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The Relationship between Major Components of $PM_{2.5}$ and Meteorological Factors in Urban Tokyo, Japan

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Abstract: In this research, the main purpose is to estimate the variation of $PM_{2.5}$ mass concentration and study the influence of meteorological characteristics on major components of $PM_{2.5}$ concentrations in urban Tokyo, Japan. The results shown that the annual mean mass concentration of $PM_{2.5}$ in urban Tokyo was higher than JEQS (Japanese Environmental Quality Standard) of the MOEJ (Ministry of the Environment Japan) (15 μg/m^3), and 41.1% of the daily $PM_{2.5}$ mass concentration exceeded the annual JEQS concentration during observation period. The major components of $PM_{2.5}$ including SO_4^{2-}, NO_3^-, NH_4^+, OC and EC were tightly related to the meteorological conditions, the correlations results shown that the wind speed and relative humidity had significant correlations with major components of $PM_{2.5}$ than the other meteorological factors. Higher relative humidity, windless and less rainfall conditions were favorable for elimination of $PM_{2.5}$ concentration. Higher temperature was beneficial to the formation of SO_4^{2-}, but higher temperature and stronger sunshine duration were not conducive to the formation of NO_3^-.

Key words: $PM_{2.5}$, major components, meteorological factors.

1. Introduction

Deterioration of urban air quality has now become an increasing and widespread concern both in the developed and developing countries. Fine particulate matter ($PM_{2.5}$) derived from motor vehicles, power plants, industries, agriculture, biomass burning, the secondary pollutants through photochemical reactions with vapor and gaseous pollutants. It is considered as important air pollutant and has adverse effects on human health, including effects on the heart, nervous, and vascular system [1, 2]. It is also well documented in various investigations that particulate matter has influence on human health in Japan [3, 4]. Moreover, $PM_{2.5}$ is proved to be linked to atmospheric visibility and global climate change, with the features of physiological toxicity, light extinction and transport at several scales [5, 6]. $PM_{2.5}$ is a very complex mixture, because of the numerous sources as shown above. $PM_{2.5}$ consists mainly of water soluble inorganic ions, carbonaceous species, crustal elements and trace elements [7-10]. To evaluate these impacts, chemical characteristics of $PM_{2.5}$ need to be investigated at different temporal and spatial scales. Several studies have shown that meteorological factors are often related to the spread and dilution of air pollutants [11], therefore, the variations of air pollutant concentration probably depends on weather conditions. In this research, authors use observation data of $PM_{2.5}$ to estimate the variation of $PM_{2.5}$ mass concentration and study the influence of meteorological characteristics on major components of $PM_{2.5}$ concentrations in urban Tokyo, Japan.

2. Material and Data

2.1 Location of Study Monitoring Station

Kameido site is the study monitoring station located east of the Tokyo metropolitan center, bounded by the Sumida-gawa to the west and the Arakawa Riverto the east, as shown in Fig. 1.

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Fig. 1 Location of study monitoring station in Tokyo.

2.2 Data

Total of 56 samples of $PM_{2.5}$ data were used in this research, obtained from May 2014 to February 2015 at Kameido local monitoring site in urban Tokyo, Japan. Authors obtained these available observed $PM_{2.5}$ and meteorological data at Kameido station from the website of MOEJ (Ministry of the Environment Japan) (http://www.env.go.jp/air/osen/pm/monitoring.html). The data were submitted to Ministry of the Environment Japan by local monitoring station and must pass several quality assurance tests before it can be saved. In addition, each site that submits the data to MOEJ annually certifies correctness of their data. Therefore, the MOEJ data are considered to be high quality.

3. Results

3.1 $PM_{2.5}$ Mass Concentration

The annual mean mass concentrations of $PM_{2.5}$ was 15.7 μg/m^3, and 24-hour mean concentrations of $PM_{2.5}$

ranged from 3.5 μg/m^3 to 50.8 μg/m^3 at Kameido station from May 2014 to February 2015 in urban Tokyo Japan, as shown in Fig. 2. The results indicated that the annual mean mass concentration of $PM_{2.5}$ in Tokyo was higher than JEQS (Japanese Environmental Quality Standard) of the MOEJ (15 μg/m^3). 41.1% of the daily $PM_{2.5}$ concentration exceeded the annual JEQS concentration (15 μg/m^3), the results also shown that 5.4% of the daily $PM_{2.5}$ concentrations exceeded the 24-hour mean JEQS concentrations (35 μg/m^3).

3.2 Major Components of $PM_{2.5}$

As shown in Fig. 3, the annual mean value of $PM_{2.5}$ concentration was mainly accounted by ionic components (50.3%), OC (17.6%) and EC (6.5%). The sum of NO_3^-, SO_4^{2-} and NH_4^+ accounted for 90.8% of the total ionic components, and the sum of SO_4^{2-}, NO_3^-, NH_4^+, OC and EC accounted for 69.8% of $PM_{2.5}$ mass concentration. The undetermined fraction (defined as "Others" in Fig. 3) represented 25.42% of $PM_{2.5}$ in Tokyo. This fraction is assumed to contain metallic elements, organic matter, crustal and analytical uncertainties of the measurement.

The results were in good agreement with the data observed in Nagoya, Japan, where the sum of SO_4^{2-}, NO_3^-, NH_4^+, OC and EC accounted for 75% of $PM_{2.5}$ mass concentration [12], and the data obtained in Chiba Prefecture, Japan: the annual mean value of $PM_{2.5}$ concentration was accounted for by ionic components (45.3%), OC (19.7%) and EC (8.0%), the sum of NO_3^-, SO_4^{2-} and NH_4^+ accounted for 93.2% of total ionic components [13]. Therefore, the results showed that the major chemical components of $PM_{2.5}$ in urban Tokyo were SO_4^{2-}, NO_3^-, NH_4^+, OC and EC.

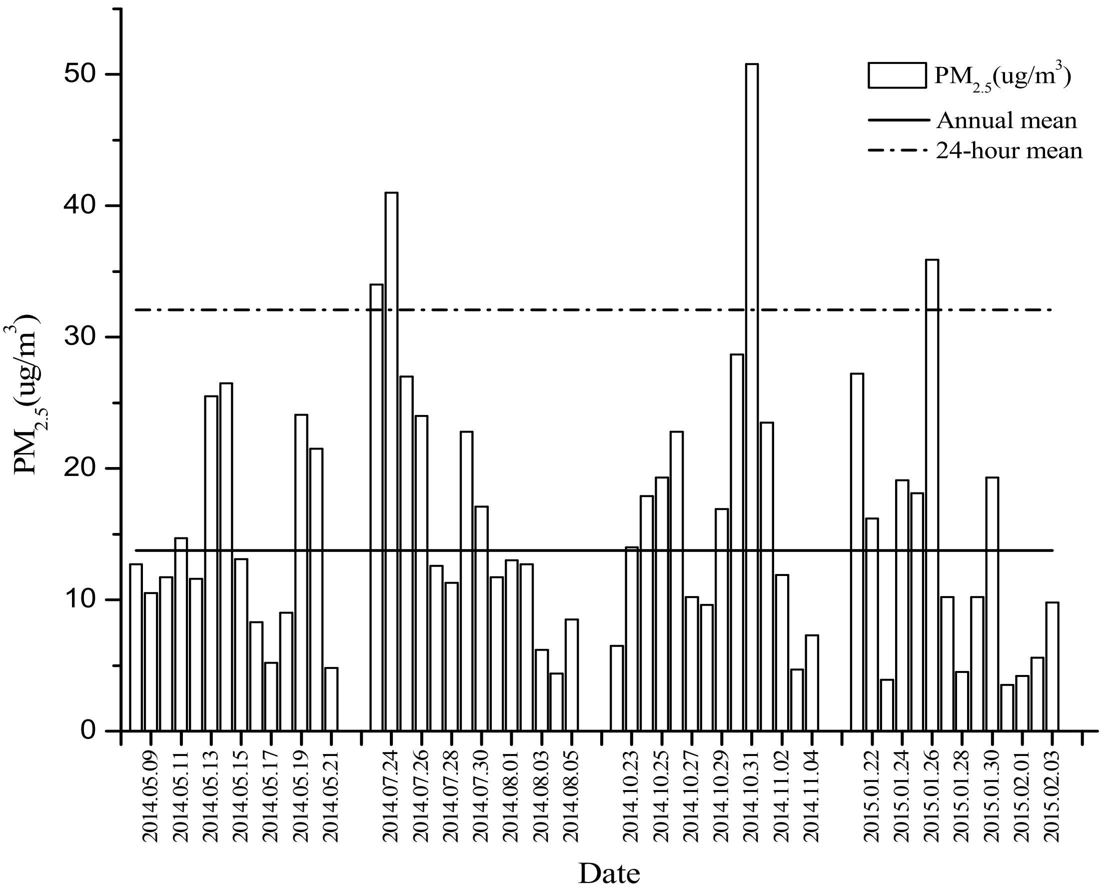

Fig. 2 Variations of $PM_{2.5}$ concentrations at Kameido station in urban Tokyo.

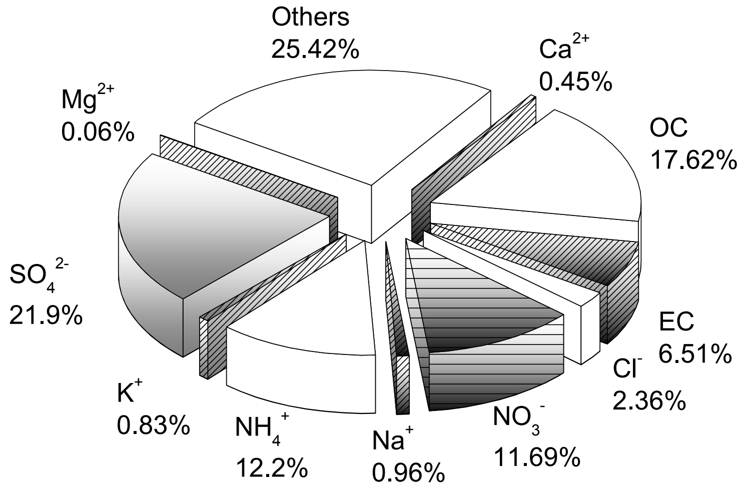

Fig. 3 Annual mean contribution of chemical components in $PM_{2.5}$ mass concentration in urban Tokyo.

3.3 Relationship between Major Components of $PM_{2.5}$ and Meteorological Factors

Authors compared the variations of $PM_{2.5}$ mass concentrations with RAIN (Rain), WS (Wind Speed), RH (Relative Humidity), TEMP (Temperature) and SUN (Sunshine Duration), as shown in Fig. 4. Rainfall, relative humidity and wind speed might be mainly responsible for the low concentration days (Fig. 4 (b), (c) and (d)). The high $PM_{2.5}$ mass concentration usually appeared with the higher relative humidity, windless and less rainfall weather, authors can found that three highest concentration days during observation period, all related with these meteorological factors. Higher RH was often associated with windless, cloudy, and insufficiently sunny days, which aggravated the accumulation and chemical reaction of pollutants [14].

To clear understand the relationships between meteorological factors and $PM_{2.5}$ concentration, authors calculated the spearman correlations between them, and it can be seen that some of the meteorological factors had correlations with $PM_{2.5}$ concentrations from Table 1. Among these meteorological factors, the wind speed and relative humidity had stronger correlations with $PM_{2.5}$ concentrations than the other meteorological factors.

Relative humidity had stronger correlations with NO_3^-, SO_4^{2-}, NH_4^+, OC, EC and $PM_{2.5}$ mass concentrations, the correlation coefficients were 0.47, 0.47, 0.59, 0.40, 0.62, 0.60 and their p-values were all less than 0.01, respectively. The significant positive correlation showed that increase of relative humidity, the concentration of NO_3^-, SO_4^{2-}, NH_4^+, OC, EC and $PM_{2.5}$ mass concentration increased. Higher relative humidity was beneficial to chemical reaction of pollutants [15, 16].

The correlation coefficients between wind speed and components of $PM_{2.5}$ were -0.69, -0.55, -0.63, -0.65 and -0.59 for NO_3^-, NH_4^+, OC, EC and $PM_{2.5}$ mass concentration, respectively, their p-values were all less than 0.01. Rain had significant correlations with NO_3^- ($r = -0.46$, $p < 0.01$), NH_4^+ ($r = 0.36$, $p < 0.01$), EC ($r = 0.34$, $p < 0.01$) and $PM_{2.5}$ mass concentrations ($r = 0.30$, $p < 0.05$), respectively. Negative correlation showed that relative humidity and rain days were favorable for elimination of air pollutants.

Sunshine duration had significant correlation with NO_3^- ($r = -0.59$, $p < 0.01$), and temperature had significant correlations with NO_3^- ($r = -0.36$, $p < 0.01$) and SO_4^{2-} ($r = 0.47$, $p < 0.01$), respectively. Higher temperature and stronger sunshine duration were beneficial to the formation of SO_4^{2-}, but not conducive to the formation of NO_3^-.

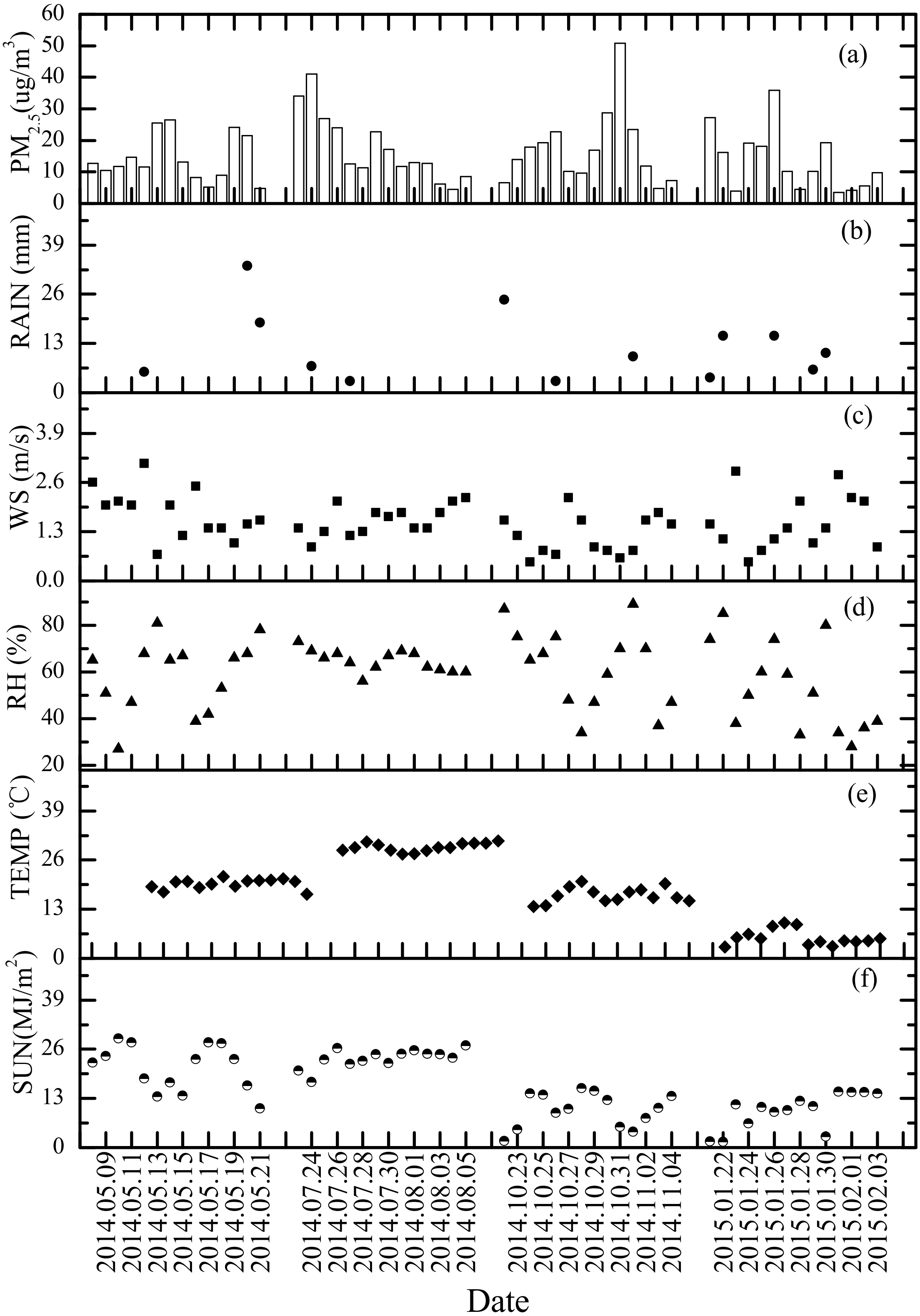

Fig. 4 **Daily mean mass concentration($PM_{2.5}$), RAIN, WS, RH, TEMP and SUN of Tokyo from May 2014 to February 2015.**

Table 1 Relationships between meteorological factors and major components of $PM_{2.5}$.

	WS	TEMP	RH	RAIN	SUN	NO_3^-	SO_4^{2-}	NH_4^+	OC	EC	$PM_{2.5}$
WS	1.00										
TEMP	0.08	1.00									
RH	-0.39**	0.18	1.00								
RAIN	-0.22	-0.22	0.64**	1.00							
SUN	0.37**	0.72**	-0.36**	-0.47**	1.00						
NO_3^-	-0.69**	-0.36**	0.47**	0.46**	-0.59**	1.00					
SO_4^{2-}	-0.26	0.47**	0.47**	0.16	0.19	0.29*	1.00				
NH_4^+	-0.55**	0.10	0.59**	0.36**	-0.22	0.69**	0.81**	1.00			
OC	-0.63**	0.22	0.40**	0.11	-0.12	0.48**	0.59**	0.66**	1.00		
EC	-0.65**	0.08	0.62**	0.34**	-0.27*	0.71**	0.53**	0.78**	0.73**	1.00	
$PM_{2.5}$	-0.59**	0.20	0.60**	0.30*	-0.14	0.62**	0.79**	0.92**	0.83**	0.85**	1.00

**. Correlation is significant at the 0.01 level.

*. Correlation is significant at the 0.05 level.

4. Conclusion

By analyzing the observation data of $PM_{2.5}$ in urban Tokyo from May 2014 to February 2015, the results indicated that the annual mean mass concentration of $PM_{2.5}$ was higher than the JEQS of the MOEJ (15 μg/m^3). 41.1% of the daily $PM_{2.5}$ mass concentration exceeded the annual JEQS concentration, and 5.4% of the daily $PM_{2.5}$ concentrations exceeded the 24-hour mean JEQS concentrations (35 μg/m^3). Therefore, $PM_{2.5}$ was still a very serious problem in Tokyo, Japan. The major components of $PM_{2.5}$ including SO_4^{2-}, NO_3^-, NH_4^+, OC and EC were tightly related to the meteorological conditions, the correlations results shown that the wind speed and relative humidity had significant correlations with major components of $PM_{2.5}$ than the other meteorological factors. Higher relative humidity, windless and less rainfall conditions were favorable for elimination of $PM_{2.5}$ concentration. The higher temperature was beneficial to the formation of SO_4^{2-}, but higher temperature and stronger sunshine duration were not conducive to the formation of NO_3^-.

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