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Effect of the air pollution on atmospheric visibility in Beijing–Tianjin area

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Abstract—Simultaneous measurements of air pollutant concentrations and atmospheric visibility were made in Beijing and Tianjin areas in 1983–1985. The relationship between air pollution and visibility was studied. It was found that atmospheric particulates have the most high contribution to visibility decreasing. The percentages of contributions of sulfates and soot are 52–58% and 22–29% respectively. According to the results, we suggest that the emission of SO_2 and particulates must be controlled in order to improve the atmospheric visibility.

Keywords: air pollutant; atmospheric visibility; SO_2; particulates.

INTRODUCTION

In the last decade, much work about visibility and the atmospheric pollution has been done (Homolya, 1978). It was found that there is a close relationship between visibility and air pollution.

Coal is the main fuel in the Beijing and Tianjin areas. Visibility is gradually decreased with the amount of coal consumption. In order to study the effect of air pollutants, field experiments were made in Beijing–Tianjin area in 1983–1985. Relationship between the visibility and air pollution was studied.

EXPERIMENT

Field experiments were taken 4 times in Beijing and Tianjin areas, December 1983, June and December 1984, June 1985. Each field experiment lasted for 10 days. There were eight field sites from Beijing to Tianjin (Fig. 1). Concentrations of SO_2, NO_x, SO_4^{2-}, TSP, carbonaceous compounds were measured continuously. The instruments used in the experiment are shown in

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Table 1. Particulate were sampled 8 times everyday. Other instruments worked continuously during the experimental period.

Table 1 Instruments and analytic methods used in the field experiment

Pollutant	Instruments and analytic methods	Type of instrument
SO_2	Pulsed fluorescent SO_2 analyzer	US. TE Co.43
NO_x	Chemiluminescent	US. TE 14D/E
	$NO-NO_2-NO_x$ analyzer	
SO_4	Thermal pyrolyze of 2-perimidyl	
	ammonium sulfate	
	Ion chromatography	US Dionex 16
	Total sulfur analyzer	US Meloy Labs SA285
Particle	High volume sampler	US General Motor
	LBL sampler	LBL
Visibility	Integrate nephelometer	US Meteorological Institute

RESULTS AND DISCUSSION

Atmospheric visibility in Beijing and Tianjin areas

In order to study the effect of the air pollution on atmospheric visibility in Beijing and Tianjin areas, visibility data in 1970–1980 were collected and analyzed. The results showed that the average visibility in Beijing at 1970-1979 decreased gradually with years. The value of visibility reduced one grade, such as from 7 grade to 6 grade that is equivalent to 4–10km.

The data of visibility and amount of coal consumption were analyzed with correlation analytical method. There is a good correlation between visibility and amount of coal consumption (Fig. 2).

The correlation coefficient was –0.82. When the amount of burned coal increased by one million tons, the visibility decreased about 0.1 grade (about 0.6–1.0km). The appearing frequency of visibility less than 4km increased with increasing of the coal consumption. Statistic results showed that the correlation coefficient was 0.97 (Fig. 3).

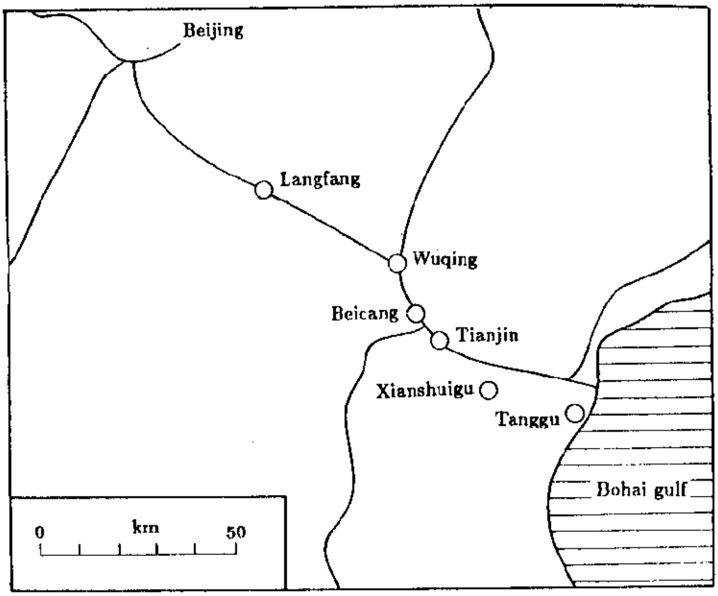

Fig. 1 The sampling stations in Beijing and Tianjin areas

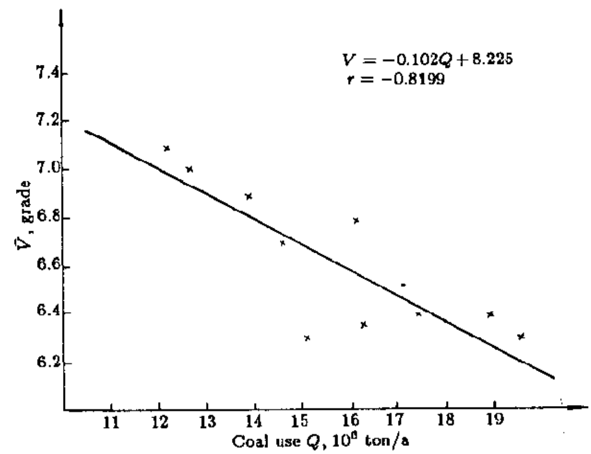

Fig. 2 The relationship between average visibility ($\bar{V}$) and annual coal consumption (Q)

It is shown that the visibility is seriously affected by air pollution. From the data of the atmospheric visibility during 1980—1984 in Beijing, it can be found that the appearing frequency of visibility less than 4km is 0.13-0.2 (Table 2). About half of them appear in 8 o'clock in the morning. The appearing frequency of visibility less than 8km is about 0.5.

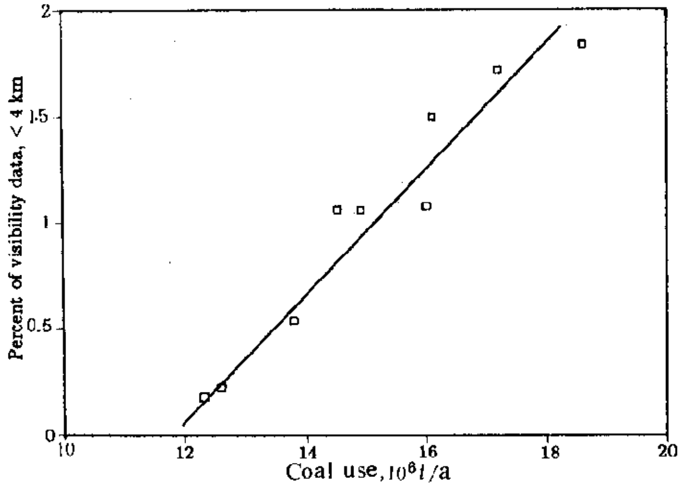

Fig. 3 Relation between percent of visibility data <4km of 12,000 data and amount of coal used in one year

Table 2 The appearing frequency of the visibility less than 4 and 8km in Beijing

	Frequency of visibility,		
Year	<4km	<8km	<4km (at 8 o'clock)
1980	0.20	0.51	0.54
1981	0.13	0.45	0.58
1982	0.15	0.53	0.51
1983	0.13	0.50	0.51
1984	0.14	0.49	0.46

In the field experiment period, the visibility was monitored with integrating nephelometers in Beijing and Tianjin areas. It is shown that the visibility in urban lower than that in suburb and it is lower in winter than that in summer. There was 50 percent of visibility that was less than 7km in December 1984 and 50 percent of visibility that was less than 13km in summer 1984.

EFFECT OF POLLUTION ON ATMOSPHERIC VISIBILITY

Atmospheric aerosol is a mixture of air, trace gases, solid and liquid particles. The atmospheric extinction depends on the chemical properties of the aerosol. The decreasing of the atmospheric visibility is contributed by the increasing of the extinction coefficient ($bext$). The extinction coefficient can be described as follows:

$$bext = bsg + bsp + bsw + bag + bap \tag{1}$$

Here bsg, bsp, bsw are the light-scattering coefficients for gas, dry particle and water; bag and bap are the light-adsorption coefficients for gas and particle.

Koschemieder considered that the extinction coefficient is usually related to the visibility:

$$V = 3.912/bext \tag{2}$$

Penndorf suggested that the extinction coefficient of clean air molecules in the visual range at 20°C, 101.325 Pa is:

$$bsg = 0.114 \times 10^{-4} m^{-1} \tag{3}$$

The gas that absorb the visual light in the atmosphere is NO_2. The extinction coefficient can be written as (Holdkinson, 1966):

$$bag = 3.3[NO_2] \tag{4}$$

where NO_2 is in the unit of ppm, bag is in the unit of $10^{-4} m^{-1}$.

Black carbon is the main contribution to adsorption coefficient in aerosol particle (Pratsinis, 1984).

$$bap = 0.09[C_B] \tag{5}$$

where $[C_B]$ is in the unit of μg/m^3 and bap is in the unit of 10^{-4}m^{-1}.

$bsp + bsw$are from experiment data.

In order to determine the individual contribution of each species to the bsp, the multiple regression analysis method was used, and bsp can be written as

$$bsp = a[S] + b[C] + c[R] + d \tag{6}$$

Where $[S]$ is the concentration of $(NH_4)_2SO_4(\mu g/m^3)$, $[C]$ is the concentration of carbon $(\mu g/m^3)$ and $[R]$ equals [TSP]-$[S]$-$[C]$, a, b, c are the regression coefficients, d is a constant.

According to these equations and experiment data, we can determine the individual contribution of each species in aerosol to the *bsp*. The results are shown in Table 3 and Fig. 4. In Table 3, it can be found that the particulates have the highest contribution to light extinction (about 88%). The figures of measured visibility are higher than that of calculation. The value of calculated visibility are relatively lower than that of measured visibility. The reason may be that the calculated visibility is the result of calculation by equation (5) in which the concentration of particulates of PM-10 is used for calculation. But only the particulates of diameter lower than $1\mu m$ can change the atmospheric extinction effectively. Since the concentration of particulates of diameter less than 10μm is higher than that of diameter less 1μm, so the results of calculation gave a higher value of atmospheric extinction and lower value of visibility than those of measured.

Table 3 The contribution of the particulates and gases to light extinction

Date unit	June, 1984		December, 1984	
term	$10^{-4}m^{-1}$	%	$10^{-4}m^{-1}$	%
bsg	0.114	1.7	0.114	1.56
bag	0.141	2.2	0.124	1.7
bap	0.56	8.5	0.65	8.8
bscat	5.78	87.7	6.45	88
bext	6.59	100	7.33	100
V(measured)	9.98km		6.18km	
V(measured)	5.92km		5.3km	
Coefficient of multiple regression	0.79		0.83	

In Fig. 4, sulfate plus water appears as the most important factor for the light extinction, and their percentages of contribution to light extinction are in the range of 52–50%. The soot also has 22–29% of contribution to light extinction. Contribution of gases is not higher than 4%. The sum of other pollutants only have 15–16% of contribution to the light extinction.

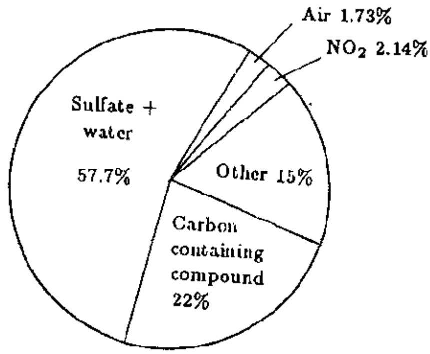

Fig. 4 The contribution of composition of aerosol to light extinction

Table 4 shows that about more than 70% of sulfate in aerosol exists in particulates of diameter less than 3.3μm, and 50% of sulfate exists in particulates of diameter less than 2.0μm in size. Most sulfates in the atmosphere are in a state of $(NH_4)_2SO_4$. This compound is easily hydroscopic. Maybe this is one of the main reason that the sulfate reduces the atmospheric visibility more severely when the relative humidity is high.

Table 4 The percentage of SO_4^{2-} in different size particle to total SO_4^{2-}

	1	2	3	4	5
Area	>7μ	3.3-7μ	2-3.3μ	1.1-2μ	<1.2μ
Beijing	21.5	7.7	13.1	7.9	49.42
Tianjin	19.6	10.5	8.5	8.6	52.7
Jugong	17.9	12.7	11.5	12.7	44.3
Langfang	13.7	11.8	12.4	12.5	49.6

According to the results, the main pollutants that decrease the atmospheric visibility are sulfate and soot. The sum of their contribution to the visibility decreasing is about 70–80%.

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