

**Appendix 3****Background Air Pollution Studies in Urban and Rural Areas in Bangladesh.**

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Abstract

Air particulate matter at two size fractions have been collected at an urban station (Dhaka) in Bangladesh for one year using a 'Gent' PM-10 stacked filter unit (SFU). Of the samples collected, 73 sets of samples (coarse and fine fractions) extending over a period of six months have been analyzed to find elemental concentrations using PIXE. These results of the analyses are presented and discussed.

1. Introduction.

In a previous study analyses of some integral aerosol samples collected from urban and rural areas of Bangladesh were done⁽¹⁾. In the integral sampling some parameters of the samples can not be strictly defined and as such results reported by different workers can not be meaningfully compared. It is, therefore, necessary to collect samples in a standard way, so that the results from different geographical locations by different workers can be compared. This is being done in the current programme using the 'Gent' sampler. As the sizes of particulate matter in very important in determining their impact specially on health, the present programme defines the sample sizes very specifically. Two types of size fractionated samples namely the coarse and the fine have now been collected over a period of about one year. Here, we report the chemical characterization of both the groups of samples over a period of six months. The implications of the results obtained are briefly discussed.

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2. Experimental

Sampling

The samplings were done by using a 'Gent' stacked filter sampler⁽²⁾. The sampler was placed on the roof of a 5m high building located about 50m away from road. The roof of the building was flat and the sampling intake was placed 2m above the roof. The sampling times were varied to ensure that the flow rate remained within the prescribed limits. This was necessary to ensure the correct size fractionation. In each sampling, one fine and one coarse particulate samples were obtained on nucleopore filters of 47mm diameter. Particulates of 2-10 μm equivalent aerodynamic diameter (EAD) were collected on the coarse filter and particulates of $<2\mu\text{m}$ EAD were collected on the fine filter. Two or more samplings were done per week during August, '93 to Sept., '94. No sampling could be done during the period 3 May, '94 to 14 June, '94 due to non availability of nucleopore filters.

Method of Analysis

The PIXE method, both external beam and internal beam were used in the analyses. In our current experimental setup, it is difficult to monitor the integrated beam current accurately in internal beam experiments. In the external beam experiments, elements lighter than Argon could not be determined due to the high background counts produced by the Argon in the air. As the internal beam experiments only gave concentration in arbitrary units, these were normalized to give the same Fe concentration as in the external beam experiments. The quality control in the experiments were ensured by irradiating suitable standards during the experiments. One in every five samples irradiated was a standard. A spectrum obtained in an internal beam experiment is shown in figure-1. Analyses of spectra were done using the code QXAS.

3. Results and Discussion.

Aerosol mass variation

Monthly variation in the aerosol mass for both the coarse and fine fractions are shown in figure-2. It can be seen that the masses are rather similar during the period Aug-Oct. There is a step increase in the mass in November and again during Nov.-Jan. period the masses are comparable. This step increase in mass actually coincides with the advent of dry season when the rain fall is scarce. Because of the step increase in the mass in November, the results in the following discussions will be grouped in two periods namely Aug-Oct. and Nov.-Jan.

Composition of the Aerosol.

The monthly averaged concentration of elements in the coarse and fine fractions are shown in tables- 1 and 2 respectively. The cases where the observed concentrations fell below the minimum detection limit (MDL) were not considered in the calculation of the averages. Hence, the averages shown are some what higher than the actual averages.

It can be seen that the concentration of most of the elements are similar during Aug.-Oct. and again during Nov.-Jan. periods. The averaged concentration of elements during these two periods are shown in table 3 and 4 respectively along with the standard deviations. The high standard deviations points to the fact that there is considerable day to day variation in the elemental concentrations. However, the general trend is the increase in concentration of most of the elements with aerosol mass increase. There are a few exceptions which will be discussed latter.

Enrichment Factors

In order to investigate the variation in the concentration apart from the aerosol mass increase, the enrichment factors compared to crustal abundance's have been calculated and these are shown in table-5. The crustal abundance data were taken from Mason ⁽⁴⁾ and the reference element chosen was Ti as we could not determine the Al concentration in the PIXE method. The enrichment factors (EF) are given by

$$EF_i = (C_i/C_{Ti})/(A_i/A_{Ti})$$

where

EF_i = Enrichment factor for element i.

C_i = Observed Concentration of element i.

A_i = Crustal abundance of element i.

The subscript 'Ti' refer to relevant quantities for Ti.

The table -5 also shows the EFs for Khartoum and geometrically averaged values for 29 cities⁽³⁾. These values were recalculated with respect to Ti reference instead of the original figures with respect to Al.

Some general trends in the EFs can be clearly seen. The elements for which enhancements are large are the same in the present case as in the case of 29 city averages. This is in contrast with Khartoum values where no enhancements were observed for Cr, Mn, Ni and Cu. The EFs are generally much higher in the case of finer fraction for S, Zn, As, Br and Pb. This indicates that these elements are mostly from vapour condensates and are most likely to originate from combustion processes. The EF for Cl is higher in Aug.-Oct. for the coarse particle indicating its sea origin. High value of EF for Pb arises from the use of leaded gasoline in the country. The EFs for As show very high values specially

in the fine fraction. It is, therefore, very likely that As has its origin in high temperature industrial processes using As such as glass making.

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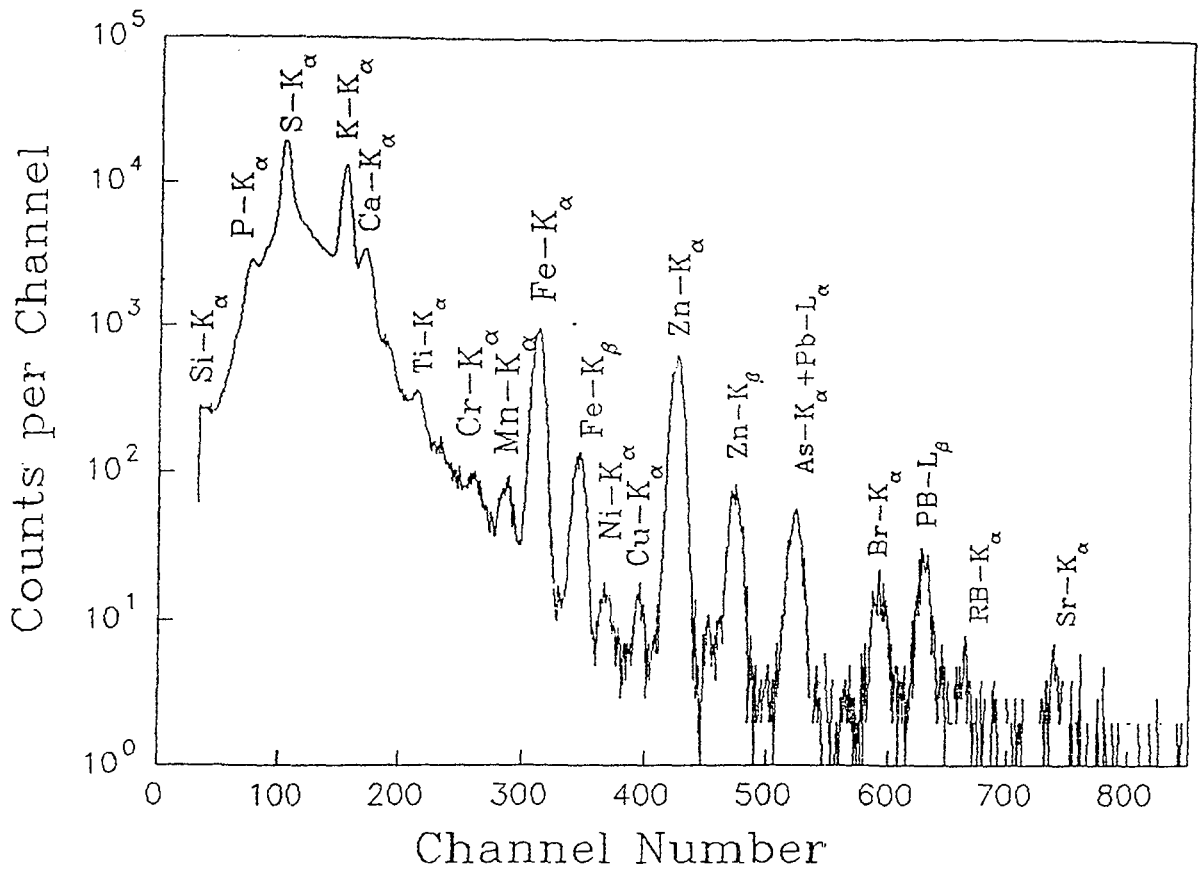


Fig 1. X-ray Spectrum of an Air Particulate Sample (fine) from Dhaka city using Internal Beam PIXE.

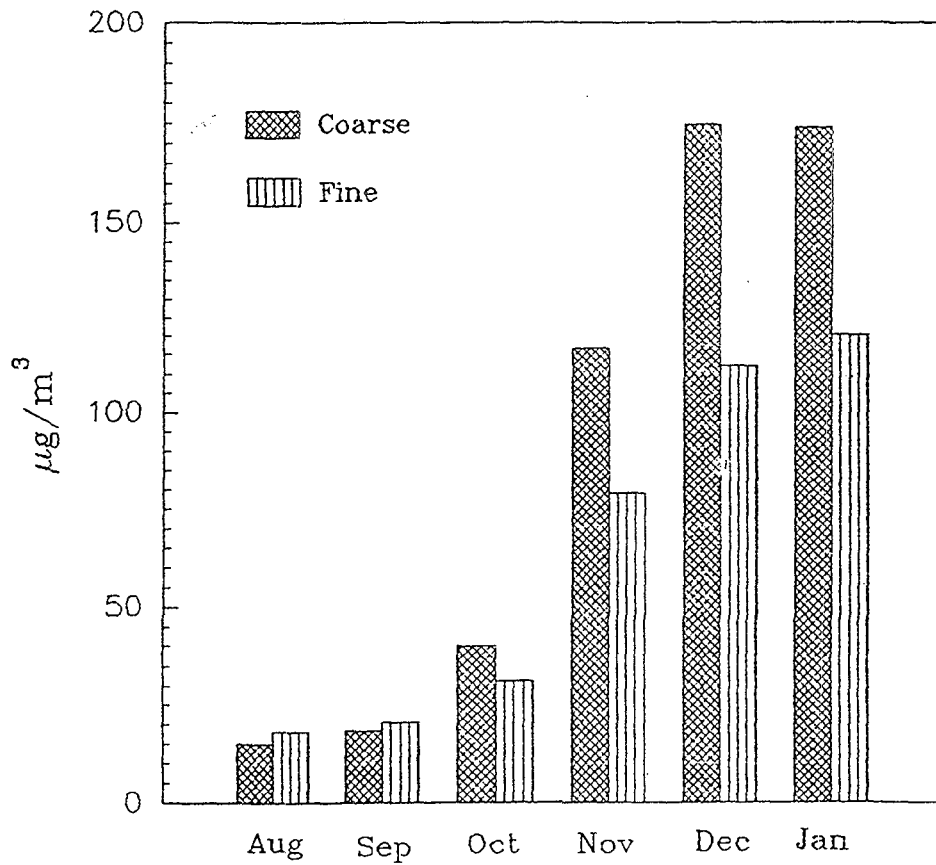


Fig 2. Monthly variation in air particulate mass (1993-1994)

Table 1. Monthly variation in concentration (ng/m³) of in coarse fraction during August '93 - January '94.

Element	Concentration (ng/m ³)					
	Aug	Sep	Oct	Nov	Dec	Jan
Si	1384	1779	2249	6198	7962	11732
P	33.8	35.6	27.4	32.1	134.1	57.8
S	270	292	435	964	2508	3055
Cl	728	531	184	320	559	180
K	193	247	357	1199	1636	2550
Ca	497	645	800	2661	2674	3315
Ti	31.1	38.2	63.4	171	239	304
Cr	5.55	8.13	6.32	13.9	24.1	24.7
Mn	9.09	11.7	16.1	41.7	52.7	62.1
Fe	372	478	649	1948	2461	2910
Ni	-	-	-	6.39	4.38	4.94
Cu	4.92	5.82	5.88	6.84	14.6	8.68
Zn	161	156	187	382	503	155
As	6.25	8.80	19.8	41.9	80.5	37.6
Br	4.02	11.1	26.9	64.1	137	87.4
Rb	-	-	-	12.5	14.0	13.6
Sr	-	-	-	15.9	16.5	16.5
Pb	66.3	103	218	306	501	440

Table 2. Monthly variation in concentration (ng/m³) of in fine fraction during August '93 - January '94.

Element	Concentration (ng/m ³)					
	Aug	Sep	Oct	Nov	Dec	Jan
Si	309	187	344	559	771	1195
P	40.9	32.3	46.9	76.4	67.0	81.5
S	814	617	922	1968	2218	3317
Cl	84.0	48.0	49.0	128	121	82
K	321	343	444	1302	1283	1959
Ca	105	90	105	246	194	297
Ti	17.2	12.5	13.2	27	29	29
Cr	4.52	-	-	12.1	11.2	11.8
Mn	6.71	7.0	6.6	12.8	9.8	14.3
Fe	147	111	107	270	228	250
Ni	-	-	3.84	5.50	6.36	5.13
Cu	5.86	5.85	5.10	9.84	7.7	6.36
Zn	301	235	176	414	230	126
As	15.5	21.5	37.1	47.1	63.1	39.8
Br	14.1	22.6	54.6	105.9	157	131.0
Rb	-	-	-	-	11.6	16.7
Sr	-	-	-	13.4	22.1	17.5
Pb	284	274	450	400	661	696

Table 3. Two Group averaged concentration in ng/m³ (Aug.-Oct., Nov.-Jan.) with standard deviation for coarse fraction.

Element	August- October		November-January	
	Average [*] (N=34)	SD	Average [*] (N=37)	SD
Si	1815 (34)	1101	8259 (37)	3459
P	32.3 (13)	23.3	85.1 (13)	57.8
S	332 (34)	139	2099 (37)	2050
Cl	477 (34)	422	383 (37)	519
K	271 (32)	134	1705 (37)	873
Ca	652 (34)	319	2825 (37)	991
Ti	44.3 (34)	30.0	214 (37)	96
Cr	6.58 (8)	1.57	20.8 (35)	14.1
Mn	12.3 (34)	6.4	51.1 (37)	19.1
Fe	502 (34)	270	2390 (37)	824
Ni	-	-	5.05 (14)	2.34
Cu	5.59 (25)	1.60	10.3 (36)	8.2
Zn	167 (34)	106	376 (37)	623
As	13.7 (21)	8.8	60.9 (25)	45.7
Br	14.1 (34)	15.6	99.3 (37)	104.2
Rb	-	-	13.4 (15)	6.22
Sr	-	-	16.35 (25)	4.87
Pb	129 (34)	106	418 (37)	518

* N is the total number of samples; Numbers in the paren-thesis corresponds to samples which have concentration above the detection limit.

Table 4. Two Group averaged concentration in ng/m³ (Aug.-Oct., Nov.-Jan.) with standard deviation for fine fraction.

Element	August- October		November-January	
	Average [*] (N=34)	SD	Average [*] (N=38)	SD
Si	273 (25)	188	816 (33)	518
P	38.6 (10)	9.9	73.3 (20)	40.9
S	774 (34)	389	2440 (38)	1268
Cl	59.0 (34)	74.0	114 (38)	911
K	369 (34)	152	1450 (38)	682
Ca	101 (24)	41	239 (36)	118
Ti	14.7 (10)	3.9	28.3 (36)	13.9
Cr	4.52 (1)	-	11.6 (30)	5.6
Mn	6.8 (31)	2.2	11.6 (30)	5.9
Fe	120 (34)	44	247 (38)	114
Ni	3.84 (1)	-	5.83 (29)	2.02
Cu	5.62 (29)	2.19	7.86 (26)	4.82
Zn	235 (34)	128	268 (38)	580
As	24.8 (34)	19.8	60.2 (38)	71.4
Br	30.5 (34)	28.5	133 (38)	108
Rb	-	-	14.1 (4)	3.1
Sr	-	-	19.1 (9)	6.0
Pb	334 (34)	271	580 (38)	818

* N is the total number of samples; Numbers in the paren-thesis corresponds to samples which have concentration above the detection limit.

Table 5. Enhancement factors with respect to Ti.

Element	Coarse		Fine		29 Cities	Khartoum
	Aug-Oct	Nov-Jan	Aug-Oct	Nov-Jan		
Si	0.65	0.61	0.3	0.46	0.48	0.35
P	2.72	1.48	9.8	9.66	1.6	1.18
S	63.3	83.0	445	730	301	46.8
Cl	151	25.1	56.0	56.5	184	59.1
K	1.04	1.35	4.26	8.7	1	0.35
Ca	1.78	1.6	0.83	1.02	1.78	0.79
Ti	1	1	1	1	1	1
Cr	3.27	2.14	6.76	9.0	3.8	0.6
Mn	1.23	1.05	2.03	1.81	1.96	0.74
Fe	1.0	0.98	0.72	0.77	1.35	0.75
Ni	1.3	-	14.4	11.3	6.63	0.95
Cu	7.93	3.03	24.0	17.5	91.4	0.51
Zn	126	58.5	533	316	184	12.3
As	272	250	1482	1872	-	-
Br	877	1276	5698	12966	1190	72.7
Rb	-	0.89	-	7.09	1.78	0.35
Sr	-	1.12	-	9.91	0.54	0.48
Pb	802	537	6248	5635	2331	29.1