SOURCE APPORTIONMENT OF $PM_{2.5}$ IN BEIJING

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Introduction

Recently, the air pollution becomes more serious in Beijing. Fine particulates pollution, which significantly impairs human health, exceeds the air quality standards greatly. Since the end of 1998, the municipal government of Beijing began to implement a series of emergent measures by phases to keep urban air pollution from becoming more serious. The effect of the four phases indicated that lowing emissions from local sources was effective for SO_2 and NO_x emission reduction, but was not very effective for fine particulates. According to the results of current control measures and future control plans, it is difficult to reduce fine particulates concentration to meet the standards. To determine the source of ambient $PM_{2.5}$ is the key issue of fine particulates pollution control.

One week integrated $PM_{2.5}$ samples were collected continuously at two sampling sites for over one year starting in July 1999. Samples were collected simultaneously at two sites in Beijing: one located at Chegongzhuang in a downtown area, and the other located one on the campus of Tsinghua University in a residential area. This paper examines the source contribution of ambient $PM_{2.5}$ by enrichment factor model and receptor model.

Experimental

A low-flow rate sampler with a 0.4l/min flow-rate was deployed at each site. X-ray fluorescence (XRF), ion chromatography (IC), and thermal/optical reflectance (TOR) were used to analyze 40 elements (from Na to U), water-soluble ions, and organic and elemental carbon (OC and EC), respectively. The detail information about Sampling system, chemical analysis, and quality control for this study has been introduced elsewhere[1].

It is considered that the element could be determined when the element concentration value is larger than double of its uncertainty value. Under this rule, fourteen elements (including Na, Mg, Al, Si, S, Cl, K, Ca, Fe, Cu, Zn, Se, Br, Pb), five ions (NH^{4+}, K^+, Cl^-, NO_3^-, SO_4^{2-}), EC and OC were used for source apportionment.

Results and Discussion

Enrichment factor of elements. Enrichment factor model is a good pollution indicator of human activity. Enrichment factor is given by the following equation:

$$EF = \frac{(C_i / C_n)_{Environment}}{(C_i / C_n)_{Background}}$$

where C_i, is the concentration of element i,

and C_n, is the concentration of background element.

Aluminium was used as the background element in this paper because its soil concentration was stable and ambient concentration was little impacted with human activity. The element background concentration in the soil of Beijing was taken as the concentration of background element[2]. The values are: Na 13.1mg/g, Mg 12.7mg/g, Al 69.9mg/g, Si 330mg/g, S 850ug/g, Cl 1000ug/g, K 19.3mg/g, Ca 15.2mg/g, Fe 29.7mg/g, Cu 23.6ug/g, Zn 102.6ug/g, Se 0.25ug/g, Br 3.05ug/g and Pb 25.4ug/g.

According to the enrichment factors, these 14 kinds of elements can be classified into two groups. One group is crustal elements, including Na, Mg, Al, Si, K, Ca, and Fe. The enrichment factors of Na, Mg, Al, Si, Ca, and Fe at the two sites were all less than 10, which is because that these elements came from crustal dust and hadn't been influenced greatly by human activities. The enrichment factor of K was a little larger than 10, due to the contribution of biomass fuel combustion around Beijing. The other group is pollutant element, including S, Cl, Cu, Zn, Se, Br, and Pb. The enrichment factors of these 7 elements were all greatly larger than 10, indicating that they were closely related with human activities. The enrichment factors of S, Zn, Se, Br, and Pb were even over 500. S mainly came from coal smoke and the conversion of SO_2 to sulfate. Zn was the trace element of municipal garbage. Se and Br were trace elements of coal combustion and oil combustion, respectively. Pb was related with various process of combustion. As Beijing now uses unleaded gasoline, Pb may come from the coal and vegetation combustion. High enrichment level of these elements showed that the anthropogenic $PM_{2.5}$ in Beijing was caused by the combustion of fossil fuel.

Table 1: Enrichment factors of elements in $PM_{2.5}$

Element	Tsinghua		Chegongzhuang	
	Number	Average	Number	Average
Na	36	3.2	36	4.3
Mg	34	1.5	36	1.7
Al	36	1	36	1
Si	36	0.7	36	0.7
S	36	803.2	36	793.3
Cl	36	372.2	36	313.7
K	36	15.6	36	14.9
Ca	36	7.3	36	7.2
Fe	36	3.7	36	3.6
Cu	36	176.4	36	169.8
Zn	36	583.8	36	498.7
Se	36	4049.2	36	4133.6
Br	36	832.7	36	596.8
Pb	36	1348.6	36	1270.9

Apparent seasonal variety of the enrichment factors at the two sample sites can be observed. Higher enrichment level occurred at the autumn and winter and lower enrichment level occurred at the spring. At the Tsinghua and Chegongzhuang sample sites, the enrichment factors of the crustal elements in winter were 49.7% and 43.1% respectively higher than those in spring. This seasonal variety was more obvious for pollutant elements. The enrichment factors of the 7 pollutant elements at the Tsinghua and Chegongzhuang sites in winter were 192.5% and 171.9% higher respectively than those in spring (as shown in **Figure 1**). According to Figure 1, except for Br, the enrichment factors of the other six elements reached peak value at winter, second highest value at autumn and lowest value at spring.

The significant seasonal difference of the pollutant elements' enrichment factors is due to the increased fossil fuel combusted in the heating periods. Besides, poor meteorological conditions in winter and autumn, such as dry climate and poor atmospheric dispersion conditions, is also an important reason that causes the seasonal difference of the enrichment factors.

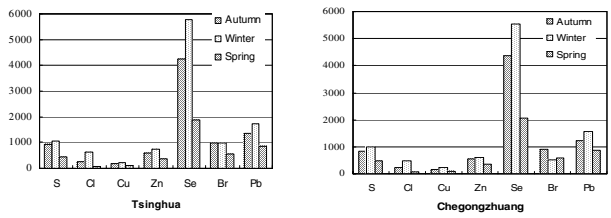

Figure1: Seasonal variation of enrichment factors on pollutant elements.

Figure 2 shows that the enrichment factors of the two samples didn't vary a lot with difference of most of the enrichment level within 10%, which is because that small particle diameter of $PM_{2.5}$ can make itself stay in the atmosphere for a long time and mix evenly in a definite spatial range.

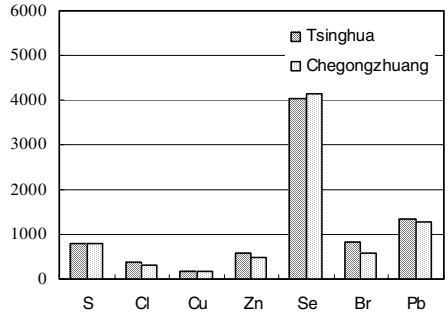

Figure 2: Spatial variation of enrichment factors on pollutant elements.

Source apportionment by receptor model

The software CMB 8.0 was used to estimate the contribution of the sources to the $PM_{2.5}$ mass of each sample in this paper. The CMB 8.0 software provides several indicators of the model results. In this study, most of main indicators were matched the model requirement.

The chemical mass balance model was used for source apportionment in this study. This method requires the detail chemical profiles of each emission source. In this study, the $PM_{2.5}$ emission source was divided into the following types: road dust, cement dust, residential boiler, industrial boiler, vehicle exhaust and secondary ammonium. The composition of road dust, residential boiler and industrial boiler were based on the study of Chen et al.[3] The cement dust profiles was adopted (SPECIATE profile No. 27204) from the EPA $PM_{2.5}$ source profiles database. The composition of vehicle exhaust was adopted from the draft result of the Beijing Air Pollution Control Project.

On average, the major contributors of $PM_{2.5}$ samples at two sites are shown in **Figure 3**. The average concentration of $PM_{2.5}$ was 146ug/m^3 and 138ug/m^3 in Tsinghua and Chegongzhuang respectively. The total contribution of the source accounts to 115.6ug/m^3 and 114.5ug/m^3, respectively. Coal boiler (residential boiler and industrial boiler) is the largest contributor of $PM_{2.5}$ at both sites, followed by secondary ammonium, road dust, vehicle exhaust and cement dust. About 20% of $PM_{2.5}$ mass was not determined by CMB. The undetermined sources maybe include biomass burning and sea salt, etc. The Source contribution to $PM_{2.5}$ at two sites was very similar, which indicates that the ambient $PM_{2.5}$ of those two sites has same sources. The coal consumption of residential boilers occupied 10%-15% of industrial boiler[4] but its contribution to $PM_{2.5}$ was similar with the industrial boilers. The major reason is from the lower fuel efficiency and higher PM emission factor of residential boilers.

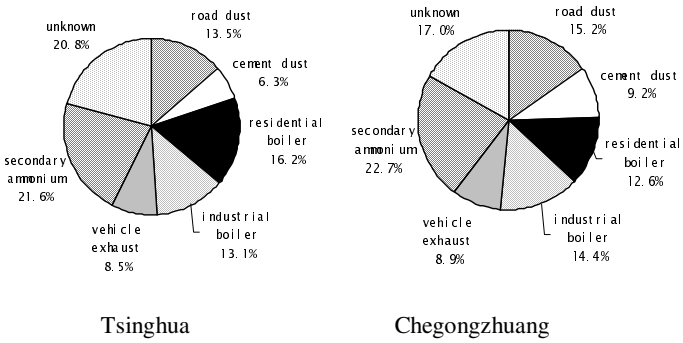

Figure 3: Average source contribution to PM2.5 at two sites.

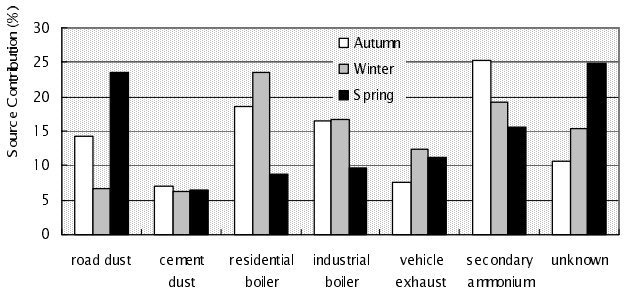

Figure 4: Seasonal variation of PM2.5 source contribution at Tsinghua site.

Figure 4 shows the seasonal variation of $PM_{2.5}$ source contribution at Tsinghua site. The similar result was found at Chegongzhuang site. The road dust contribution to $PM_{2.5}$ reached the peak in spring because of the dust storm. The contribution from coal boilers reached the peak in the winter due to the heating system working.

Acknowledgment

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