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Study of aerosol composition in some clean areas of China

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Abstract—On Peak Namjagbarwa (Tibet Plateau), Lushan Mountain (Province Jiangxi), Flower Mountain and Shangdianzi (Beijing, near Great Wall) aerosol samples have been collected by cascade samplers. For comparison aerosol samples from Beijing City, Pacific Ocean and South Pole also have been collected. Samples were analyzed with PIXE or XFA instruments. Factor analysis and enrichment factor calculation were performed to process the data.

Keywords: aerosol; PIXE; XFA; enrichment factor; factor analysis.

Aerosol particles are the trace components in the atmosphere and the compounds in aerosol contain many kinds of elements. The content of each element depends on its sources and the meterological conditions. The concentrations and components of the particles can be varied by influence of many reasons such as sea-gas exchange, land-gas exchange, volcano eruption, yellow sand transport, pollution of human activities and transformation of the trace gases. So the aerosol chemical composition is a good tracer for atmospheric study, and atmospheric scientists and ecologists are very interested in studying the aerosol composition. One of the most important research works on aerosol is to collect the aerosol samples in background stations or natural clean areas, then perform physical and chemical analysis to obtain the basic data of aerosol elemental composition (Adams, 1977; Winchester, 1981). With these data, scientists can explore and predict the possibility and reason of environment changes in some regions or whole world. The research results in China may offer some contribution to the studies of regional or global change.

For this purpose, aerosol samples were collected with cascade samplers on Peak Namjagbarwa (Tibet, 3600—5000 m) (Ma, 1986), Lushan Mountain (Jiangxi Province, 1440 m) (Song Wenzhi, 1988), Zhangjiajie (Ma, 1988), Flower Mountain (Beijing, 2000 m) and Shangdianzi (Beijing, 150 m) (Ma, 1988). In order to compare the data, samples in Beijing City (50 m), Pacific Ocean and South Pole were also collected and analyzed. The sampling locations are shown in Fig. 1. The samples were analyzed by using PIXE or XFA. For studying the aerosol

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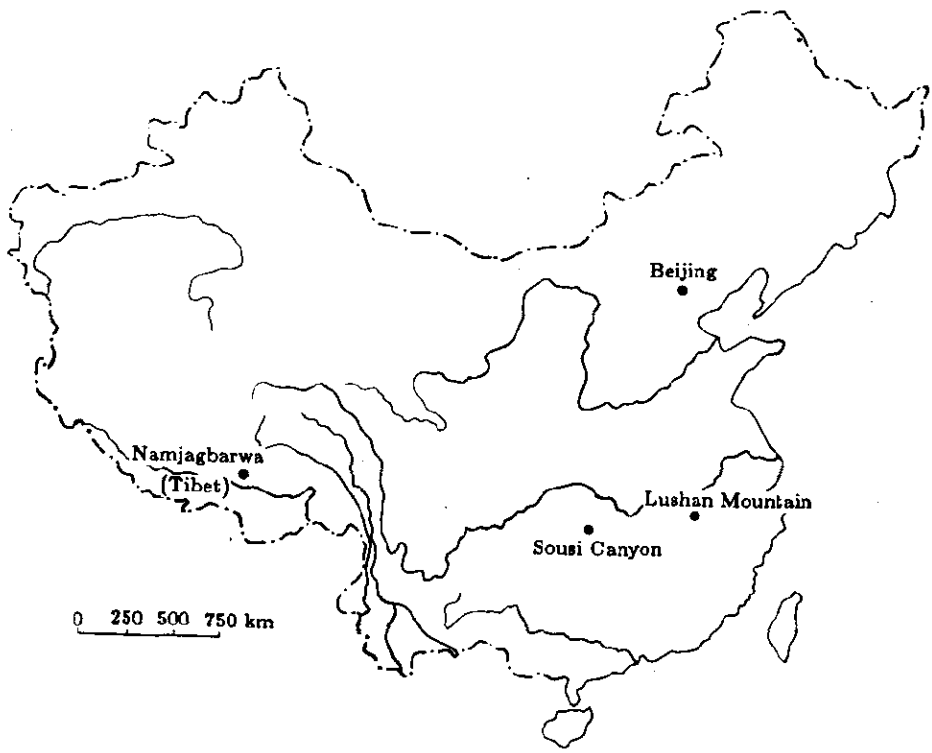

Fig. 1 Places of aerosol sampling in China

components and their sources, factor analysis and enrichment factor calculation were performed to process the data.

Concentrations of aerosol elements in these places are shown in Table 1. Concentrations of Si, Ca and S in the samples of Namjagbarwa are lower than that of Flower Mountain and Zhangjiajie, but slightly higher than that of South Pole, Pacific Ocean and Chacaltaya. The concentrations of Cl are relatively higher than that of other places. The Ca concentration of samples on Lushan Mountain is similar to that of Chacaltaya. It is shown in Fig.2 that the Namjagbarwa in Tibet is clean than Flower Mountain and Zhangjiajie. Although there are plants in Zhangjiajie that can prevent the earth crust from being blown up, but the Si concentration there is also higher than that of Namjagbarwa. The Si concentration on Flower Mountain is higher than that of Namjagbarwa by one order. It is probably because that the weather in northern China is relatively dry and there is more dust in the air. Therefore, Tibet is more clean than other places. Investigating the relationship between the Si concentration and particle size, it can be found that most of the Si element is in 2–8 μm particles in Namjagbarwa, but in other places, Si concentration became higher as the particle size became larger. It can be concluded that particle concentrations in Tibet are little affected by earth crust.

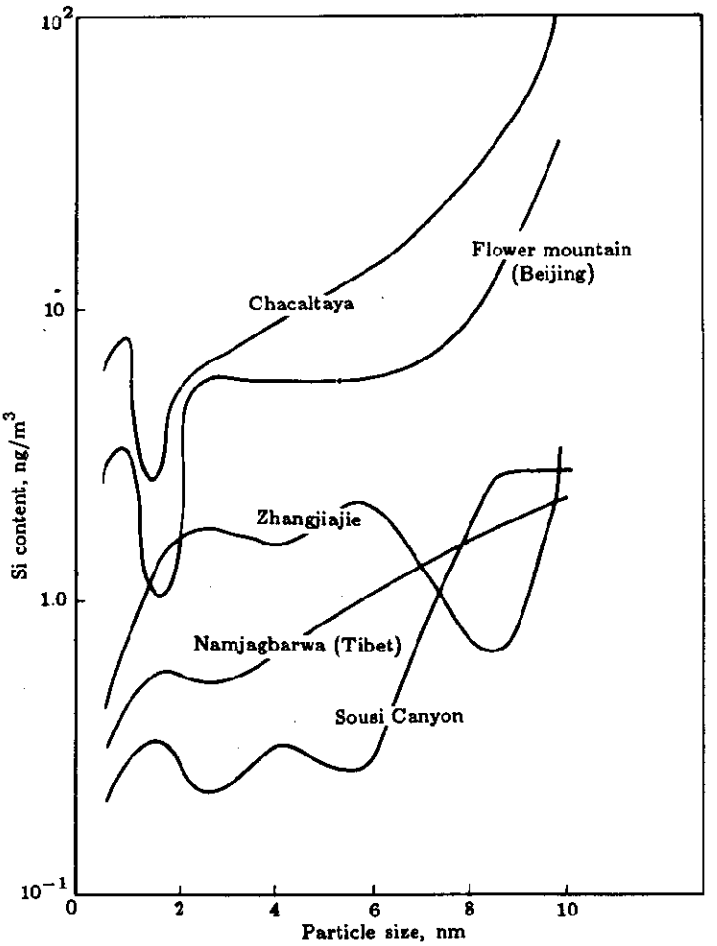

Fig. 2 Si content in the aerosol of Tibet and other clean areas in China

Previous research work showed that S element of aerosol particles is basically in the state of sulfate (Su , 1987). Fig. 3 gives the variation of S content of aerosol with particles size in different places. In Beijing, the concentration of S element in 2 μm fine particles are relatively high. It can be concluded that sulfate is the new product of transformation of its precursor SO_2. In Chacaltaya, South America, S element in aerosol is mainly in 4–9 μm coarse particles, there sulfate is the component of aged aerosol particles. In other words, there are few or no S sources there or nearby. The particle size distributions of S element in Zhangjiajie and Sousi Canyou are also similar to that in Chacaltaya, but the concentration of fine particles is slightly higher (Fig. 3 and Table 2).

The ratios X/Fe of coarse particles ($D > 11$ μm) in Zhangjiajie are shown in Table 3. X/Fe of S element is 0.975, its enrichment factor is relatively high which can reach up to 190. But in Table 4, the enrichment factor of S in fine particles ($D < 1.2$ μm) is 0.15. It is obviously

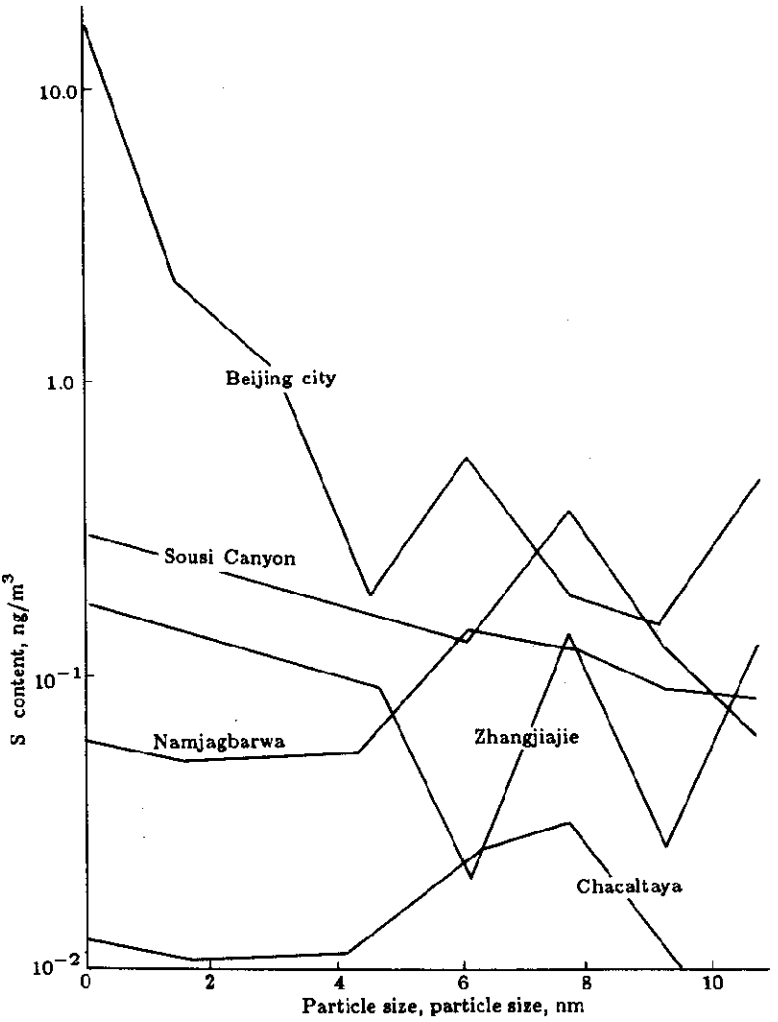

Fig. 3 Variation of S content of aerosol with the particle size in different places

shown that S element of aerosol in clean areas is remained in aged particles. Enrichment factor of S element of aerosol in Beijing City and Shangdianzi (150 km north of Beijing) are higher than 100. Enrichment factors of Se and Sb are higher than 1000. For As and Pb are higher than 100. This is the distinct difference between clean and unclean area.

The factor analysis results of aerosol on Lushan Mountain are shown in Table 5. The sum of the 1st to 4th factors accounted for 87.5% of the variance in the data. First factor contributed 49% to the variance. Here the elements of the largest loading are Si, Ca, Ti, V and Fe and so on which are elements in earth crust. So they come from earth dust into the aerosol. Second factor contributed 20% to the variance. The loadings of S and Pb are very large. It is well

known S and Pb come from fuel burning. Third factor contributed 11% to the variance. The loading of Cr is large. Cr comes from the iron-steel plant.

Table 1 Concentrations of some elements in aerosol of different places, $\mu g/m^3$

Locations	Si	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Zn	Pb	As	Ni	Cr	Br
Beijing City	12.77	28.84	5.92	3.96	5.35	0.216	0.145	1.959	0.034	0.166	0.185	—	0.008	0.035	0.013
Flower Mountain, Beijing	25.28	1.92	1.63	0.659	2.796	0.147	0.041	1.602	0.132	0.023	0.016	—	$<10^{-4}$	0.038	—
Namjagbarwa	6.64	0.683	2.22	0.207	0.529	0.002	0.002	0.537	0.049	0.035	<0.01	<0.01	0.027	<0.005	<0.001
Tibet	3.58	0.566	4.415	0.339	0.287	0.030	0.013	0.302	0.070	0.056	0.076	< 0.01	$<10^{-4}$	<0.005	<0.001
Chacaltaya	2.34	2.00	0.130	0.128	0.109	0.026	0.005	0.284	0.026	0.036	0.120	0.025	4.10	0.023	0.001
South Pole	0.0067	0.32	0.30	0.02	0.051	0.02	0.006	0.09	$<10^{-4}$	$<10^{-5}$	0.002	$<10^{-3}$	$<10^{-4}$	$<10^{-3}$	0.0015
Lushan Mountain	0.09	1.03	0.684	0.231	0.66	0.059	0.006	0.40	0.051	0.004	0.02				
Pacific Ocean	0.005	0.225	1.159	0.067	0.61	—				—		1.353		—	

Table 2 Concentrations of some elements in different size range of aerosol in Sousi Canyou, $\mu g/m^3$

Size, μm	>11	7.7-11	5.0-7.7	3.5-5.0	2.3-3.5	1.2-2.3	0.7-1.2	<0.7
Element								
Si	2.61	2.61	0.25	0.31	0.21	0.35	0.26	<0.019
S	0.087	0.12	0.57	0.12	0.16	0.38	0.39	0.46
Cl	0.078	0.15	<0.0038	0.10	0.11	<0.0038	0.21	<0.0052
K	0.032	<0.002	<0.002	0.0069	0.011	0.0048	0.014	0.011
Ca	0.18	0.048	0.048	0.029	0.025	0.023	0.023	0.029
Mn	0.0012	0.0013	0.00095	0.0011	0.0024	0.0017	0.0003	<0.00076
Fe	0.13	0.012	0.014	0.038	0.046	0.027	0.008	<0.0008
Ti	0.012	0.0014	0.002	0.027	0.0019	0.009	0.0025	<0.0024
Cu	0.0046	<0.00024	0.036	<0.00024	0.013	0.0096	<0.00024	<0.00026
Zn	0.0047	0.0019	0.020	0.011	0.018	0.011	0.0001	<0.0004

Table 3 Enrichment factor of some elements in coarse aerosol particulates ($D > 11\ \mu m$) of Zhangjiajie $E.F. = (X/Fe)$ coarse particulates/(X/Fe) earth's crust

Element	Coarse particulates, X/Fe	Earth's crust, X/Fe	Enrichment factor
Si	15.17	5.5	2.76
S	0.975	0.005	195
Cl	0.825	0.003	275
K	0.367	0.52	0.71
Ca	1.333	0.72	1.85
Mn	0.192	0.019	10.1
Fe	1.000	1.000	1.00
Ti	0.100	0.088	1.14
Cu	0.0367	0.011	3.34
Zn	0.0433	0.001	43.3

Table 4 Enrichment factor of some elements in fine aerosol particulates($D < 1.2\mu m$) of Zhangjiajie $E.F. = (X/Fe)$fine particulates / (X/Fe) earth's crust

Element	Concen. in fine particulate, $\mu g/m^3$	Fine particulate, X/Fe	Samples in the South Pole, X/Fe	Enrichment factor $E.F.$
Si	0.26	9.63	/	/
S	0.327	12.11	80	0.15
Cl	0.25	9.26	4.2	2.205
K	0.0153	0.567	1.1	0.515
Ca	0.0407	1.507	/	/
Ti	0.0041	0.152	/	/
Mn	0.0011	0.0407	0.021	1.938
Fe	0.027	1.00	1.00	1.00
Cu	0.0087	0.322	0.047	6.85
Zn	0.0029	0.107	0.053	2.02

Table 5 Result of the factor analysis of Lushan Mountain aerosol data

	Factors				
Variable	1	2	3	4	Communalities
Si	0.91	−0.10	0.07	0.02	0.88
S	−0.03	0.95	0.04	0.09	0.92
K	0.33	0.20	0.06	0.89	0.95
Ca	0.84	−0.12	0.22	0.33	0.87
Ti	0.93	0.02	0.06	0.20	0.92
V	0.89	0.17	0.14	0.19	0.87
Cr	0.05	−0.01	0.93	0.02	0.87
Mn	0.49	0.09	0.01	0.57	0.88
Fe	0.91	−0.08	0.10	0.32	0.95
Pb	−0.02	0.96	0.002	0.07	0.93
Variance	49	20	11	7.5	
	Probable crustal Source	Coal burning motor	Steel mill	Meteoro-logical station	

The loading of K element in fourth factor is large. The loading of Mn element is medium. It can be considered that the sources of aerosol on Lushan Mountain are mainly from the natural earth crust and human activities. The elements transported from outside are mainly from iron-steel plant. The results are fitted to the real conditions sicce Lushan Mountain is a scenic spot. Besides natural resources pollutants of human activities and traffic are mostly the important sources of aerosol components, and at about 300 km south of Lushan Mountain, there is a iron-steel plant.

CONCLUSION

It has been found that on Tibet Plateau the aerosol is not polluted too much, its sulfur and silica contents are relatively lower than that at other clean areas. Lushan Mountain and Zhangjiajie are relatively clean too. As a trace element for pollution sulfur exits mainly in coarse particles and has a high enrichment factor ($E.F.$) of about 190, but for fine particles $E.F.$ of sulfur is low. This shows that particles in Tibet and some clean areas do not contain much new product of atmospheric reaction but mostly aged particles. The results of factor analysis shows that the main source of particles at clean area is from earth crust since in the first factor Si, Ca, Ti, Fe have high loadings. The other source of particles is the primary and secondary air pollutants of human activities since the loadings of S and Pb have maximum in the second factor.

Atmospheric aerosol data of background stations or natural clean areas are very important for the study of global atmospheric chemistry. Enrichment factor calculation and factor analysis can be used to assess the clearness degree of atmosphere, to discover the abnormal situations of aerosol components and explore the causes. This study is also meaningful for looking for and assessing a place where a background monitoring station on Asian mainland will be located

since we still do not have such a station for global atmospheric chemistry study. On the basis of this study, a monitoring station for global atmospheric chemistry study could be located at Tibet Plateau and the other investigated places would be used for regional study. For further studying the change of trace components in the atmosphere and their effects on environment the long term measurement of aerosol, and especially the process of data have to be enforced an organized better.

REFERENCES

Adams, F., Dams, R., Guzman, L. and Winchester, J. W. Atmos. Environ., 1977, 11:629

Ma Ciguang, Huang Yanchu and Liu Quanyou *et al.*, Environ. Sci. 1986, 7(6): 51

Ma Ciguang, Li Ming and Huang Yanchu *et al.*, Acid Environ. Monitor., 1988, 2(2): 11

Ma Ciguang, Li Min and Li Hongzhen *et al.*, Aerosol composition at the South Pole (St. Great Wall), 1988 (to be published)

Song Wenzhi, Su Weihan and Zhang Qiupeng *et al.*, Study of aerosol on Lushan Mountain, 1988 (to be published)

Su Weihan, Zhang Qiupeng and Song Wenzhi, Adv. in Atmos. Sci., 1987, 4(2): 225

Wang Mingxing, Winchester, J. M. and Li Shaomeng, Nuclear Instruments and Methods in Physics Research, B22, North-Holland Amsterdam, 1987: 275

Winchester, J. M., Atmos. Environ., 1981, 16:933