4.6 The chemical composition of fine particles and quantitative relationship between the mass concentration and meteorological condition in Beijing *

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Introduction

Fine particles are air pollutants with complex chemical composition including poisonous materials. As they can be breathed in the man's lung deeply, and very difficult to be ventilated out, therefore they are very harmful to human health. Fine particles can also result in atmospheric visibility deterioration through light extinction. Current researches indicate that there is a good negative correlation between the atmospheric visibility and the mass concentration of fine particles. In recent years, the fine particle pollution has become one of the most important issues in air pollution research in China. However, studies in this field in China so far are still relatively weak. Thus an integrated monitoring of fine particles and simultaneous meteorological data will make it possible to investigate the linkage between mass concentrations of fine particles and the meteorological parameters, and to help in improving atmospheric visibility in Beijing.

For this purpose, Beijing Meteorological Bureau, in cooperation with Peking University, performed a monitoring of PM2.5 and meteorology in 2001 at four seasons which were spring (March), summer (June), autumn (September), and winter (December). The sampling sites were the observation field of Atmosphere Exploration Base of China Meteorological administration (AEBCMA), Peking University (abbreviated as PKU thereafter) and Beijing downtown site DongSi (abbreviated as DS thereafter) Monitor Station. The atmosphere visibilities were read through the DPVS (Digital Photo Visibility System) (Xie, 1999) directly, other relevant meteorological data were available from routine observation at AEBCMA. Mass concentrations of PM2.5 were monitored in real time by Anderson's CAMMS, samples collected by Anderson's RAAS-400 were used for chemical compositions of PM2.5 including sulfate, nitrate, trace metals, crustals , EC and OC. Filter samples of PM2.5 were collected with Anderson's RAAS-400 sampler. Elements, ion and OC/EC of PM2.5 were analyzed by ICP, x-ray fluoresces and thermo-optical method.

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1 Fine particles pollution characteristics

1.1 Mass concentrations of PM2.5

The pollution level of PM2.5 in Beijing City has been very serious. As China has not yet the national ambient air quality standard for PM2.5, the standard proposed by US EPA （Environmental Protection Agency）in 1997, that is, day average concentration of 65 μg/m^3 and annual average of 15 μg/m^3, was adopted for assessment. From our measurement, the seasonal average mass concentrations of ambient PM2.5 in Beijing ranged between 63 μg/m^3 to 167μg/m^3 , the annual average level were 110 μg/m^3, more than 7 time as the US air quality standards of PM2.5.

The data in figure 1 also showed that PM2.5 had higher concentration in summer and winter. In summer time, the PM2.5 may mainly come from secondary reaction that makes serious pollution at regional scale, while in winter AEBCMA at southern part of Beijing had much higher level of PM2.5 because of more coal burning in that area.

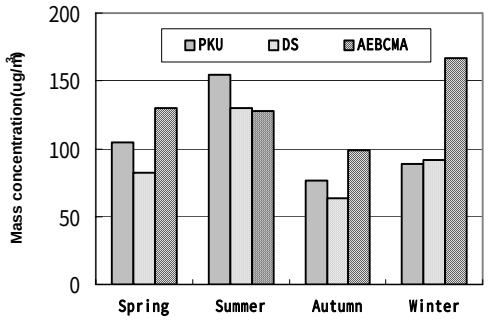
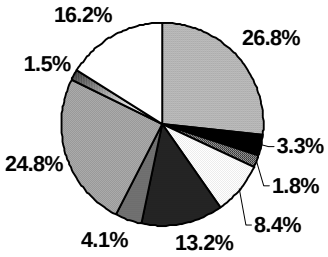


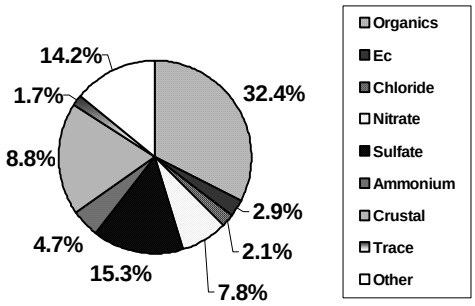
Figure 1　Mass concentrations of PM2.5 measured at 3 monitor sites of Beijing city in 2001

1.2 Chemical compositions of PM2.5

The chemical compositions of PM2.5 showed very similar pattern at different site in Beijing. The annual average chemical composition in 2001 at PKU and DS was shown in figure 2. At both sites the organics and crustal elements were the largest contributors to the PM2.5 mass, sulfate and nitrate had also significant portion. The nearly identical chemical composition in figure 2 hinted that the PM2.5 pollution was a regional issue.



(a)PKU



(b) DS

Figure 2　The chemical composition characteristics of PM2.5 at PKU and DS in 2001

However, the chemical composition of PM2.5 seemed to change with season. Using the data measured at AEBCMA as an example, the major chemical species in PM2.5 showed different contribution to PM2.5 in summer, autumn and winter (figure 3). Similar to the figure 2, organics, sulfate and nitrate were main species in PM2.5, the organics (OC) was the largest contributor. The ratio of OC to EC in atmosphere was used as an indicator for

secondary pollution in the air, the ratios of OC/EC of PM2.5 in figure 3 were 7 to 11, much larger than the critical value of 2 (Liu, 2002) , showing the existence of secondary pollution in Beijing.

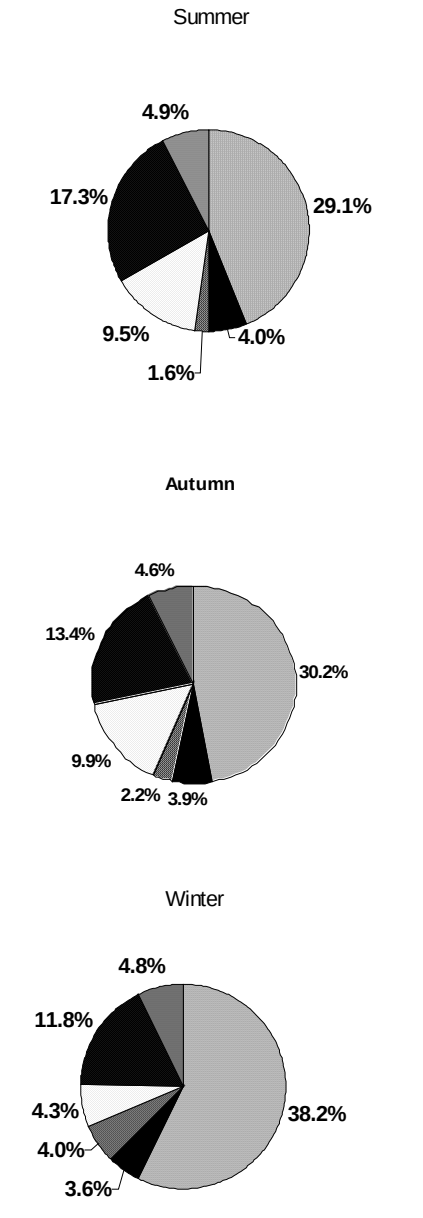


Figure 3 The chemical composition of PM2.5 in summer, autumn and winter at AEBCMA (crustal and trace metals were not analyzed at the site)

2 The relation between PM2.5 and meteorological conditions

2.1 Spring time

Beijing city in Spring is dry and windy, and it is favorable for the out-spreading of pollutants. In the spring of 2001, Beijing had less precipitation, higher temperature, stronger wind and more dusty days than normal.

Figure 4 shows diurnal variation of PM2.5 mass concentrations and humidity in breeze (wind speed less than 4m/s) days. A good correlation between the mass concentrations of PM2.5 and the relative humidity was found in these days. The variation of PM2.5 concentrations with wind speeds were indicated that there was a close anti-correlation between the mass concentrations of PM2.5 and the wind speeds in breeze day, but the anti-correlation in stronger wind seemed not as good as the case in breeze.

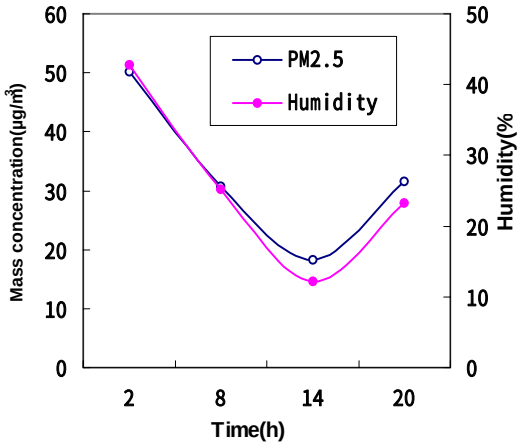


Figure 4 The variation of PM2.5 mass concentration and humidity in the breeze days (Average from March 28 to March 31)

2.2 The pollution features of fine particles in summer

The average temperature was 26.1ºC in summer of 2001 in Beijing, 1.3ºC higher than

that in summer of common years (24.8ºC), even 1.6ºC higher in June.

Beijing had more precipitation and smog in summer than in other seasons, the relative humidity was therefore higher in summer. In no precipitation days in summer, the relative humidity was low, and particles diffusion was efficient, consequently the mass concentration of PM2.5 was low. The relative humidity and the mass concentrations of PM2.5 in the light rainy days were comparable to that in smog days. But the relative humidity in light rainy days was a little higher than that in smog days, and the mass concentrations of PM2.5 was a little lower than that in smog days, hinting played a role in wash-out of PM2.5. Though relative humidity became very higher in heavy rain, the mass concentrations of PM2.5 were significantly low as shown in figure 5. The mass concentrations of PM2.5 dropped rapidly in the heavy rain, which started at three o' clock in this chart, and remained at low level during the heavy rain from eleven to thirteen o' clock in this chart, then the mass concentrations of PM2.5 went up after heavy rain.

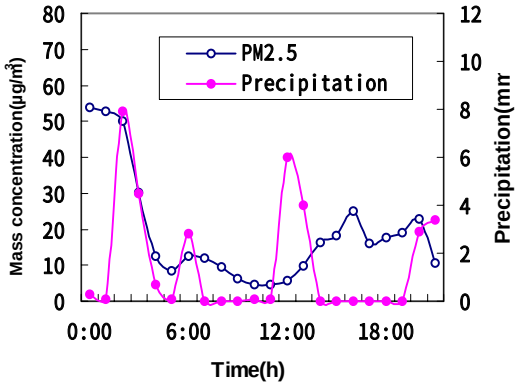


Figure 5 The process of a heavy rain and variation of mass concentrations of PM2.5 in summer of Beijing

There was an obvious correlation between the mass concentrations of PM2.5 and humidity further in summer.

2.3 Autumn time

In the fall, the humidity was still high, but lower than that in summer in Beijing.

The same as above, a good correlation between the mass concentration of PM2.5 and relative humidity was shown in Figure 6 in foggy days in autumn. When relative humidity dropped to less than 30% and from 30 percent to 60 percent in no fog days, the correlation was not as good as that in days with higher humidity. It's interesting to find that correlation between the mass concentrations of PM2.5 and relative humidity seemed to have dependency on relative humidity itself, and the correlation was getting closer while relative humidity became higher.

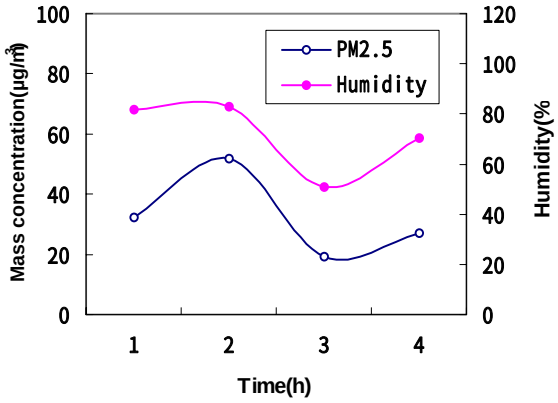


Figure 6 Diurnal variation of the mass concentration of PM2.5 and the relative humidity in foggy days in autumn of Beijing (Average from Sep.12 to Sep.16)

2.4 Winter time

The PM2.5 pollution in winter time was influenced by three major factors: (1) coal burning in winter made the primary emission of fine particles increase; (2) atmospheric inverse layer was the lowest in a year, and formed earlier but destructed later in a day, therefore fine particles could accumulate to higher concentrations in winter; (3) cold air of large scale from north of Beijing brought dry

air with strong wind in Beijing. In this case the PM2.5 could be very low.

The factors above made the PM2.5 pollution level in winter varies greatly (Song, 2003). Figure 7 showed the mass concentrations of PM2.5 measured in 5 days continuously at AEBCMA.

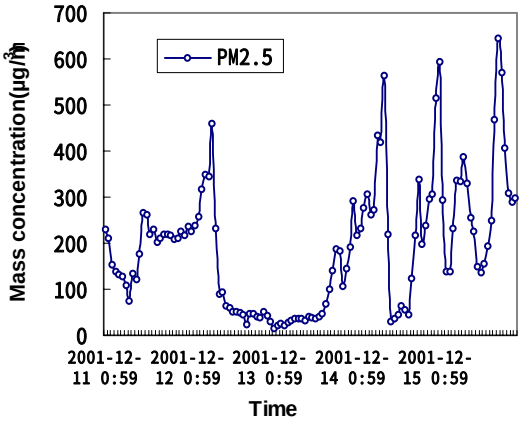


Figure 7 The variation of the mass concentrations of PM2.5 in winter (from Dec.11 to Dec.15)

When the average diurnal variation of the mass concentrations of PM2.5 and wind speeds in breeze days in winter, we knew that the mass concentrations of PM2.5 decreased obviously when the wind speed was larger than 2m/s. On the contrary, the mass concentration of PM2.5 increased obviously when the wind speed was less than 1.5m/s. This illustrated the anti-correlation between the mass concentrations of PM2.5 and wind speeds. But the anti-correlation of PM2.5 and wind when strong wind in heavy sandy days occurred.

2.5 Diurnal variation of PM2.5 pollution

The average diurnal variation of PM2.5 measured in summer at AEBCMA was given in Figure 8. The monitoring duration had high temperature and days with fog were more than 70 percent in June. The samples were taken in foggy and rainy days. From this chart, we could see the mass concentrations of PM2.5 were higher at night and lower at daytime. And the highest level appeared between 2:00 to 8:00 in the morning, and the lowest values appeared between 14:00 to 16:00 in the afternoon. This was consistent with the weather condition in June. The fog in summer appeared after the midnight, and last till 7:00 or 8:00 in the morning. The humidity data of four times per day of AEBCMA in June of 2001 showed the average humidity at 2:00 and 8:00 in the morning was above 70%, while only 49.7 % after 14:00 in the afternoon.

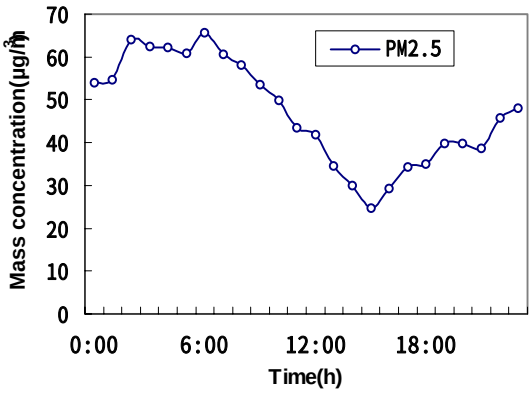


Figure 8 The diurnal variation of the mass concentrations of PM2.5 in summer of Beijing (average from Jun.16 to Jun.26)

However, the diurnal pattern of PM2.5 in winter was different (Figure 9). We saw from figure 9 that PM2.5 began to be enhanced from 17:00 in winter, and reached its maximum around 21:00 to 23:00 in the evening, and then faded away. The inverse layer started to form after midday in winter, from when the wind speed began to slow down and then PM2.5 pollution built up gradually. After midnight, wind speeds went up and the pollution in the inverse layer began to diffuse away. Also found in figure was a small peak between 7:00 and 11:00 in the morning, which was probably due to traffic emission in rush hours.

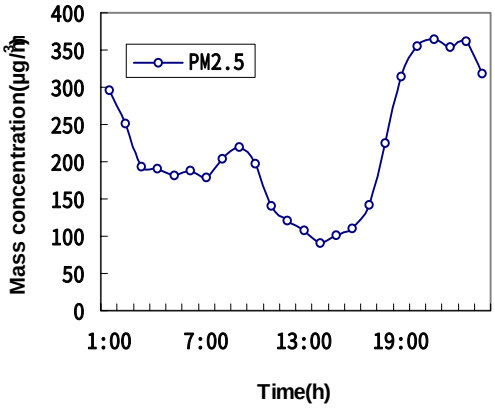


Figure 9 Diurnal variation of PM2.5 mass concentrations in winter of Beijing (average of data in December)

3 The observational results of visibility in four seasons in Beijing City

3.1 The observational results of visibility in four seasons at AEBCMA

The figure 10 shows the average of every season's visibility at AEBCMA in 2001. From this figure, we can make out the transformation rule of the visibility: it in autumn is the best, and in spring is in the next, and in summer and winter is the worst. The mass concentration of PM2.5 and the weather condition are important causes together to the level of the visibility. Now, we make an analysis of lower visibility in summer and winter.

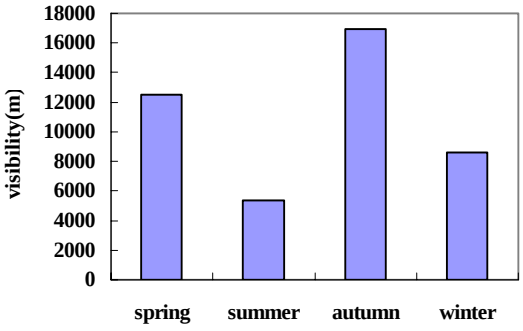


Figure 10 The monthly average of the visibility in each season

3.2 The analysis of lower visibility in summer and winter of 2001

The figure 11 and the figure 12 show the observational results of the mass concentration of PM2.5 and visibility at AEBCMA in summer and winter of 2001. The observational period in summer was 11 continuous days from June 16 to 26, and the observational period in winter was 7 continuous days from December 17 to 23. From the figures, we can see that there is a good negative correlation between the mass concentration of PM2.5 and the visibility.

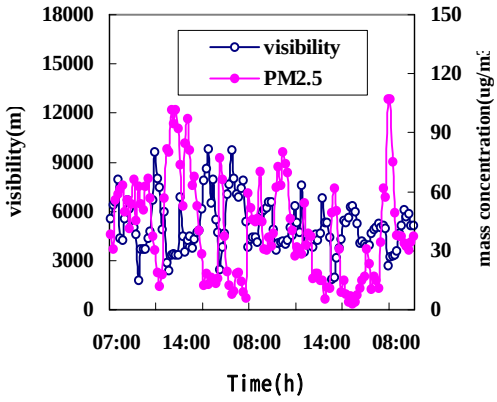


figure 11 The contrast between visibility and the mass concentration of PM2.5 in summer (From June 6 to June 26)

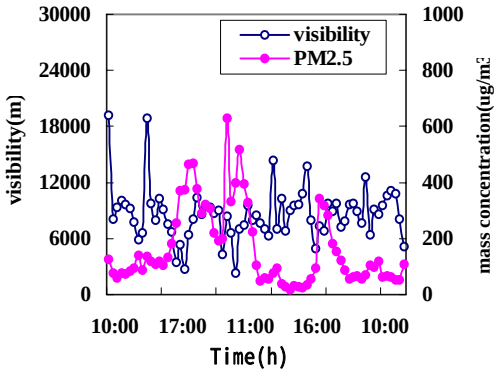


figure 12 The contrast between visibility and the mass concentration of PM2.5 in winter (From Dec. 17 to June 23)

The average temperature in June, 2001

in Beijing was 1.6°C higher than the common year's . The lasting high temperature made the light chemical reaction in atmosphere more active than the common time, so the pollution level of fine particles can reach to very high. On the other hand, there were more foggy days in summer of 2001, and the humidity was high and the average wind speed was lower, which was beneficial to the mass of the pollutant. According to the above analysis, we can easily conclude that the visibility in June of 2001 must be lower.

The average temperature in December,2001 in Beijing was higher 1.4°C than the common year's. The smog days was up to 71 percent in December. On the other hand, the coal burning for indoor warming made the amount of fine particles increase. The fine particles can easily accumulate as the radiation inversion temperature forms early and disappears late in winter. These weather conditions made the level of pollution of fine particles much high in winter, which caused the decrease of visibility.

3 Conclusion

(1) The chemical composition of PM2.5 was similar at different sites in Beijing but changed with seasons;

(2) The mass concentrations of PM2.5 in Beijing violated air quality standards proposed by US EPA, the major components of PM2.5 were organics;

(3) There is a correlation between the mass concentrations of PM2.5 and the relative humidity. And the higher the relative humidity, the closer the correlation ;

(4) There was an anti-correlation between the mass concentrations of PM2.5 and the wind speeds when the wind speed were less than 4m/s. The correlation between the mass concentration of PM2.5 and wind speed was not good at strong wind.

(5) There is a good negative correlation between the mass concentration of PM2.5 and the visibility.

Epilogues

PM2.5 is a serious air pollutants but only the USA proposed its National Ambient Air Quality standards (NAAQS) for PM2.5. China has only NAAQS for PM10 so far. We do hope that the exploring the relations between the weather conditions and PM2.5 levels may provide the necessary scientific basis for the establishment of NAAQS of PM2.5 in China.

Acknowledgement: We thanks C.S. Kiang for his help in developing experimental methods.

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