American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-8, Issue-7, pp-162-168
www.ajer.org
Research Paper Open Access

Seasonal Chemical Characteristics of PM2.5 in Zhuhai, China

Tianxiang Zheng
Shenzhen Tourism College,Jinan University, Shenzhen, Guangdong, China, 518053

ABSTRACT: *Fine particulate matter (PM2.5) is associated with adverse health effects but exactly which characteristics of PM2.5 are responsible for this is still widely debated. We evaluated seasonal dynamics of the composition and chemical characteristics of PM2.5 in Zhuhai, China. PM2.5 characteristics at five selected sites within Zhuhai city were analyzed. Sampling began on January 10, 2015, and was conducted for 1 year. The ambient mass concentration, carbon content (organic and elemental carbon, OC and EC) and level of inorganic ions of PM2.5 were also determined. Study finds that average concentrations of PM2.5 (36.43±22.56 $\mu g/m^3$) in Zhuhai are lower than the National Ambient Air Quality Standard (NAAQS) 24 hour average of 65 $\mu g/m^3$. Study also reveals that the daily PM2.5 concentration in Zhuhai city exhibits clear seasonal dynamics, with higher daily PM2.5 concentrations in autumn and winter than in spring and summer.*

KEYWORDS:*PM2.5, Chemical composition, Seasonal characteristic, Zhuhai*

Date of Submission: 05-07-2019 Date of Acceptance: 21-07-2019

I. INTRODUCTION

Atmospheric particulate matter (PM) has been identified as one of the most serious air pollutants in urban areas (Chang et al., 2013). Numerous studies have demonstrated that airborne fine particulate matter (PM2.5) has adverse effects on the environment, leading to reduced visibility and an increase in albedo, as well as on public health, causing chronic respiratory, cardiopathic, and carcinogenic diseases(Sena et al., 2013). In China, diesel vehicles have contributed significantly to urban PM2.5 air pollution. Besides vehicle emissions, coal combustion, biomass burning, and cooking activities are important PM2.5 sources. In recent years, frequent severe haze episodes over a vast area of China have drawn public attention. These events disturb local and regional transport systems and interfere with urban activities (Wu et al., 2016).

PM2.5 is a complex mixture of primary and secondary particles that consists of water-soluble ions, carbonaceous species (organic and elemental carbon, OC and EC), and other elements (Kulshrestha et al., 2009; Lonati et al., 2005; Xu et al., 2012). Therefore, understanding the chemical composition of PM2.5 and assessing its impact on air quality and human health are essential (Liu et al., 2016). Many studies of atmospheric pollution sources have been conducted in coastal regions and islands (Ikeda et al., 2014; Manousakas et al., 2017; Yin et al., 2014) because characterizing coastal or island aerosols can provide information about atmospheric inputs to the adjacent land and ocean ecosystems (Liu et al., 2016). To date, numerous scientific studies have addressed PM2.5 levels, chemical composition, and sources in Chinese coastal regions, including studies in Qingdao (Guo et al., 2004),Tianjin(Li et al., 2009), Xiamen(Viana et al., 2007) and Fuzhou(Xu et al., 2012).

Being one of the most developed regions in China, the Pearl River Delta in southern China is highly polluted. With recent increases in economic activity and the number of vehicles in the region, high PM2.5 levels and poor visibility have become serious problems. Zhuhai is a city in southern Guangdong Province, China, located on the western Pearl River estuary at the southern edge of the Pearl River delta, and is one of the four initial Chinese Special Economic Zones (SEZs) chosen in 1980 for economic reform experiments. Today, Zhuhai is an exemplary city, suppressing industrialization to preserve high environmental quality for sustainable development, which led to its recognition by the United Nations as a Best Model of International Residential Environment Improvement in 1998, making it the third Chinese city to earn that distinction. Therefore, control of the PM2.5 level in Zhuhai is essential to improve visibility and protect human health. At present, insufficient studies of the detailed chemical composition and source apportionment of aerosols have been conducted, and there is a lack of long-term data. In this study, we determined PM2.5 pollution levels, as well as its chemical properties. This information will help determine the effectiveness of pollution-control strategies and provide useful data for regulatory agencies to create strategies to control PM2.5 in the atmosphere.

II. MATERIALS AND METHODOLOGY

2.1 Study site and sample collection

Zhuhai city, located in the south of the Tropic of Cancer, has a subtropical monsoon climate with a mean annual temperature of 22.4°C, mean annual precipitation of 2011 mm, and potential evaporation of 1469 mm (Fu et al., 2012).Zhuhai is witnessed by four major seasons: spring (March, April, May), summer (June, July, August), autumn (September, October, November), and winter (December, January, February).

2.2 Chemical Analysis of PM2.5 Composition

The 24 hour PM2.5 samples were collected simultaneously at five sites in 1-day intervals between January 10, 2015, and November 10, 2015, in Zhuhai city (Fig 1). At each site, 10 medium-volume samplers (4 from Tianhong TH-16A, 6 from Zhongrui ZR-3930D, China) were deployed simultaneously to collect the desired samples. Two channels of the samplers were loaded with Teflon filters (Pall, 47 mm, USA) for mass measurement and ion and metal analysis, while another two were loaded with quartz filters to analyze carbon fractions (OC and EC). The samples were placed into plastic Petri dishes right after sampling and stored in a freezer at −18°C. All quartz filters were baked in advance (550°C for 5 h), and pre- and post-weighed with an analytical balance (reading precision 10 µg) after stabilization at a controlled temperature of 25 ± 1°C and humidity of 40 ± 3%. The PM2.5 concentration was obtained gravimetrically with an analytical balance (Sartorius 0.01 mg, Germany) as the difference in mass of filters before and after sampling.

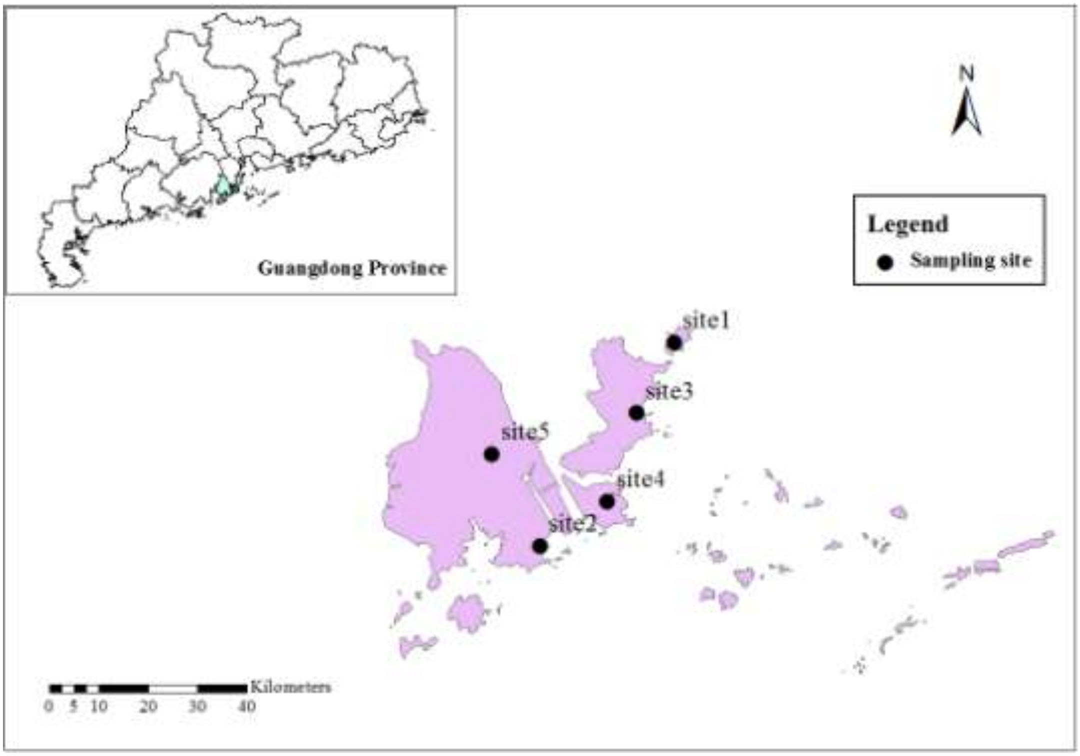

Fig. 1 Locations of five sampling sites in Zhuhai city, China

III. RESULTS: Chemical Components in PM2.5

3.1 Seasonal characteristic of ambient PM2.5 concentration

The seasonal and annual average concentrations of PM2.5 observed in Zhuhai are summarized in Figure 2. Seasonal average PM2.5 mass concentrations ranged from 17.09±7.77 µg/m^3 in summer to 62.22±21.35 µg/m^3 in winter, with an annual average level of 36.43±22.56 µg/m^3. According to Chinese ambient air quality standards (GB 3096-2012), the recommended limits of annual PM2.5 concentration for Class 2 and Class 1 ambient air quality zones are 35 µg/m^3 and 15 µg/m^3, respectively. The daily PM2.5 concentration in Zhuhai was 36.43±22.56 µg/m^3, about 2.4 times greater than that required by the ambient air quality standards for class one. Furthermore, the daily concentration in Zhuhai exhibited clear seasonal dynamics, with values of 26.93±9.11, 17.09±7.77, 36.99±16.14, and 62.22±21.35 µg/m^3 in spring, summer, autumn, and winter, respectively. The daily concentrations in autumn and winter were higher than those in spring and summer, with seasonal averages in winter 2.2 times greater than those in summer. Values in autumn and winter were greater than 35 µg/m^3, similar to observations in other cities in China, such as Lanzhou (Hang and Oanh, 2014),Guangzhou(Tao et al., 2014) and Shanghai(Wang et al., 2013). Researcher reported that this typical seasonal pattern was not only related to meteorological conditions, but also was attributed to various contributions from local and regional emission sources between seasons(Li et al., 2009).

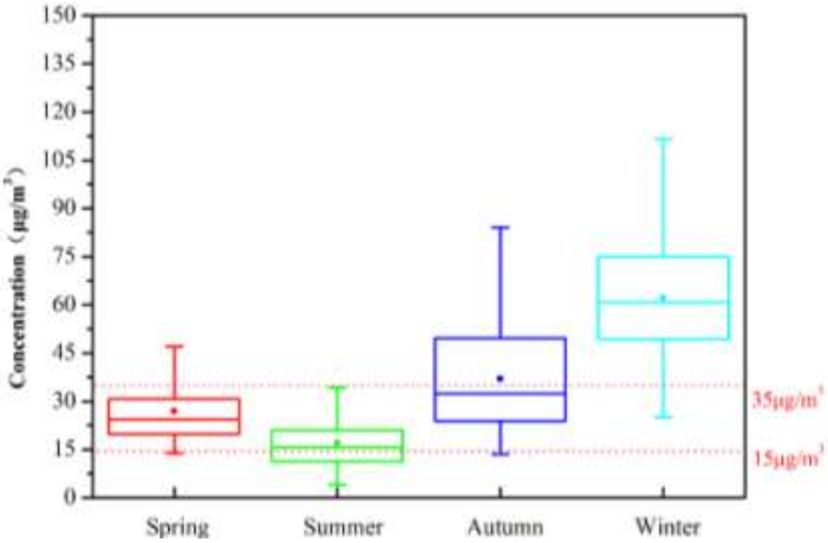

Fig 2. Seasonal variation in PM2.5. The dots represent average PM2.5 concentrations, the upper bars represent maximum values, and the lower bars represent the minimum values of observed PM2.5 concentrations

It was found that PM2.5 concentration is not only often associated with wind speed and wind direction, but also affected by other meteorological parameters, including temperature, relative humidity(Zhou et al., 2015). The meteorological parameters such as temperature, relative humidity (RH), wind speed and wind direction were recorded in site 1. Sampling site was selected in order to evaluate the effects of meteorological conditions on PM2.5 concentrations, and correlations between PM2.5 concentrations and ambient temperature (T), relative humidity (RH), atmospheric pressure, wind direction and wind speed were also determined. The results of correlation analyses are listed in Table 1.

Table1 Correlation analysis among hourly PM2.5 concentration and major meteorological factors (n=8760)

	PM2.5(μg/m^3)	WS (m/s)	WD (°)	T (℃)	RH (%)	AP (hPa)
PM2.5(μg/m^3)	1					
WS (m/s)	-.331**	1				
WD (°)	.013	.460**	1			
T (℃)	.029	-.304**	-.423**	1		
RH (%)	-.094**	-.079**	.104**	.317**	1	
AP (hPa)	.187**	.113**	.120**	-.587**	-.550**	1

** Correlation is significant at the 0.001 level (two-tailed);WS: wind speed; WD: wind direction; T: ambienttemperature; RH: relative humidity; AP: atmospheric pressure; n=number of samples.

As shown in Table 1, it was revealed that the PM2.5 concentration was positively correlated with ambient pressure ($p < 0.05$), and negatively correlated with the wind speed and relative humidity during the sampling periods ($p < 0.05$). Therefore, PM2.5 concentration is closely related to the wind speed, relative humidity and atmospheric pressure.

In order to further study the influences of wind speed and wind direction on local ambient PM2.5 concentrations, PM2.5 concentrations against wind speed and wind direction was plotted(Fig 3). Very stable with abnormally high frequency of calm wind is one of the key reasons for heavy air pollutions, while higher wind speed (>4.4m/s) could move out of the air mass and lead to low PM2.5 levels(He et al., 2017). The dominant wind directions in Site 1 during the sampling period were south (22%), south-south-west (11.9%), south-south-east (11.9%) and east-south-east (11.9%), and the wind directions with wind speed (1-2 m/s) (71.2%), 1-2 m/s(13.6%), 0-1 m/s(11.9%), respectively. And when the wind directions were south, south-south-west, south-south-east, ratio of PM2.5 concentrations of more than (>20μg/m^3) were 15.3%, 10.2% and 10.2%, respectively. So, it can conclude that wind speed and wind direction had a great influence on the spread of ambient of PM2.5 in Zhuhai city.

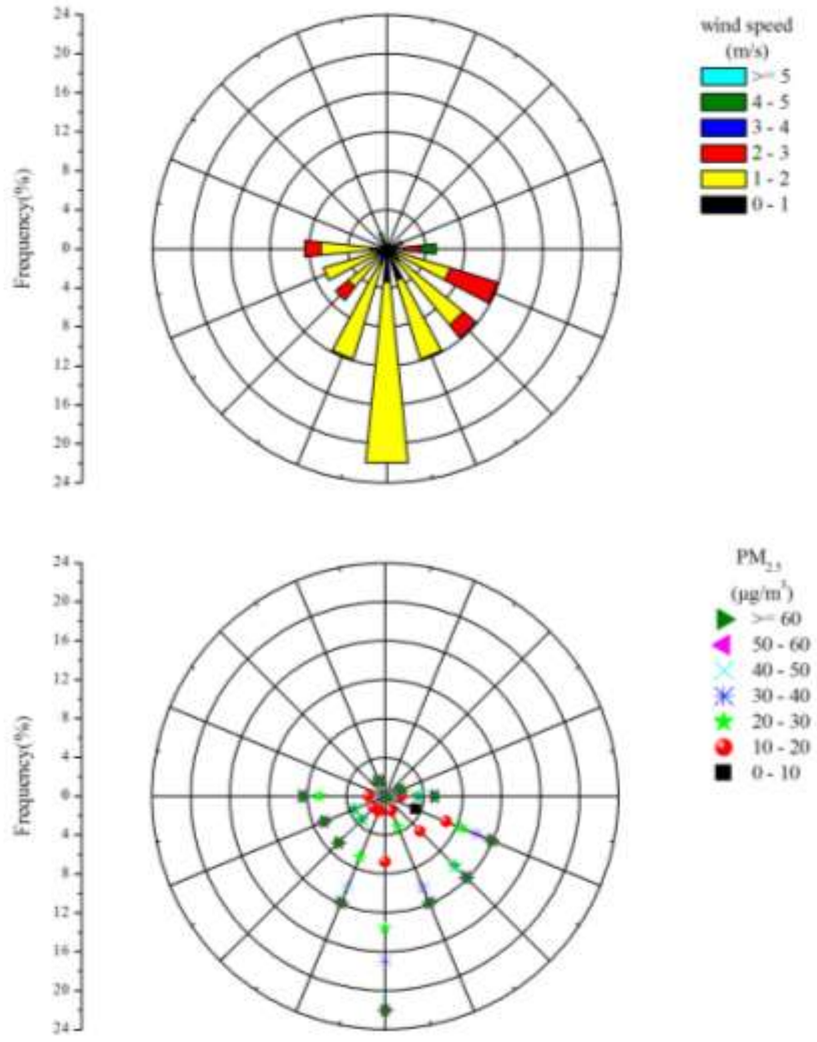

Fig 3. Polar plotting of PM2.5 against wind speed and wind direction

3.2 OC and EC

Concentrations of both OC and EC (Fig. 4) exhibited obvious seasonal variation, with average concentrations that were generally highest in winter and lowest in summer, similar to previous observations (Lv et al., 2016). The average concentrations of OC and EC in summer were 3.42±1.66 μg/m^3 and 0.89±0.60 μg/m^3, respectively, and their levels were roughly 3.4 and 4.0 times higher in winter than in summer. Although OC and EC exhibited the same seasonal pattern, with the highest concentrations in winter and lowest in summer, OC exhibited greater seasonal variability than EC.

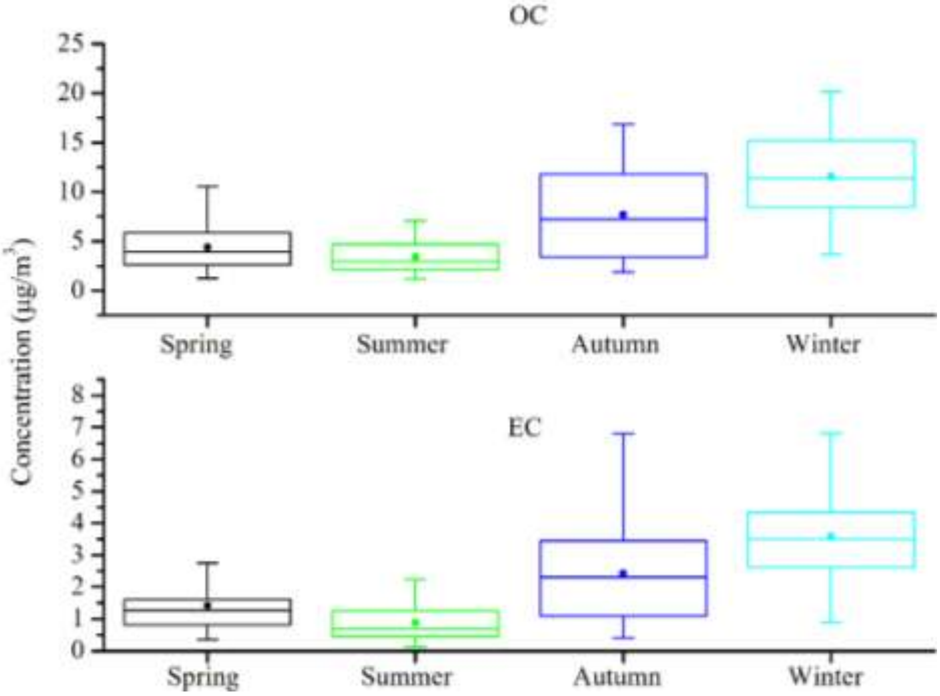

Fig 4. Seasonal variation in OC and EC concentrations

Carbonaceous aerosols, comprising primary species and secondary organic compounds, are composed of EC and OC, and are emitted from sources such as coal combustion, vehicles, and biomass burning(He et al., 2009), OC can also come from secondary reactions (Lv et al., 2016).

OC and EC concentrations in winter are higher than those in summer, but the OC/EC ratio is higher in summer than in winter, with means of 4.53±1.56 and 3.29±0.50, respectively (Table 2). The OC/EC ratio has been used to distinguish among sources of carbonaceous aerosols (Viana et al., 2007). The average daily OC/EC ratio in Zhuhai in all seasons was 3.56, while a ratio greater than 2 indicates that the main carbon component is secondary organic carbon (SOC). Previous studies have found that the average OC/EC ratios in Xi'an are 3.0 for coal combustion and 1.6 for vehicle exhaust (Cao et al., 2005; Gray et al., 1986). The ratios in Colorado are 2.7 for coal combustion and 1.1 for motor vehicle exhaust (Watson et al., 2001). Thus, the ratios in Zhuhai indicate direct emissions from combustion sources.

Table 2 Average ratios and correlation between OC and EC

	Spring (n=69)	Summer (n=75)	Autumn (n=80)	Winter (n=80)
OC/EC	3.16±0.78	4.53±1.56	3.26±0.58	3.29±0.50
R^2	0.77**	0.86**	0.88**	0.83**

** Correlation is significant at the 0.001 level

The occurrence of the lowest OC/EC ratio in summer might also be attributable to lower emissions from coal combustion and more rainy days, which may effectively remove OC from the atmosphere but not EC, due to the lower washout efficiency of EC(Wang et al., 2015). OC/EC ratios can also be influenced by photochemical reactivity. The average ratio in summer was higher than in other seasons, perhaps because the greater rate of photosynthesis and higher humidity promote the formation of secondary aerosols in summer or because more precipitation falls in summer than in winter (Fig. 5). Thus, we concluded that higher OC/EC ratios in summer in Zhuhai might be the result of increased photosynthesis and higher humidity during this season.

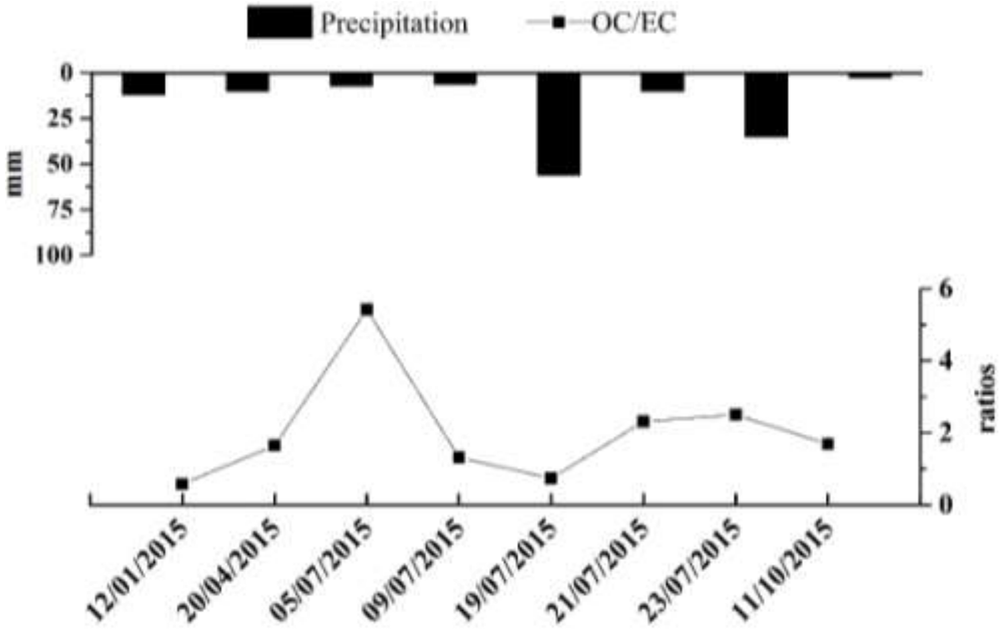

Fig 5. Selected ratios of OC/EC and daily precipitations during the observation period in sampling site 1

The correlation between OC and EC can reflect the source of inhalable particulate pollution to some extent, and the stability and consistency of OC and EC can be determined using correlation analysis. As shown in Table 2, OC and EC were significantly correlated (average R2=0.84 and P＜0.001) in all seasons. Strong correlations between OC and EC indicated a common source of these components(Wang et al., 2015), and coal combustion and vehicle exhaust were considered to be the dominant sources of carbonaceous aerosols in Zhuhai.

IV. CONCLUSION

Ambient PM2.5 and its major components were measured in all four seasons of 2015 in Zhuhai, and ambient PM2.5 pollution in Zhuhai was low during the study period. The seasonal averages of PM2.5 in winter were 2.2 times higher than those in summer. Meteorological conditions, local and regional contribution were closely correlated to the PM2.5 concentrations. NH_4^+, SO_4^{2-}, NO_3^- and Na^+ were the major water-soluble ions in aerosols, and the highest and lowest concentrations of the dominant chemical components were also observed in winter and summer, respectively. Additional work is needed to discover the chemical species and source identificationof PM2.5 in Zhuhai.

V. ACKNOWLEDGEMENTS

The author expresseshis deep appreciation to Z.B. Liang of the Sun Yat-sen University, for his technical assistance, helpfuldiscussions and valuable suggestions.

REFERENCES

[1]. Cao, J. J., Wu, F., Chow, J. C., Lee, S. C., Li, Y., Chen, S. W., An, Z. S., Fung, K. K., Watson, J. G., Zhu, C. S. & Liu, S. X. (2005). Characterization and source apportionment of atmospheric organic and elemental carbon during fall and winter of 2003 in Xian, China. Atmospheric Chemistry and Physics, 5(11), 3127-3137.
[2]. Chang, S. Y., Chou, C. C. K., Liu, S. & Zhang, Y. H. (2013). The Characteristics of PM2.5 and Its Chemical Compositions between Different Prevailing Wind Patterns in Guangzhou. Aerosol and Air Quality Research, 13(4), 1373-1383.
[3]. Fu, C., Chen, J., Dong, L. & Jiang, H. (2012). Field investigation and modeling of runoff generation in a granitic catchment in Zhuhai, China. Journal of Hydrology, 458–459, 87-102.
[4]. Gray, H. A., Cass, G. R., Huntzicker, J. J., Heyerdahl, E. K. & Rau, J. A. (1986). Characteristics of atmospheric organic and elemental carbon particle concentrations in Los Angeles. Environmental science & technology 20(6), 580-589.
[5]. Guo, Z. G., Feng, J. L., Fang, M., Chen, H. Y. & Lau, K. H. (2004). The elemental and organic characteristics of PM2.5 in Asian dust episodes in Qingdao, China, 2002. Atmospheric Environment, 38(6), 909-919.
[6]. Hang, N. T. & Oanh, N. T. K. (2014). Chemical characterization and sources apportionment of fine particulate pollution in a mining town of Vietnam. Atmospheric Research, 145, 214-225.
[7]. He, Q. S., Yan, Y. L., Guo, L. L., Zhang, Y. L., Zhang, G. X. & Wang, X. M. (2017). Characterization and source analysis of water-soluble inorganic ionic species in PM2.5 in Taiyuan city, China. Atmospheric Research, 184, 48-55.
[8]. He, X., Li, C. C., Lau, A. K. H., Deng, Z. Z., Mao, J. T., Wang, M. H. & Liu, X. Y. (2009). An intensive study of aerosol optical properties in Beijing urban area. Atmospheric Chemistry and Physics, 9(22), 8903-8915.
[9]. Kulshrestha, A., Satsangi, P. G., Masih, J. & Taneja, A. (2009). Metal concentration of PM2.5 and PM10 particles and seasonal variations in urban and rural environment of Agra, India. Science of the Total Environment, 407(24), 6196-6204.

[10]. Li, W. F., Bai, Z. P., Liu, A. X., Chen, J. & Chen, L.(2009). Characteristics of Major PM2.5 Components during Winter in Tianjin, China. Aerosol and Air Quality Research, 9(1), 105-119.

[11]. Liu, B., Song, N., Dai, Q., Mei, R., Sui, B., Bi, X. & Feng, Y. (2016). Chemical composition and source apportionment of ambient PM2.5 during the non-heating period in Taian, China. Atmospheric Research, 170, 23-33.

[12]. Lonati, G., Giugliano, M., Butelli, P., Romele, L. & Tardivo, R. (2005). Major chemical components of PM2.5 in Milan (Italy). Atmospheric Environment, 39(10), 1925-1934.

[13]. Lv, B., Zhang, B. & Bai, Y. (2016). A systematic analysis of PM2.5 in Beijing and its sources from 2000 to 2012. Atmospheric Environment 124, Part B, 98-108.

[14]. Manousakas, M., Papaefthymiou, H., Diapouli, E., Migliori, A., Karydas, A. G., Bogdanovic-Radovic, I. & Eleftheriadis, K. (2017). Assessment of PM2.5 sources and their corresponding level of uncertainty in a coastal urban area using EPA PMF 5.0 enhanced diagnostics. Science of the Total Environment, 574, 155-164.

[15]. Meng, C. C., Wang, L. T., Zhang, F. F., Wei, Z., Ma, S. M., Ma, X. & Yang, J. (2016). Characteristics of concentrations and water-

[16]. Sena, E. T., Artaxo, P. & Correia, A. L. (2013). Spatial variability of the direct radiative forcing of biomass burning aerosols and the effects of land use change in Amazonia. Atmospheric Chemistry and Physics, 13(3), 1261-1275.

[17]. Tao, J., Zhang, L., Ho, K., Zhang, R., Lin, Z., Zhang, Z., Lin, M., Cao, J., Liu, S. & Wang, G. (2014). Impact of PM2.5 chemical compositions on aerosol light scattering in Guangzhou — the largest megacity in South China. Atmospheric Research, 135–136, 48-58.

[18]. Viana, M., Maenhaut, W., ten Brink, H. M., Chi, X., Weijers, E., Querol, X., Alastuey, A., Mikuska, P. & Vecera, Z. (2007). Comparative analysis of organic and elemental carbon concentrations in carbonaceous aerosols in three European cities. Atmospheric Environment, 41(28), 5972-5983.

[19]. Wang, G., Cheng, S., Li, J., Lang, J., Wen, W., Yang, X. & Tian, L. (2015). Source apportionment and seasonal variation of PM2.5 carbonaceous aerosol in the Beijing-Tianjin-Hebei Region of China. Environmental Monitoring and Assessment, 187(3), 143.

[20]. Wang, J., Hu, Z. M., Chen, Y. Y., Chen, Z. L. & Xu, S. Y. (2013). Contamination characteristics and possible sources of PM10 and PM2.5 in different functional areas of Shanghai, China. Atmospheric Environment, 68, 221-229.

[21]. Watson, J. G., Chow, J. C. & Houck, J. E. (2001). PM2.5 chemical source profiles for vehicle exhaust, vegetative burning, geological material, and coal burning in Northwestern Colorado during 1995. Chemosphere, 43(8), 1141-1151.

[22]. Wu, B., Shen, X., Cao, X., Yao, Z. & Wu, Y. (2016). Characterization of the chemical composition of PM2.5 emitted from on-road China III and China IV diesel trucks in Beijing, China. Science of The Total Environment, 551–552, 579-589.

[23]. Xu, L., Chen, X., Chen, J., Zhang, F., He, C., Zhao, J. & Yin, L. (2012). Seasonal variations and chemical compositions of PM2.5 aerosol in the urban area of Fuzhou, China. Atmospheric Research, 104–105, 264-272.

[24]. Yin, L., Niu, Z., Chen, X., Chen, J., Zhang, F. & Xu, L. (2014). Characteristics of water-soluble inorganic ions in PM2.5 and PM2.5–10 in the coastal urban agglomeration along the Western Taiwan Strait Region, China. Environmental Science and Pollution Research, 21(7), 5141-5156.

[25]. Zhou, B., Shen, H., Huang, Y., Li, W., Chen, H., Zhang, Y., Su, S., Chen, Y., Lin, N., Zhuo, S., Zhong, Q., Liu, J., Li, B. & Tao, S. (2015). Daily variations of size-segregated ambient particulate matter in Beijing. Environmental Pollution, 197, 36-42.

Tianxiang Zheng "Seasonal Characteristics of Chemical Compositions of PM2.5 in Zhuhai, China."International Journal of Humanities and Social Science Invention(IJHSSI), vol. 8, no. 7, 2019, pp. 162-168