 respectively while Mg which belongs to group 2 having the least mean.

Table 4. Correlation matrix (DF=8).

	Fe	Cr	Cu	Ni	Cd	Pb	Zn	Co	Mn	Ca	Mg	PM_{10}
Fe	1											
Cr	0.30	1										
Cu	0.42	0.67*	1									
Ni	-0.02	0.39	0.75**	1								
Cd	0.14	-0.03	-0.39	-0.31	1							
Pb	0.22	-0.27	-0.62*	-0.70*	0.60*	1						
Zn	0.16	0.70*	0.17	-0.08	0.25	-0.10	1					
Co	0.43	0.17	0.14	-0.24	-0.13	-0.27	0.27	1				
Mn	0.89**	0.39	0.62*	0.22	-0.01	-0.14	0.22	0.18	1			
Ca	0.25	0.39	0.42	0.14	-0.25	-0.56*	0.52	-0.08	0.59*	1		
Mg	0.75**	0.16	0.06	-0.19	0.07	0.45	-0.02	0.37	0.57*	0.01	1	
PM_{10}	0.71*	0.39	0.23	-0.13	-0.17	0.15	0.37	0.36	0.66*	0.42	0.71*	1

* = significant ($p<0.05$), ** = significant ($p<0.01$)

The concentration of PM_{10} (Table 5) was found in the range of 107.6-237.8 $\mu g/m^3$ among the locations. It ranges between 127.2-166.5 $\mu g/m^3$ and 127.3-237.8 $\mu g/m^3$ in residential and commercial areas respectively and 107.6 $\mu g/m^3$ in one industrial area. Relative difference (%) of PM_{10} with NAAQS (National Ambient Air Quality Standard) showed that it is exceeding to NAAQS levels in all the locations except Amausi. The lowest exceedance factor 0.7 was found at Amausi (industrial) and the highest 2.4 was at Aminabad (commercial). Exceeding factor of residential areas has a constant ratio (1.3 to 1.7) whereas in commercial it varies (1.3 to 2.4). This means variations in the concentrations of PM_{10} are mainly due to commercial areas.

Average concentrations of PM_{10} were almost double to NAAQS, which is considered to be an alarming indicator of adverse health of city dwellers. Lippmann (1998) estimated that the total daily mortality increased by approximately 1% for every 10-$\mu g/m^3$ increase in PM_{10} concentration. Keeping with this fact and considering NAAQS level as a standard, we predicted the

mortality rate (%) for all the locations. Mortality in Aminabad was estimated to be the highest (13.8%) and minimum in Aliganj and Chowk (2.7%). Amausi the industrial area was found to be the safe. Mean mortality in residential and commercial areas was predicted to be 4.7% and 7.8% respectively. The rate of mortality in commercial may be 1.7 times higher than the residential and 2.8 times than the industrial areas.

Table 5. Comparison of PM_{10} with National Ambient Air Quality Standard

Area/ Locations	PM_{10} ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)	Relative difference (%)	Mortality rate (%)	Exceedance factor
Residential	146.9	100	47	4.7	1.5
Aliganj	127.2		27	2.7	1.3
Vikas nagar	166.5		67	6.7	1.7
Indira nagar	157.8		58	5.8	1.6
Gomti nagar	136.1		36	3.6	1.4
Commercial	178.4	100	78	7.8	1.8
Hussainganj	214.2		114	11.4	2.1
Charbagh	172.2		72	7.2	1.7
Alambagh	140.3		40	4.0	1.4
Chowk	127.3		27	2.7	1.3
Aminabad	237.8		138	13.8	2.4
Industrial		150			
Amausi	107.6		-28	-2.8	0.7

The concentrations of PM_{10} in air were found higher almost double than the NAAQS. For this, concentrations of trace metals Fe, Mn and Mg were found responsible. The residents of commercial areas were found to be more sensitive. The adverse health of PM_{10} related to Fe, Mn and Mg may be the frequent hospital visitors, especially the children, elderly, smokers, poor in health and people suffering from cardiovascular diseases, especially allergy and asthma, and those with chronic respiratory difficulties have been identified more vulnerable group. Considerable abatement at root levels in the sources of these metals may reduce the concentration of PM_{10} and thus the air quality as well as the health of the city dwellers especially the human population will certainly improve.

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