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Carbonaceous aerosols in PM_{10} and pollution gases in winter in Beijing

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Abstract

An intensive observation of organic carbon (OC) and elemental carbon (EC) in PM_{10} and gaseous materials (SO_2, CO, and O_3) was conducted continuously to assess the characteristics of wintertime carbonaceous aerosols in an urban area of Beijing, China. Results showed that the averaged total carbon (TC) and PM_{10} concentrations in observation period are 30.2±120.4 and 172.6±198.3 μg/m^3, respectively. Average OC concentration in nighttime (24.9±19.6 μg/m^3) was 40% higher than that in daytime (17.7±10.9 μg/m^3). Average EC concentrations in daytime (8.8±15.2 μg/m^3) was close to that in nighttime (8.9±15.1 μg/m^3). The OC/EC ratios in nighttime ranging from 2.4 to 2.7 are higher than that in daytime ranging from 1.9 to 2.0. The concentrations of OC, EC, PM_{10} were low with strong winds and high with weak winds. The OC and EC were well correlated with PM_{10}, CO and SO_2, which implies they have similar sources. OC and EC were not well correlated with O_3. By considering variation of OC/EC ratios in daytime and night time, correlations between OC and O_3, and meteorological condition, we speculated that OC and EC in Beijing PM_{10} were emitted as the primary particulate form. Emission of motor vehicle with low OC/EC ratio and coal combustion sources with high OC/EC ratio are probably the dominant sources for carbonaceous aerosols in Beijing in winter. A simple ratio method was used to estimate the relative contribution of sources to carbonaceous aerosols in Beijing PM_{10}. Motor vehicle source accounts for 80% and 68%, while coal combustion accounts for 20% and 32% in daytime and nighttime, respectively in Beijing. Averagely, the motor vehicle and coal combustion accounted for 74% and 26%, respectively, for carbonaceous aerosols during the observation period. It points to the motor vehicle is dominant emission for carbonaceous aerosols in Beijing PM_{10} in winter period, which should be paid attention to control high level of PM_{10} in Beijing effectively.

Key words: organic carbon; elemental carbon; diurnal variation; PM_{10}

Introduction

Atmospheric carbonaceous aerosols comprise significant fraction of ambient respirable suspended particulates (PM_{10}) ranging from approximately 10% in remote areas to approximately 40% in urban areas and industrialized areas (Seinfeld and Pandis, 1998). Carbonaceous aerosols play an important role in the atmosphere with regard to radiative transfer, health effects, and atmospheric chemistry (Hőller *et al*., 2002; Watson, 2002; Bond *et al*., 2004). They are generally divided into organic carbon (OC) and elemental carbon (EC) (also called black carbon, BC). OC containing polycyclic aromatic hydrocarbon and other components with possible mutagenic and carcinogenic effects, can be directly emitted from sources (primary OC) or produced from atmospheric reactions involving gaseous organic precursors (secondary OC, SOC) (Turpin and Huntzicker, 1995; Molnár *et al*., 1999). Recently, EC is of special interest due to its warm effect on climate (Zhang *et al*., 2005a). EC is regarded to be the second most important component of global warming in terms of direct forcing, after CO_2 (Jacobson, 2001). Simulation study by Menon *et al*. (2002) implies that EC emissions from China and India may be responsible for the increase in droughts in North China and flooding in South China in the summer observed during the last 20 years. Due to the importance of OC and EC on climate and atmospheric chemistry, information concerning the concentrations and distributions of carbonaceous aerosol in atmosphere is of great interested (Zhang, 2004).

Beijing, one of the biggest cities in the world, also the capital of China, has 14 million populations and 2.1 million motor vehicles by the end of 2003. Due to increased economic activities and the number of vehicles and urbanization, high particulate matter pollution and poor visibility have become a serious problem in Beijing.

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From 1999, the municipal government undertook several powerful control measures to reduce particle pollution for the Olympic Game to be held in Beijing in 2008. The air quality has improved since 1999. The mass concentrations of PM_{10}, however, are still at high levels. According to the Environmental Annual Report from Beijing Environmental Protection Bureau, from 1999 to 2001, the annual average concentration of TSP in atmosphere over Beijing is 364, 353, and 370 μg/m^3, respectively; and that of PM_{10} is 180, 162 and 165 μg/m^3, respectively (Liu *et al*., 2004). As a consequence, an investigation of atmospheric carbon pollution in the Beijing is important, as it is a major component of particulate pollutions. In recent years, many studies have been performed in the world focusing on the carbonaceous aerosols (Turpin *et al*., 2000; Chow *et al*., 2004; Novakov *et al*., 2005). However, there were limited studies on the OC/EC in Asia, with fewer focused on OC and EC in China. To date several studies on carbonaceous particles in PM_{10} in China were reported (Cao *et al*., 2003, 2004, 2005; Yu *et al*., 2004), but few studies concentrated on continuous observation of OC and EC (Duan *et al*., 2005; Wang *et al*., 2005).

In this work, we measured carbonaceous aerosol in PM_{10} continuously in winter period because (1) China Environment Protection Administration (China EPA) adopts PM_{10} air pollution standard; (2) winter is the worst pollution season in Beijing and is of the most concern; (3) till now, there is no report about the relationship between carbonaceous aerosols and pollution gases. Continuous concentration of PM_{10} and pollution gases of CO, SO_2, and O_3 are also monitored simultaneously. The objective of this paper is to present the diurnal variation of OC/EC and their fraction in PM_{10} in Beijing and their relation to pollution gases in Beijing.

1 Methodology

1.1 Observation site

Measurements of carbonaceous aerosol and gases were performed at the Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (CAS), which lies between the North Third Ring Road and the North Fourth Ring Road in Beijing (39°58′N, 116°22′E). This location is a typical urban area. The instrumentation used in this work was setup on the roof of two-storey (10 m above ground) of a building of IAP/CAS. A 325-m high meteorological tower, 50 m to the north of this observation site, provides wind speed and wind direction. This site was a super observation site of ACE-Asia for aerosol and dust storm research (Zhang *et al*., 2005b).

1.2 Experiment

1.2.1 PM_{10} mass concentration

The tapered element oscillating microbalance (TEOM) 1400a series, manufactured by Rupprecht and Patashnick Co. Inc., was used for the continuous measurement of PM_{10} mass concentration. It is a US EPA equivalent method providing PM_{10} masses from a 16.7 L/min air flow (Salter and Parsons, 1999). It has a high accuracy with ±1.5 μg/m^3 and high resolution with 0.1 μg/m^3. However, TEOM records slightly lower concentration values than those determined by reference samplers. The TEOM is widely used in different aerosol studies (King, 2000; Hőller *et al*., 2002; Kuhlbusch *et al*., 2001; Even *et al*., 2000).

1.2.2 Continuous observation of organic and element concentrations

The concentrations of particulate OC and EC were continuously detected by a thermal analysis method using ambient carbon particulate monitors, Model 5400 manufactured by Rupprecht and Patashnick Co. Inc. This instrument performs a thermal evolution analysis of carbonaceous material (Hőller *et al*., 2002; Long *et al*., 2003). Sampling interval was set at 3-h here. The sample is collected on impactors instead of filters to reduce positive artifacts due to adsorption of organic vapor. Analysis of the samples is performed in a closed cycle, which includes the impactor, a NDIR CO_2 sensor, and an afterburner, which heats the gas stream to 750°C to burn all remaining material. The amounts of carbonaceous substances evolved at 280, 340°C were defined as organic carbon (OC) and 750°C as total carbon (TC). And then, the difference between the amounts of TC and OC gives the amount of EC. Comparison between the Aethalometer and the R&P 5400 ambient carbon particulate monitor (Artaxo *et al*., 1999) shows good agreement and both instruments give confidence in the measurement of the black carbon concentration for urban areas. More detailed description of this instrument has been given in the previous studies (Hőller *et al*., 2002; Matsumoto *et al*., 2003a, b; Castanho and Artaxo, 2001). R&P 5400 has a high resolution of 0.25 μg/m^3. The R&P 5400 is calibrated by Beijing Branch of Rupprecht & Patashnick Co. Inc. before observation. The thermal method used by the R&P 5400 is one of the major techniques for carbonaceous aerosols measurements (Cachier *et al*., 1989). But, it faced negative artifact problems, which were caused both by the missing collection of particles smaller than 0.14 μm and by the evaporation of the organic gases (Matsumoto *et al*., 2003a, b), and this problem still need to be resolved.

1.2.3 Ozone (O_3), carbon monoxide (CO), and sulfur dioxide (SO_2)

O_3 was monitored using a commercial UV photometric instrument (Thermo-Environmental Instruments, Inc. TEI), Model 49C, which had a detection limit of 1 ppbv and a precision of 1 ppbv for a 1-min average. CO was measured with an infrared gas filter correlation analyzer (TEI, Model 48C). The detection limit was estimated to be 40 ppbv for a 1-min integration time, and the precision was approximately 40 ppbv. SO_2 was detected by using a pulsed UV fluorescence analyzer (TEI, Model 43S). The detection limit for this analyzer is 0.06 ppbv with a precision of about 0.2 ppbv. More details about above gases instrument has been given in previous studies on air pollution in Beijing (Liu *et al*., 1999; Chen *et al*., 2000).

Calibration of for monitoring O_3, CO, and SO_2 were

conducted before observation. Calibration of O_3 (49C) was performed before and controlled after the campaign with a Thermo-Environmental Instrument 49PS model for ozone. Calibration of CO (48C model) was performed with calibrated gases from National Standard Material Center of China. Calibration of SO_2 (43S model) was performed with calibration gas cylinders from National Standard Material Center of China. The data of PM_{10}, OC, EC, SO_2, CO, O_3 and wind are obtained in observation period during 1–15 January 2004 by using above instruments. As sampling interval was set at 3-h for R&P 5400, the PM_{10}, 1-min interval data of O_3, CO and SO_2 are averaged in the same periods as OC and EC.

2 Results and discussion

2.1 Diurnal variations of concentrations of organic carbon and elemental carbon

Fig.1 compares the temporal variations of OC, EC, PM_{10} concentration, TC/PM_{10}, OC/EC, wind speed and direction (at the height of 102 m), SO_2, CO, and O_3 during 1–15 January 2004. There is no notable precipitation recorded in observation period. The PM_{10} concentration in observation period varied between 24.2–401.6 μg/m^3 with averaged value of 172.6±98.3 μg/m^3, which has exceeded 100 μg/m^3, the Second Annual Ambient Air Quality Standard of PM_{10} by China Environmental Protection Administration. It means that the PM_{10} pollution in Beijing is still serious. The OC in PM_{10} varied between 3.0–72.3 μg/m^3 with averaged value of 21.2±16.0 μg/m^3. The EC concentration in PM_{10} varied between 1.7–20.1 μg/m^3 with averaged value of 8.9±5.1 μg/m^3. OC/EC ratio varied from 1.2 to 5.7 with averaged value of 2.3. The OC, EC and TC account for (12.4±6.4)%, (5.6±2.3)% and (18±9.2)% to PM_{10} mass respectively.

However, the concentrations of OC, EC, PM_{10} and

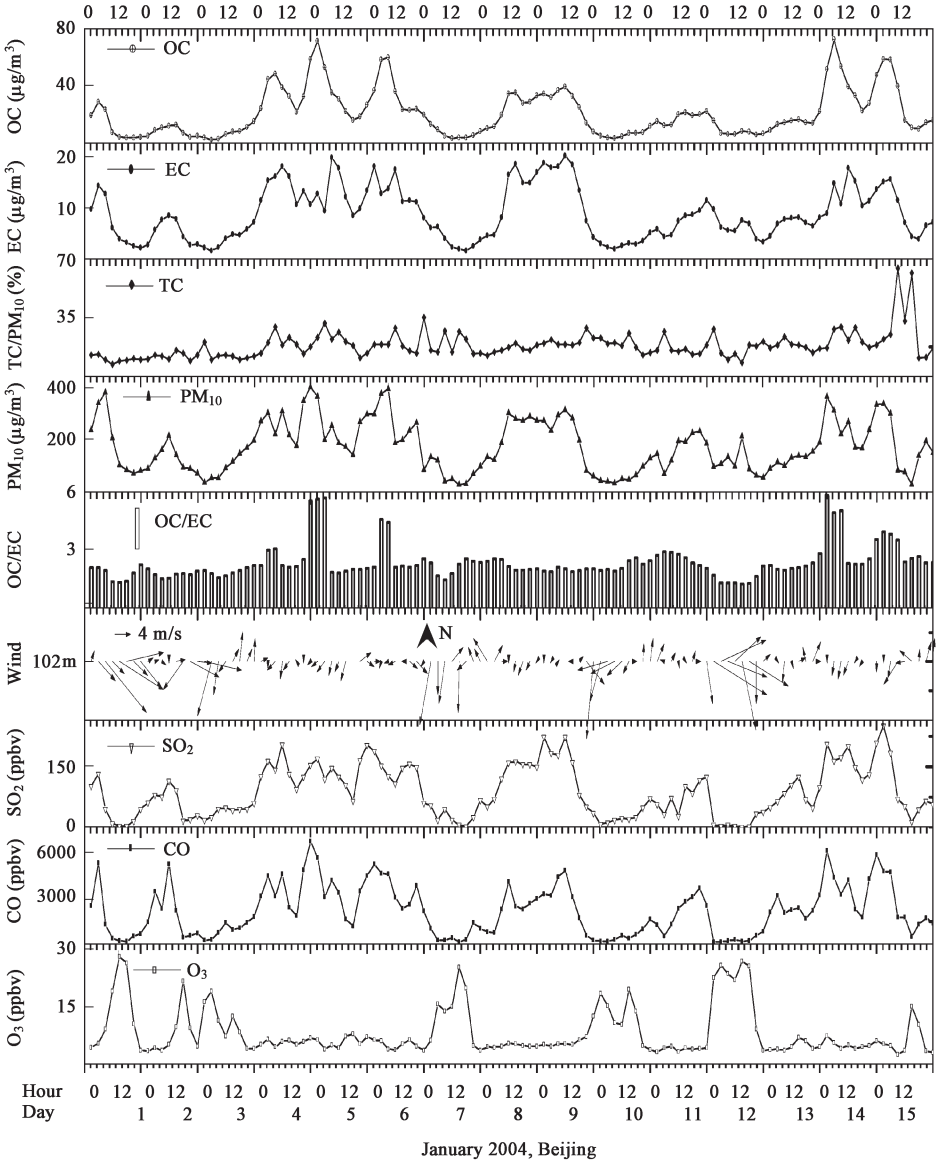

Fig. 1 Time series of surface OC, EC, TC/PM_{10}, PM_{10}, OC/EC, wind, SO_2, CO, and O_3 in January 2004 in Beijing. TC=OC+EC, wind is at the height of 102 m.

OC/EC ratio varied significantly in different day as they are influenced greatly by meteorological condition and emissions. Dynamical processes and meteorological conditions may cause perturbations in the boundary layer and can influence atmospheric trace constituent concentrations (Bhugwant and Bremaud, 2001). The concentrations of OC, EC, PM_{10} reach low values on 1, 2, 3, 7, 10, 12, 15 January 2004 when the correspondence wind is strong. The wind strength can be associated to the "cleaning effect" of the air at observation site through the dispersion of particles and trace gases. This can explain the above low concentration of particles matters. OC/EC ratios reach minimum of approximately 1.2 in the afternoon on 1 January and 1:30–16:30 on 12 January 2004 in strong wind period. The concentrations of OC, EC, PM_{10} reach the high when the wind is weak. When wind speed is low, the atmosphere is often stable and slow dispersion occurred. The emitted pollutants will be easily accumulated, resulting with high concentration of PM. The variations of SO_2 and CO are similar to that of OC, EC and PM_{10} as they are mainly emitted from the ground sources. O_3 concentration is low when wind is not strong and reaches peak value when strong wind occurs.

Table 1 presents the diurnal variations of OC, EC, PM_{10} and OC/EC ratio, TC/PM_{10} ratio at Beijing in January 2004. The PM_{10} concentrations in nighttime are obviously higher than that in daytime. The boundary layer usually becomes deeper in daytime because of stronger turbulent eddies (Zhang *et al*., 2002). This dilutes particle pollutions released at the surface and results in lower ambient concentration. Average OC concentrations are 17.7±10.9 μg/m^3 in daytime and 24.9±19.6 μg/m^3 in nighttime, respectively. OC concentrations are obviously higher in nighttime than in daytime and have peak value in midnight due to accumulation of emission in stable atmosphere. Averaged EC concentrations in daytime (8.8±5.2 μg/m^3) are close to that in night time (8.9±5.1 μg/m^3). For EC, a distinct morning peak clearly corresponds to the morning traffic rush hour. The OC/EC ratios in nighttime ranging from 2.4 to 2.7 were higher than that in daytime ranging from 1.9 to 2.0.

Table 2 gives the comparisons of several studies by using R&P 5400 instrument for $PM_{2.5}$ carbonaceous aerosol in winter period. $PM_{2.5}$ constitutes 64% of PM_{10} mass in Beijing (He *et al*., 2001). Although PM_{10} is determined in this study and $PM_{2.5}$ is observed in others study, the TC concentration in Beijing is still higher than that in USA and Japan. Prior study by He *et al*. (2001) also reported high level of the carbonaceous aerosol loading in $PM_{2.5}$ in winter. The OC/EC ratios between PM_{10} and $PM_{2.5}$ (He *et al*., 2001) were similar in Beijing (2.3 for PM_{10} and 2.7 for $PM_{2.5}$); and such value was very closely to that in Brazil, but much higher than that in Japan and USA. The results implied that the sources of OC and EC in Beijing might be different from that in USA and Japan but similar with that in Brazil.

2.2 Relationship of organic carbon and elemental carbon

The sources of carbonaceous aerosols can be qualitatively estimated by studying the relationship between OC and EC concentrations (Turpin and Huntzicker, 1995). If major fractions of OC and EC are emitted by a dominant primary source (e.g., vehicle emissions, coal combustion), the correlation between the OC and EC concentrations should be high because the relative rates of OC and EC emission would be proportional to each other. The regression between the OC and EC concentrations in PM_{10} samples during winter in Beijing is given in Fig.2. There is an excellent correlation between OC and EC in daytime (R^2=0.94) which implies that motor vehicles exhaust is probably the dominant sources in daytime. There is a relatively weaker correlation between OC and EC in nighttime (R^2=0.58), which suggests that OC and EC fractions in Beijing PM_{10} may not be released from a single, dominant primary source. The reason for this difference may be explained by the impact of other sources besides local vehicular emissions (i.e., secondary OC or

Table 1 Diurnal variation of concentration of OC, EC, PM_{10} and ratio of OC/EC, TC/PM_{10} at Beijing in January 2004

	Local time	OC (μg/m^3)	EC (μg/m^3)	OC/EC average	TC (μg/m^3)	PM_{10} (μg/m^3)	TC/PM_{10} (%)
Day	9 (07:30–10:30)	21.2±13.5	10.6±6.2	1.9±0.4	31.8±19.6	177.3±91.4	18.1±6.8
	12 (10:30–13:30)	18.7±10.9	9.5±5.4	2.0±0.4	28.2±16.2	153.1±79.1	21.3±12.3
	15 (13:30–16:30)	15.1±7.9	7.6±3.9	2.0±0.4	22.6±11.7	144.2±66.2	15.8±3.9
	18 (16:30–19:30)	16.0±9.1	7.5±3.9	2.1±0.3	23.5±12.9	173.6±92.5	13.9±4.5
Night	21 (19:30–22:30)	20.8±15.1	7.9±4.3	2.5±0.9	28.7±18.7	172.2±106.7	17.1±5.9
	0 (22:30–01:30)	25.4±20.2	8.9±5.2	2.7±1.3	34.3±24.2	192.7±114.8	17.7±4.8
	3 (01:30–04:30)	28.1±22.6	9.3±5.2	2.7±1.3	37.4±26.9	186.3±111.1	19.0±6.3
	6 (04:30–07:30)	25.2±18.5	9.7±5.4	2.4±1.1	34.9±22.9	176.9±113.1	21.7±13.1
Average		21.2±16.0	8.9±5.1	2.3±0.9	30.2±20.4	172.6±98.3	18.0±9.2

Values represent average standard deviation; TC=OC+EC.

Table 2 Comparison of recent studies in winter period by R&P 5400

Location	Winter sampling period	TC (μg/m^3)	OC (μg/m^3)	EC (μg/m^3)	OC/EC	PM	Reference
Beijing, China	2004.01	30.2	21.2	8.9	2.3	PM_{10}	This study
Uji, Japan	1998.12	6.23	2.57	3.66	0.7	$PM_{2.5}$	Hőller *et al*., 2002
	1999.02	4.5	1.96	2.54	0.8	$PM_{2.5}$	Hőller *et al*., 2002
Sao Paulo, Brazil	1997.07–09	23.4	15.8	7.6	2.1	$PM_{2.5}$	Castanho and Artaxo, 2001
Salt Lake City, USA	1999–2000 winter	18.7	10.8	7.9	1.4	$PM_{2.5}$	Long *et al*., 2003

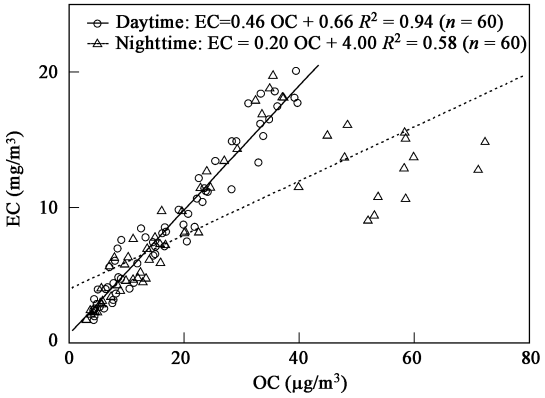

Fig. 2 Relationship between OC and EC concentration in PM_{10} samples during winter in Beijing.

coal combustions).

Among 60 values in nighttime, OC and EC concentrations of 46 values are close to the regression line from daytime data (Fig.2), which implies that OC, EC may have similar and main sources (i.e. vehicles exhaust) in both daytime and nighttime. Also there exist discrete data in 14 values, which have high OC concentrations ranging from 44.5–72.3 μg/m^3 occurred at midnight with moderate EC concentrations ranging from 9.0–16.1 μg/m^3. The high OC value resulted in high OC/EC ratio. This implies that other sources besides vehicles exhaust source exist in nighttime.

Diurnal differences in OC and EC concentrations were tested by the one-way analysis of variance (ANOVA) method, using the statistical software package SPSS v 11.0, and the results are shown in Table 3. OC has significant (p<0.05) diurnal variability, and EC was not statistically different. It means that OC has different sources in daytime and night time, which is consistent with previous description.

Table 3 One-way analysis of variance (ANOVA) for OC and EC on diurnal variables

OC		EC	
F-ratio	p-Value	F-ratio	p-Value
6.51	0.01	0.03	0.87

EC is essentially emitted as a primary pollutant; OC may derive from emitted particles (primary OC) as well as particles that are formed from gaseous precursors (secondary OC, SOC). Pandis' study (2002) indicated that the formation of secondary organic aerosol (SOA) in the ambient air was mainly controlled by temperature. The temperature at Beijing ranged from –6°C to 9°C with short duration of sunshine in observation period. It is not favorable meteorological conditions for the gas-particle conversion of gaseous hydrocarbon precursors to produce SOC. So the formation of SOA in Beijing may be low. Research by Cabada *et al*. (2002) showed that the corresponding contributions of SOC to the total organic PM concentration were nearly zero in winter in Pittsburgh, USA. Cao's study (2005) also showed that there was almost no SOC at Xi'an during winter. Study by Ma *et al*. (2004) indicated that a large amount of the organic compounds was emitted as the primary particulate form from various combustion sources in heavily industrialized Kansai region in Japan in winter.

Watson *et al*. (2001) reported that OC/EC ratio is 1.1 from motor vehicle and 2.7 from coal combustion. Recent research by Cao *et al*. (2005) showd that OC/EC ratio from coal combustion is 12. These studies show that the OC/EC ratio is high in particles emitted from coal combustion and low from motor vehicle exhaust. As shown in Table 1, the minimum value of the OC/EC ratio occurs in the morning, coincident with the time of traffic peak. This is an evidence of the higher influence of direct vehicle emissions with relative low OC/EC ratio. During the nighttime, OC/EC ratios are relatively high. In Fig.1, OC/EC ratio reach maximum of approximately 5.6 in midnight on 4 and 13 January 2004. This can be due to the lower EC emission from less activity of mobile vehicles and high organic carbon emission from coal combustion in the night.

2.3 Correlations between OC, EC and PM_{10}, SO_2, CO, and O_3

The daily variations of SO_2, CO, and O_3 at Beijing during 1–15 January 2004 are also shown in Fig.1. The variation of SO_2 and CO are similar to OC, EC and PM_{10} that reach low concentration on 1, 2, 3, 7, 10, 15 January and high concentration on 4, 5, 6, 8, 9, 14 January 2004. This implies that OC, EC, and SO_2, CO are mainly emitted from proximate sources. Table 4 presents correlation coefficients between OC, EC, and PM_{10}, SO_2, CO and O_3. The OC, EC have good correlations with PM_{10}, which implies that OC and EC are important components of PM_{10} in Beijing. In Beijing CO is mainly emitted from motor vehicles (Liu *et al*., 1999) and SO_2 from coal combustion (Chen *et al*., 2000). OC, EC, are well correlated to CO and SO_2 which provided another proof that motor vehicles and coal combustion may be dominant sources of OC and EC in PM_{10}.

Table 4 Correlation between OC, EC, and PM_{10}, SO_2,CO and O_3

	SO_2	O_3	CO	PM_{10}
OC	0.67[a]	0.18	0.68	0.68
EC	0.72	0.17	0.55	0.65

[a] Correlation coefficient (R^2).

But OC and EC are not well correlated with O_3 which means O_3 sources are not mainly from local sources, different with OC, EC. O_3 has noticeable high concentration and OC, EC has low concentration on 1, 2, 3, 7, 10, 15 January when there is strong wind. In troposphere, O_3 concentration usually increases with increase of height (Liu *et al*., 1999), strong wind can bring down ozone rich air and disperse ground OC and EC. OH and O_3 are required in oxidation reaction to produce SOC (Na *et al*., 2004). Model calculation by Lu and Khalil (1991) shows that OH concentration reaches maximum in July and minimum in January in the northern hemisphere. This also implies that there is no favorable photochemical reaction condition to produce SOC and the carbonaceous

aerosols in Beijing in winter are dominantly from primary emissions.

2.4 Relative contribution to sources of organic carbon and elemental carbon

Coal combustion is one important source of atmospheric particles in typical cities in northern part of China during heating period (Shi *et al*., 2002). Though coal combustion has not been permitted to use in main urban areas in Beijing since 1999 (Zhang *et al*., 2002), coal combustion is wildly used in the suburb and neighboring areas of Beijing especially in heating period because of its low cost. So coal combustion is an important source for atmospheric aerosol in Beijing (Chen *et al*., 2000; Dan *et al*., 2004). Moreover, concern over emissions from mobile sources has been growing along with the amount of vehicles. For example the number of vehicles in Beijing now exceeds 2.1 million. Motor vehicle exhaust is another important source for ambient particles in Beijing in winter (He *et al*., 2001; Dan *et al*., 2004). Recent study by using scanning electron microscope (SEM) analysis (Shi *et al*., 2002) indicate that most PM_{10} at Beijing in winter period are from coal combustion and diesel exhaust. So here we try to investigate the contribution of the two major sources using OC/EC ratio with the speculation that carbonaceous aerosols are from primary emission in Beijing in winter period. In Fig.1, the OC/EC ratios reached a lowest value from 1:30 a.m.–16:30 p.m. 12 January 2004 with averaged value of 1.2, when strong wind occurred. OC and EC emission can be due to dominant sources of motor vehicles at this time. So 1.2 is used as the OC/EC ratio from motor vehicles. The OC/EC ratio reach the highest value from 21:00 p.m 4 January to 4:30 a.m. 5 January and 0 a.m. 13 January with averaged 5.6, in the night time, when there is few motor vehicles and dominant source can be due to coal combustion. So 5.6 is used as the OC/EC ratio from coal combustion. Then, a simple source apportionment equation is given as the following:

$$1.2\gamma + 5.6(1-\gamma) = C_{\text{avg}} \quad (1)$$

where, γ is the fraction of carbonaceous aerosol of motor vehicle origin and $(1-\gamma)$ is fraction of carbonaceous aerosol of coal combustion origin, C_{avg} is averaged OC/EC ratio in day time, night time, or all time. The average OC/EC in all observation period, daytime and night time are 2.3, 2.0, and 2.6, respectively. The calculated contribution from coal combustion and motor vehicle is shown in Fig.3. For the carbonaceous aerosol of Beijing PM_{10} in winter period, the motor vehicle source account for 74%, 82% and 68% in total time, daytime and night time, respectively, while coal combustion account for 26%, 18% and 32% in total time, daytime and night time, respectively.

3 Conclusions

To understand the diurnal variation characteristics of carbonaceous aerosols in Beijing PM_{10}, a real-time observation of OC, EC, and PM_{10} is undertaken besides other related parameters such as SO_2, CO, O_3 during 1–15 January 2004 in urban areas of Beijing. On average, the OC, EC, TC, PM_{10} concentrations and OC/EC ratio are 21.2±16.0, 8.9±5.1, 30.2±20.4, 172.6±98.3 and 2.3±0.9 $\mu g/m^3$, respectively. The concentration of OC, EC, PM_{10} are low with strong wind and high with not strong wind.

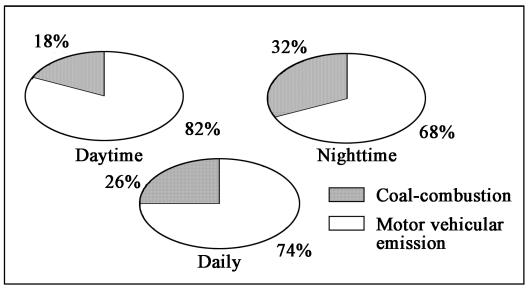

Fig. 3 Sources contribution of carbonaceous aerosol in Beijing PM_{10}.

Average OC concentration in nighttime (24.9±19.6 $\mu g/m^3$) is 40% higher than that in daytime (17.7±10.9 $\mu g/m^3$). Average EC concentrations in daytime (8.8±5.2 $\mu g/m^3$) are close to that in night time (8.9±5.1 $\mu g/m^3$). The OC/EC ratios in nighttime ranging from 2.4 to 2.7 are higher than that in daytime ranging from 1.9 to 2.0. The OC and EC are well correlated to PM_{10}, CO and SO_2, which implies they have proximate sources. OC and EC are not well correlated with O_3. The averaged temperature is only 0.7°C in observation period, which is not favorable condition for SOC production. Considering OC/EC ratio in daytime and night time, correlations between OC and O_3, and meteorological condition, we speculate that OC and EC were emitted as the primary particulate form and no much SOC was produced in winter period in Beijing. Emission of motor vehicle with low OC/EC ratio and coal combustion sources with high OC/EC ratio are dominant sources for carbonaceous in Beijing.

A simple ratio method is used to estimate the relative contribution of sources to carbonaceous aerosols in Beijing PM_{10}. Averagely, the motor vehicle and coal combustion account for 74% and 26%, respectively for carbonaceous aerosols in observation period, which suggests the motor vehicle is dominant emission for carbonaceous aerosols in Beijing PM_{10} in winter period. The results reveal that motor vehicle sources should be paid attention by China EPA in order to control high level of PM_{10} in Beijing effectively.

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