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Characteristics of air particulate matter and their sources in urban and rural area of Beijing, China

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Abstract: During October 1993 and March 1996, the samples of fine and coarse air particulate matter have been collected at representative urban and rural site of Beijing with the Gent Stacked Filter Unit Sampler. Instrumental neutron activation analysis (INAA) and proton induced X-ray emission (PIXE) method were used to determine the elemental composition of the particulate matter. Average elemental concentrations and enrichment factors were calculated for the fine and coarse size fractions. Based on the particulate matter data obtained at urban and rural site together with the chemical constituents of the aerosol from the different sources are discussed. The results show that the relative particulate mass and elemental concentrations of crustal and pollutant elements in the air particulate matter collected over the urban are higher than rural and winter heating period are higher than in ordinary season. Beijing atmosphere is polluted by aerosols from regional and faraway sources. It was noticed that the toxic or harmful elements such as As, Sb, Pb, Cu, Ni, S and Zn were mainly enriched in fine particles with diameter less than $2\ \mu\text{m}$. A receptor model was used to assess the relative contribution of major air pollution sources at receptor sites in Beijing. Trace elements were used as the markers for the above assessment. Factor analysis method was used to identify possible emission sources of air particles. The major sources of dust-soil, coal burning, motor vehicle emission, industry emission and refuse incineration were identified.

Key words: atmospheric particulate matter; urban; rural; source; aerosol

Introduction

There is a growing awareness to the importance of air pollution in major cities. A number of studies have shown that the concentrations of certain trace elements in the urban atmosphere have been elevated by pollution, and therefore, the highest concentrations of these chemical contaminants are observed over the cities (Yang, 1987; 1989). So, an assessment of the relative contribution of major air pollution sources at major cities is important for setting up the priority for implementing controlling measures in order to prevent the existing air quality from further deterioration. It was found that the elements for potentially influencing human's health are mainly enriched in the fine particles with the dimension less than $2\ \mu\text{m}$. Thus, to help identify the sources and behaviors of aerosols, it is very important to measure both the fine and coarse size distribution and composition of aerosols in urban air. In order to achieve our research objectives, the aerosol samples are analyzed by one or more analysis techniques: gravimetry (for the particulate mass), instrumental neutron activation analysis (INAA) and proton induced X-ray emission analysis (PIXE) (for over 40 elements). To identify the sources, the multi-element data are used as the markers for assessing the relative contribution of major air pollution sources. Factor analysis method, one of the widely applied receptor models was used in present work for identification of sources in Beijing area.

1 Methods

1.1 Sampling

The samples were collected in two size ranges $2\text{--}10\ \mu\text{m}$ (coarse fraction) and $<2.0\ \mu\text{m}$ (fine fraction) on 47 mm nuclepore filters of $8.0\ \mu\text{m}$ and $0.4\ \mu\text{m}$ pore sizes using Gent Air Sampler with stacked filter unit (IAEA, 1994). The urban sampling site was in a western of Beijing, China (40°N , 116°E), and was about 10 km from the city center. Aerosol samples were collected on the roof

of building about 20m high housing of the National Center for Marine Environment Forecasts, State Oceanic Administration, in order to minimize re-suspended dust-soil from the nearby street. The major sources of air pollution in the close vicinity are expected to be residential heating, road dust, and auto motive emissions. A total of 99 sets of samples were collected during October 22, 1993 and October 17, 1994.

For the study of rural aerosol characteristics, we used the Gent stacked filter unit for the sampling of air particulate matter in a representative rural site, north-eastern of Beijing (Xinglong Meteorological Observatory, 40.2°N, 117.1°E). The sampling site was approximately 100 km from the city center. The aerosol sampling devices was placed about 5m above the ground and was carried out on a 24h basis twice a week. Sampling period from June 1995 through March 1996. There are two main air pollution sources in this rural sampling site: dust-soil and transportation. Dust-soil may be a natural component caused by entrance of soil by the wind, and anthropogenic pollutants transported from urban to rural with atmospheric motion, no other local pollution sources affect this sampling site.

1.2 Analytical techniques

Instrumental neutron activation analysis (INAA) and proton induced X-ray emission (PIXE) were used to determine the elemental composition of the aerosols, each filter was cut up in 2 parts, three quarters for analysis by INAA, and remaining quarter for analysis by PIXE. The concentrations of Al, Br, Ca, Cl, I, In, Mg, Mn, Na, Ti and V were determined by "short" INAA. A second part of elements was determined by "long" INAA procedure which measured the nuclide of As, Ba, Ce, Co, Cr, Cs, Eu, Fe, Hf, K, La, Lu, Na, Nd, Rb, Sb, Sc, Se, Sm, Ta, Tb, Th, Yb and Zn. 20 elements were looked for in the PIXE spectra (Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Br and Pb). To test the accuracy of the method, we also analyzed the standard reference material SRM 1632a from the National Institute of Standards and Technology (NIST). A comparison between our analytical results and the value reported in the literature for several elements is given in Table 1. A satisfactory agreement was obtained.

Table 1 Comparison between our analytical results and elemental content of NIST standard reference materials SRM-1632a, ppm

Element	Our results*	Literature results	Element	Our results*	Literature results
Pb	12.8 ± 0.8	12.4 ± 0.6	Ce	29.2 ± 1.3	30
Cr	35.1 ± 1.2	34.4 ± 1.5	Cs	2.3 ± 0.1	2.4
Fe	11075 ± 126	11100 ± 200	Co	6.7 ± 0.3	6.8
Se	2.6 ± 0.7	2.6 ± 0.7	Eu	0.56 ± 0.02	0.54
Th	4.45 ± 0.13	4.5 ± 0.1	Hf	1.57 ± 0.09	1.6
V	1.24 ± 0.02	1.28 ± 0.02	Rb	33.4 ± 1.5	31
Sb	0.56 ± 0.07	0.58	Sc	6.48 ± 0.14	6.3

* Average of ten determinations

2 Results and discussion

2.1 Aerosol particulate mass concentration

The average particulate mass in coarse and fine size fractions of urban and rural aerosol for various months are presented in Fig. 1 and Fig. 2, it can be seen that the particulate mass concentration for urban and rural aerosol varies from season to season. Variations of the particulate mass concentration may be obvious due to the difference in the origins of aerosol and meteorological conditions. The average particulate mass concentrations of urban coarse fraction in winter heating period (from November to March) are higher than in ordinary season. Coal is the major fuel used for warming in Beijing area, as is the lack of pollution control or abatement technology for the coal furnaces and stoves. So that the pollution caused by coal combustion in air must be quite

predominant in the heating period. The particulate mass concentrations of the coarse size fractions in urban site ranged between 31—284 $\mu\text{g}/\text{m}^3$ and of the fine size fractions between 18.8—99.8 $\mu\text{g}/\text{m}^3$. However, in the rural site particulate mass concentrations of the coarse fractions ranged between 8.5—70.2 $\mu\text{g}/\text{m}^3$ and of the fine fractions between 10.9—70.4 $\mu\text{g}/\text{m}^3$. There is an obvious difference in the mass concentration between urban and rural aerosols. At urban site, particulate mass concentration in coarse fraction are large than fine fraction, but at rural site, a reverse trend was observed, the fine particulate mass was large than coarse ones. This may indicate that the rural aerosols mainly come from long-range transport of natural and anthropogenic pollutants, which transported from urban to rural area by wind.

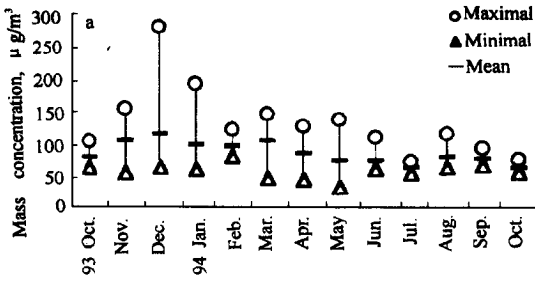


Fig. 1a Monthly mean particulate mass in coarse fractions of urban site

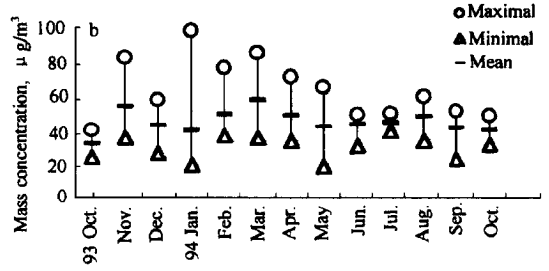


Fig. 1b Monthly mean particulate mass in fine fractions of urban site

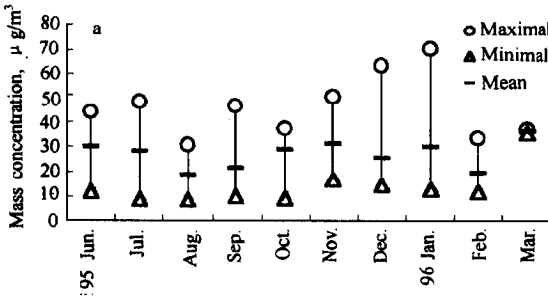


Fig. 2a Monthly mean particulate mass in coarse fractions of rural site

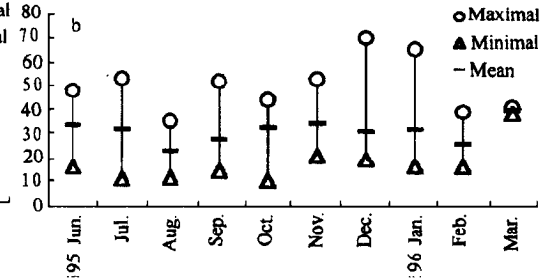


Fig. 2b Monthly mean particulate mass in fine fractions of rural site

2.2 Average concentrations of elements

The ranges, means and standard deviations of the trace elemental concentrations at urban and rural sampling site are given in Table 2a and 2b, each of the elemental concentrations listed in Table 2 trend to be higher at the urban site than at the rural site, except for Cl and Mo (in fine size fraction). Variations of the concentrations of chemical constituents in aerosol may be very obvious due to the difference in the origins of aerosol and meteorological conditions. The average elemental concentrations of urban aerosol in winter heating period are higher than in ordinary seasons, except for Ca. Such trends were attributed the coal combustion in heating emission over the city. During the non-heating period (especially spring season) the soil related elements have higher concentrations, this increase is due to increasing amounts of dust-soil which brought into the air and mixed in the atmosphere by wind. One of the common features of all trace elemental data sets (urban or rural) are large variabilities in the concentrations of elements, this is usually reflected in high standard deviations.

Table 2a Elemental concentration for the coarse and fine size fractions of urban site Unit:ng/m³

Elements	Coarse particles			Fine particles		
	Range	Mean \pm SD	N	Range	Mean \pm SD	N
PM	31000—284000	87193 \pm 34934	99	18800—99800	46848 \pm 14502	99
Al	590—10790	2721 \pm 1580	99	50—3960	983 \pm 673	99
Si	1170—34976	8877 \pm 4927	99	590—12499	3490 \pm 2322	99
P	50—1168	352 \pm 182	99	41—893	307 \pm 156	97
S	297—10230	2000 \pm 1688	99	408—14265	3197 \pm 2520	99
Cl	13—2252	267 \pm 294	94	3.0—543	103 \pm 107	82
K	162—4262	1166 \pm 704	99	171—2623	1087 \pm 585	99
Ca	486—12000	4985 \pm 2758	99	230—3870	1242 \pm 638	99
Fe	181—9350	2864 \pm 1590	98	126—3180	905 \pm 527	99
Zn	15—1832	285 \pm 283	99	13—1029	318 \pm 218	99
Mg	492—17000	3073 \pm 2326	98	235—8900	1251 \pm 1292	85
Na	131—3280	786 \pm 469	98	119—1360	446 \pm 194	99
Ti	41—990	331 \pm 189	99	3.0—427	87 \pm 58	99
Mn	9.0—458	119 \pm 82	99	4.3—228	88 \pm 52	99
V	1.0—34.7	8.04 \pm 5.46	99	0.236—12.2	2.81 \pm 1.86	99
Cr	11—90	28.2 \pm 12.0	98	3.52—44.6	26.8 \pm 6.61	99
Co	0.77—14.1	3.61 \pm 2.66	99	0.125—6.06	1.49 \pm 1.09	98
Ni	0.5—166.1	43.2 \pm 29.6	99	2.1—93.9	23.7 \pm 16.5	99
Cu	1.1—256.2	54.2 \pm 38.4	99	2.6—119.7	30.7 \pm 21.7	99
As	1.11—158.4	32.0 \pm 26.4	99	3.2—89.4	27.8 \pm 16.7	99
Se	0.2—51.3	9.50 \pm 10.1	99	0.2—33	8.41 \pm 7.23	99
Br	0.8—39.1	9.42 \pm 8.39	99	1.7—42.2	16.6 \pm 8.43	99
Pb	0.5—562.2	112 \pm 100	98	2.0—441	145 \pm 104	98
Ba	10.3—918	126 \pm 146	98	8.6—415	45.5 \pm 60.3	98
Cs	0.14—3.04	0.85 \pm 0.55	98	0.11—1.96	0.64 \pm 0.33	99
Ga	7.28—99.2	22.4 \pm 15.0	55	6.38—114	21.5 \pm 15.8	62
I	1.53—10.5	4.46 \pm 2.29	38	0.9—11.4	3.98 \pm 1.87	87
In	0.139—0.91	0.45 \pm 0.24	15	0.081—0.58	0.22 \pm 0.11	60
Hf	0.088—1.68	0.48 \pm 0.32	96	0.0353—0.65	0.15 \pm 0.09	74
Mo	0.49—124	8.11 \pm 14.5	98	0.521—21.4	3.96 \pm 3.23	98
Rb	1.25—25.8	8.59 \pm 5.19	98	1.91—15	5.96 \pm 2.99	96
Sb	0.24—78.3	4.88 \pm 8.19	98	0.335—16.8	4.90 \pm 2.98	99
Sc	0.103—4.85	1.18 \pm 0.82	98	0.0197—4.39	0.34 \pm 0.62	97
Ta	0.341—3.13	0.13 \pm 0.35	75	0.0243—0.129	0.05 \pm 0.03	18
Th	0.16—4.54	1.38 \pm 0.88	98	0.0263—1.59	0.33 \pm 0.23	99
U	0.124—3.61	0.76 \pm 0.64	98	0.06—1.52	0.45 \pm 0.32	98
W	0.23—6.31	1.29 \pm 1.09	96	0.175—2.66	0.81 \pm 0.46	96
La	0.39—14.9	4.51 \pm 2.59	98	0.189—8.6	1.33 \pm 1.06	99
Ce	0.76—28.6	8.83 \pm 5.14	98	0.311—18.5	2.57 \pm 2.08	99
Nd	0.24—10.4	3.14 \pm 1.85	98	0.087—8.12	0.92 \pm 0.86	99
Sm	0.052—2.27	0.60 \pm 0.37	98	0.013—1.7	0.18 \pm 0.19	99
Eu	0.022—0.42	0.13 \pm 0.08	96	0.012—0.16	0.05 \pm 0.02	72
Tb	0.01—0.31	0.10 \pm 0.06	96	0.011—0.126	0.03 \pm 0.02	86
Yb	0.056—0.908	0.27 \pm 0.15	98	0.046—0.876	0.12 \pm 0.10	91
Lu	0.003—0.159	0.047 \pm 0.028	98	0.007—0.090	0.019 \pm 0.012	96

"N" is the total number of samples

Table 2b Elemental concentration for the coarse and fine size fractions of rural site Unit:ng/m³

Elements	Coarse particles			Fine particles		
	Range	Mean ± SD	N	Range	Mean ± SD	N
PM	8500—70200	26788 ± 13529	64	10900—70400	31178 ± 13036	64
Al	120—1950	587 ± 332	64	46—410	234 ± 80	64
Si	310—3670	1387 ± 668	64	170—1300	610 ± 260	62
P	90—980	297 ± 123	62	73—1600	316 ± 219	64
S	120—1710	564 ± 368	63	320—7490	1703 ± 1773	64
Cl	20—480	145 ± 87	57	14.0—540	122 ± 85	57
K	60—1400	403 ± 297	61	86—3420	570 ± 627	59
Ca	280—3820	1156 ± 676	64	120—1490	355 ± 210	64
Fe	49—1200	349 ± 224	64	18—340	113 ± 72	64
Zn	2—150	24 ± 24	60	2—130	35 ± 30	64
Mg	8—8820	1044 ± 1472	63	6—5560	430 ± 800	63
Na	1—1190	201 ± 186	64	7—910	102 ± 119	64
Ti	8—270	65 ± 41	64	1.0—56	24 ± 12	62
Mn	3.0—120	19 ± 19	64	1—55	15 ± 12	64
V	0.2—6.78	1.80 ± 1.23	64	0.18—1.75	0.80 ± 0.37	64
Co	0—2.22	0.58 ± 0.50	41	0.04—0.9	0.38 ± 0.32	64
Cu	10—27.4	16.0 ± 2.68	64	10.5—27.1	17.0 ± 3.11	64
As	0.06—14.2	1.07 ± 2.35	44	0.06—10.2	1.49 ± 1.75	48
Se	1.3—6.72	4.61 ± 1.25	12	1.4—9.2	5.49 ± 1.86	21
Br	1—8	3.36 ± 2.44	11	0.16—21.3	3.82 ± 4.12	60
Pb	2.5—36	12.8 ± 8.82	52	3.2—130	30.2 ± 28.2	55
Ba	8—353	109 ± 88.2	20			
Cs	0.02—0.91	0.29 ± 0.25	29	0.0—0.86	0.35 ± 0.24	42
Ga	0.74—6.02	2.26 ± 1.36	26	0.64—3.44	1.64 ± 0.81	22
I	0.29—2.99	0.95 ± 0.70	20	0.11—4.32	1.28 ± 0.92	63
Mo	0.19—49.3	6.98 ± 9.57	37	0.14—41.5	4.85 ± 6.54	38
Sb	0.09—6.02	0.56 ± 0.88	51	0.09—3.73	0.82 ± 0.94	61
Sc	0.02—0.78	0.18 ± 0.15	62	0.04—0.18	0.05 ± 0.04	53
Th	0.15—0.74	0.41 ± 0.14	35	0.23—0.45	0.33 ± 0.06	7
U	0.22—1.04	0.48 ± 0.25	18	0.2—0.78	0.45 ± 0.17	18
W	0.2—0.56	0.35 ± 0.11	24	0.11—0.65	0.34 ± 0.15	22
La	0.07—2.82	0.92 ± 0.61	63	0.04—0.821	0.32 ± 0.18	57
Ce	0.15—5.3	1.93 ± 1.26	39	0.12—6	1.07 ± 1.22	19
Sm	0.01—0.47	0.15 ± 0.10	62	0.007—0.42	0.06 ± 0.06	59
Eu	0.01—0.17	0.08 ± 0.05	19	0.005—0.152	0.05 ± 0.05	6
Lu	0.004—0.08	0.01 ± .001	43	0.0016—0.012	0.01 ± 0.00	43

"N" is the total number of samples

Using the individual coarse and fine atmospheric elemental concentrations data, coarse/fine ratios were calculated for each element in every urban and rural sample and these ratios were subsequently averaged over all samples. The mean coarse/fine ratios are shown in Fig. 3a and 3b, it can be seen that the elements Al, Si, Fe, Ca, Co, Ta, Th, Ti, Hf, Sc, V and rare earths, which are predominately from crustal origin in both size fractions, the average coarse/fine ratios are of the order of 2—4. For the anthropogenic elements S, Pb, Br and Zn, the coarse/fine ratio of urban aerosol are about 0.5—0.8, and the coarse/fine ratios of As, Se, K, Cr, P, Sb, I and Ga

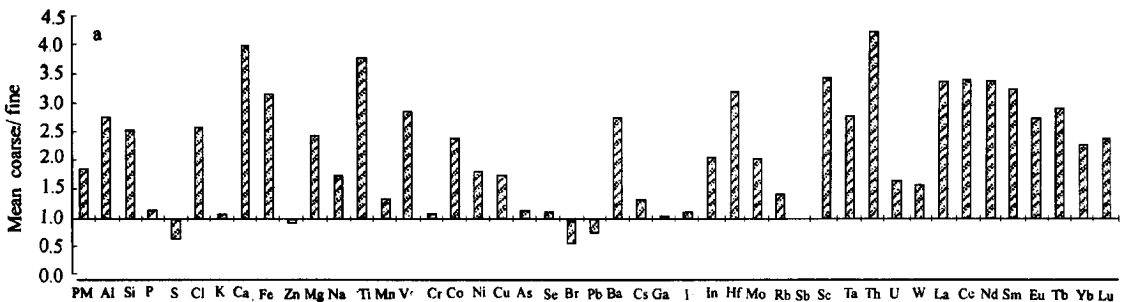


Fig. 3a Mean coarse/fine concentration ratios for the particle mass and 44 elements in 99 samples collected at urban site

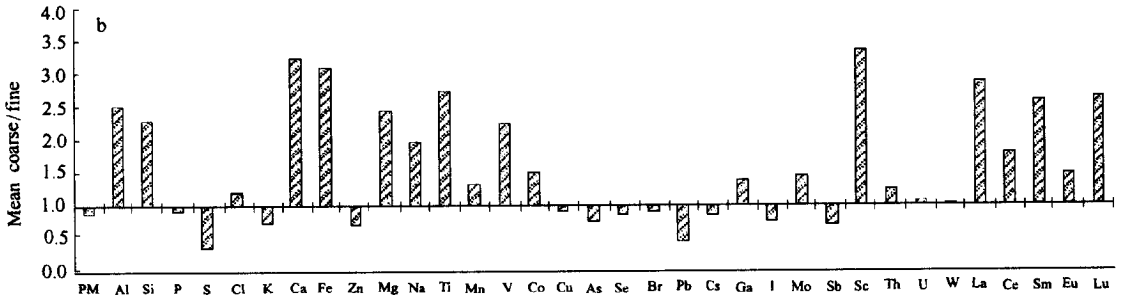


Fig. 3b Mean coarse/fine concentration ratios for the particle mass and 34 elements in 64 samples collected at rural site

approach to unity, but in Fig. 3b it is shown the anthropogenic elements As, Sb, S, Br, Pb, Cu, I and Zn, the coarse/fine ratios of rural aerosol are about 0.3—0.9. It is suggested that high concentrations of these elements in urban coarse fractions is due to increasing fall-amounts of flyash, which brought into air by wind.

According to mean elemental concentrations for coarse and fine size fractions of aerosols, it may be concluded as follows: (1) these elements are predominately associated with coarse particles (Al, Si, Ca, Fe, Mg, Na, Ti, Mn, V, Co, Ga, Mo, Sc, U, Th and rare-earth), which may be from natural sources, and caused by entrance of dust-soil by the wind; (2) the fine fractions contain more S, Pb, Br, As, Sb, Se, I, Cu and Zn than the coarse fraction. Their major sources are coal and oil combustion, motor-vehicle, and industrial emissions; (3) the fine fractions contain approximately the same as the coarse fractions for Cs, K, P and W, it is suggested that the elements in question have multiple sources.

2.3 The elemental enrichment factor in aerosol

The enrichment factor (EF) is commonly used to determine natural or anthropogenic source of elements in the atmosphere. Enrichment factors with respect to Mason’s average crustal rock (Mason, 1966) were calculated for the various elements in the fine and coarse size fractions, Sc was used as reference element. Mean enrichment factors of fine and coarse fractions at urban and rural site are shown in Fig. 4 and 5, it was observed that the EF (Sc, crust) values of elements Al, Si, Fe, Co, Na, Ca, Ta, Ti, V and rare earth were approach to unity or less than 10. This group of elements is commonly associated with dust-soil particles, and their relatively large particle size indicates a physical entrance process. In contrast, the EF values of elements Pb, Br, As, Se, I, In, S, Mo, Cu, Ni, Ga, W, Sb and Zn were large than 10 and even to 10⁴ for Se. These elements are associated with combustion process, such as automotive exhaust (Pb, Br), refuse incineration (Cu, Ni, Sb, Zn) or coal combustion (As, Sb, Se, S, I, Mo). Most of these enriched elements come from fuel combustion process. The particles generated by these sources can

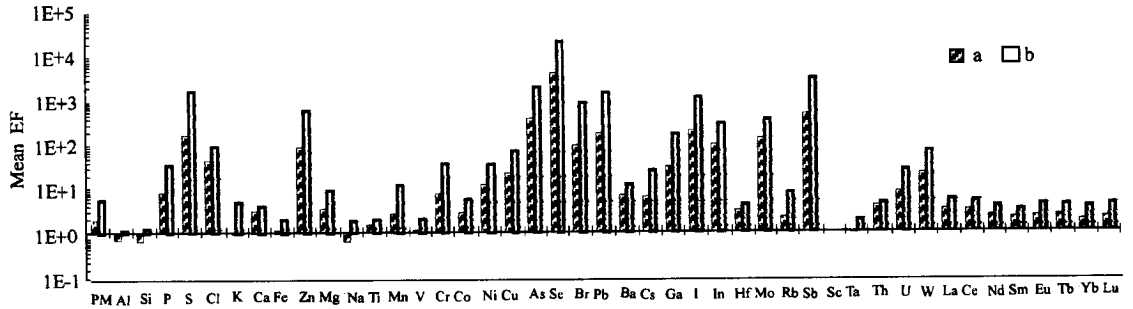


Fig. 4 Mean crustal enrichment factors for PM and elements in coarse (a) and fine (b) size fractions of SFU samples from urban site, Beijing

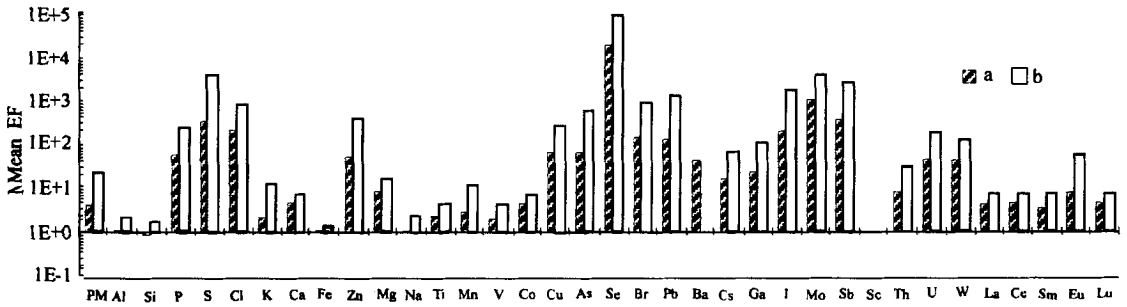


Fig. 5 Mean crustal enrichment factors for PM and elements in coarse (a) and fine (b) size fractions of SFU samples from rural site, Beijing

be both coarse and fine, however, combustion processes trend to generate the fine particles and mechanical or grinding processes the coarse ones. The generation of power through the burning of large amounts of coal generates fine particles. It is well known that coal is a kind of main fuel in Beijing, especially, during the winter heating period. Therefore, we can easily understand why the enrichment factors of anthropogenic pollutant elements are higher than those of other elements for the fine particle size. The average EF (Sc, crust) for coarse particle mass is approach to 10, so that only a minor fraction of coarse particles can be attributed to crust sources. Of interest in the coarse and fine size fraction is that the EF value of Ca and Mg is about 8, thus suggesting that most of Ca and Mg has to be attributed to noncrustal sources, it may be increased contribution from construction of building.

2.4 Identification of atmospheric particle sources using factor analysis

For the greatest improvement of air quality, emission controls should be applied first to the sources that contribute most to the atmospheric pollution. This means that we must have information on the relative contributions from possible sources. A receptor model was used to assess the relative contribution of major air pollution sources at receptor sites in Beijing. Trace elements were used as the markers for above assessment. Factor analysis method was used to identifying emission sources of air particles (Hopke, 1985). Five emission sources have been found in urban and rural site by this method. Table 3 lists the varimax rotated factor matrix, with the communalities. Table 3a (all urban fine aerosol samples) shows the first factor included crustal elements such as Th, V, Ti, Co, Al and Fe, this factor was identified as dust-soil. The second factor was consist of anthropogenic elements Pb, Br and Zn and identified as motor vehicle factor. The factor 3 had La, Ce and Nd and identified as crustal erosion materials. The factor 4 had Ni, Cu and As and mainly attributed to coal combustion. The last factor has S and Sb and identified as industrial emission. Table 3b (all rural fine aerosol samples) indicates the first factor included crustal elements such as Si, Fe, Ca, Al, V, Ti and Sc, this factor was identified as dust-soil. The second factor was consist of anthropogenic elements Pb and Br and identified as motor vehicle factor. The third factor has Sm, and La and identified as crustal erosion materials. The factor 4 had As and Sb and mainly attributed to coal combustion. The last factor had Zn and Na and identified as industry emission or refuse incineration. The regression model was formulated using multiple regression analysis. The results for urban fine aerosol indicates that about 37.6% of particles is due to dust-soil, while coal combustion about 21.3%, motor vehicle or oil burning about 13.2% and industry emission about 14.6%. For rural fine aerosol indicates that about 67.1% of particles is due to dust-soil, while motor vehicle or oil burning about 10.6%, industry emission and coal combustion about 13.7% and 6.8%, respectively.

Table 3a Varimax rotated factor matrix for the urban fine fraction aerosol

	F1	F2	F3	F4	F5	Com
Th	0.897					0.922
V	0.887					0.886
Ti	0.798					0.730
Co	0.725			0.407	0.455	0.909
Al	0.587			0.576		0.729
Pb		0.854				0.857
Zn		0.809		0.374		0.815
Br		0.747				0.700
Fe	0.516	0.593	0.436			0.832
Ce			0.964			0.993
Nd			0.945			0.947
La			0.943			0.953
Ni				0.894		0.946
Cu		0.447		0.818		0.914
As		0.439		0.682		0.757
S		0.537			0.642	0.791
Sb	0.430	0.500			0.622	0.854
Eigenvalue	7.72	2.71	2.23	1.17	0.702	14.53
Pct of var, %	45.4	16.0	13.1	6.9	4.1	85.5

* Only factor loadings above 0.30 are shown

Table 3b Varimax rotated factor matrix for the rural fine fraction aerosol

	F1	F2	F3	F4	F5	Com
Si	0.938					0.914
Fe	0.831					0.779
Ca	0.826					0.715
Al	0.741	0.358				0.815
V	0.729		0.441			0.768
Ti	0.677				0.448	0.724
Se	0.605	0.536	0.348			0.801
Br		0.877	0.301			0.894
Pb		0.816		0.330	0.301	0.884
I	0.345	0.753	0.384			0.869
Cu		0.749				0.761
S		0.696			0.419	0.691
La	0.354		0.893			0.965
Sm	0.341		0.892			0.957
As				0.872		0.803
Sb		0.546		0.771		0.913
Zn		0.374			0.796	0.812
Na				0.322	0.652	0.608
Eigenvalue	7.53	3.33	1.49	1.22	1.11	14.68
Pct of var, %	41.8	18.5	8.3	6.8	6.2	81.6

* Only factor loadings above 0.30 are shown

3 Conclusion

The average annual concentration of PM-10 particles in urban and rural aerosol is $67.0 \mu\text{g}/\text{m}^3$ and $28.9 \mu\text{g}/\text{m}^3$ respectively.

The relative particulate mass and elemental concentrations of the crustal and pollutant elements in the air particulate matter collected over the urban are higher than rural.

The average elemental concentrations of urban aerosol in winter heating period are higher than in ordinary seasons.

It was found the harmful or toxic elements (Pb, As, Sb, Cu, Ni and S) are mainly enriched in the fine particles with the dimension less than $2 \mu\text{m}$, being easily inhaled by human.

Our research results indicated that the most important sources of air pollution in Beijing area were dust-soil and emission from coal combustion, followed by the contributions from motor vehicle, industry emission and refuse incineration.

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