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Pollution characteristics and influencing factors of atmospheric particulate matter (PM2.5) in Chang-Zhu-Tan area

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Pollution characteristics and influencing factors of atmospheric particulate matter (PM2.5) in Chang-Zhu-Tan area

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Abstract. Using the same time data of PM2.5 concentration and meteorology from May 1st to May 31st in 2013 in Chang-Zhu-Tan area. This paper analyses the variation characteristics of PM2.5 concentration and the correlations between the variation characteristics and meteorological factors. In view of time, the results showed that the 24-h PM2.5 concentration varied with the two peaks and two valleys styles in Chang-Zhu-Tan area. And the daily PM2.5 concentration tends to the instability and great variation characteristics with the multi-peaks and multi-valleys style. In view of space, PM2.5 concentration values of the three cities from high to low are Zhuzhou>Xiangtan>Changsha. For cities and suburbs, PM2.5 concentration values of central towns are greater than that of the suburbs in Changsha and Xiangtan; however, the PM2.5 concentration values of the central town in Zhuzhou are slightly lower than the suburbs. At the same time, the correlation analysis between PM2.5 concentration and meteorological factors showed that the correlation from high to low was the relative air humidity>soil temperature>air temperature>soil humidity> wind velocity>rainfall. Among the above meteorological factors, wind velocity, rainfall, air temperature, soil temperature and soil humidity are negatively correlated with PM2.5 concentration, but the relationship between relative air humidity and PM2.5 concentration is a positive correlation.

1. Introduction

With the rapid development of global environmental change and the society and economy, atmospheric particulate matter (PM) has already become the primary pollutant which affects air quality in most cities in China. Now, PM2.5, known as the fine particles, is not only one of the important factors of air pollution, but also a key factor which affects the air environment quality in some areas [1]. Moreover, PM2.5 is greatest harmful to human health. Previous research showed the PM2.5 concentration in the air environment is proportionate to the incidence and mortality of the corresponding diseases [2-3]. At the same time, previous research also showed PM2.5 is the leading cause of hazy weather. Thus, it can be used as judgment indicators of haze weather [4-5]. So, research on PM2.5 has already become a hot topic in global change research.

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In 2012, monitoring projects on the fine particulate matter and ozone, etc. already were carried out in some key regions, such as Beijing, Tianjin, Hebei, the Yangtze River Delta, the Pearl River Delta, municipalities and the provincial capital city. And in 2013, projects have already covered 113 key environmental protection cities and the national environmental protection model cities. By 2015, it is estimated that the projects will cover all prefecture level and above cities. But for the research on PM2.5 in China, it carried out only more than ten years. However, due to limitations of researchers and technical condition, research on PM2.5 has only been carried out in some economically developed city (such as Beijing) at present. Therefore, there are no systematic research results and the evaluation systems on the physicochemical characteristics and environmental effects of these fine particle pollutants have not yet formed [6-7]. In fact, Chang-Zhu-Tan area, as the important agglomerations in Hunan province and central China and "Two-typed Social Demonstration Zone", the research on PM2.5 is less. Thus, taking Chang-Zhu-Tan area as an example, this paper tried to analyze the PM2.5 pollution characteristics of the study area, and on this basis to explore the meteorological factors how to impact PM2.5.

2. General Situation of Research Area

Chang-Zhu-Tan area, including Changsha, Zhuzhou and Xiangtan, located in the northeast of Hunan Province (110˚53' to 114˚15', 26˚3' to 28˚40'). Chang-Zhu-Tan area is the core of economic development and an important industrial base in Hunan province, even in the whole nation. Some industries in Zhuzhou, Changsha, and Xiangtan have already become the main industrial sources of atmospheric pollution. In recent years, the city ecological system continues to expand in Chang-Zhu-Tan area and the construction of "A Resource-Saving and Environment-Friendly Society" Comprehensive Reform Experimental District in Changsha- Zhuzhou- Xiangtan City Agglomerations has already been made certain progress [8-9]. Obviously, the research on the temporal and spatial distribution characteristics of PM2.5 concentration can provide the theoretic foundation for future studying and making the corresponding pollution-control measures in Chang-Zhu-Tan area.

3. Data Sources and Processing Methods

3.1. PM2.5 Data

There are 23 automatic monitoring stations (10 stations in Changsha, 6 stations in Zhuzhou, 7 stations in Xiangtan) of PM2.5 in Chang-Zhu-Tan area. Most stations are located in urban areas, only a small number of monitoring stations, such as Shaping, Shaoshan and Dajing scenic area, are distributed in relatively remote suburbs.

PM2.5 concentration data of 23 automatic monitoring stations of Chang-Zhu-Tan area from May 1st to May 31st in 2013 is collected from the real time publishing platform of national cities' air quality. And PM2.5 monitoring data are updated every hour. In order to ensure the calculation effectiveness of the daily average PM2.5 concentration, the site data which were updated more than 20 hours are selected as the daily average PM2.5 concentration value. In this paper, the evaluation criteria on the PM2.5 content relied on "Ambient Air Quality Standard" (GB3095 - 2012), which issued by China in March, 2013.

3.2. Meteorological Data

Meteorological data of Xiangtan in the paper are collected by using PH meteorological data acquisition instrument each 15 minutes from May 1st to May 31st in 2013. The collected meteorological data include 6 indicators, such as wind velocity, rainfall, air temperature, soil temperature, soil humidity, relative air humidity.

3.3. Data Processing Methods

The datum is analyzed through the partial correction analysis function of SPSS software. Partial correlation analysis can control the influence variables when a linear relationship between the two variables is analyzed. And this method can reflect the real linearity degree between the two variables. The partial correlation coefficient is an indicator which measures the partial correlation degree and direction. And it can better reflect the relationship between two variables than a simple linear correlation coefficient.

4. Result and Discussion

4.1. Temporal Distribution Characteristics of PM2.5 Concentration in Chang-Zhu-Tan area

4.1.1. 24-h Variation Characteristics of PM2.5 Concentration. 24-h variation trends of PM2.5 concentration in Zhuzhou, Changsha, Xiangtan are nearly the same and all showed two peaks (8:00-10:00 and 19:00-22:00) and two valleys (4:00-7:00 and 15:00-18:00) styles in the curves of 24h PM2.5 concentration (Figure 1). Obviously, the results are essentially consistent with the results studied by Sun Zhenquan, Yu Jianhua, Tan Ronghua et al [10-12].

4.1.2. Daily Average Variation Characteristics of PM2.5 Concentration. 548 valid data of PM2.5 concentration is used to analyze and the difference is about 13 times between the maximal value (116μg/m³, Dajing scenic area) and the minimum value (9μg/m³, Tiantai mountain villa). The monthly mean values of PM2.5 concentration was 52μg/m³ in Changsha, 54μg/m³ in Zhuzhou and 53μg/m³ in Xiangtan respectively, and all of them are below 75μg/m³ of the daily average secondary standard concentration which is limited by the "Ambient Air Quality Standard" (GB 3095-2012). The proportion of PM 2.5 time-average concentration values, which is not less than the standard, was 9.02%, 10.08% and 6.13% within the monitored time respectively. All the above facts showed PM2.5 pollution is relatively not serious, and the environmental quality is good (Figure 2).

4.2. Spatial Variation Characteristics of PM2.5 Concentration in Chang-Zhu-Tan area

4.2.1. Contrastive analysis of PM2.5 concentration of Chang-Zhu-Tan area. Due to the different natural environment, economic development level and people's behavior habits in Changsha, Zhuzhou and Xiangtan, PM2.5 concentration also appeared their different characteristics. Of the three cities, the monthly average PM2.5 concentration from high to low is Zhuzhou > Xiangtan > Changsha. However, the difference is not significant.

Based on the secondary standards of PM2.5 concentration, which is limited by the "Ambient Air Quality Standard" (GB 3095-2012), for the excess standard rate of the three cities, Zhuzhou was highest and reached 10.08%, Changsha and Xiangtan reached 9.02% and 6.13% respectively. PM2.5 air pollution level of Zhuzhou is most serious among the three cities.

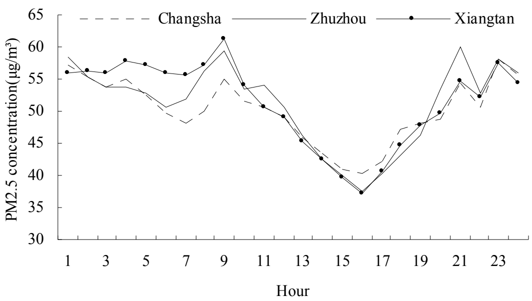

Figure 1. 24-h PM2.5 concentration variation in Chang-Zhu-Tan area in May, 2013

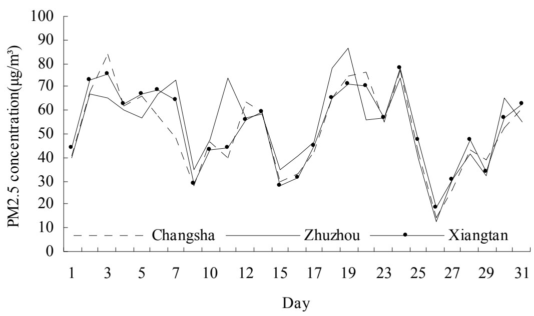

Figure 2. Daily average changes of PM2.5 concentration in May in Chang-Zhu-Tan area

4.2.2. PM2.5 concentration contrast between central city and suburbs in Chang-Zhu-Tan area. As well known, the pollutants' emissions and accumulation of a different region will appear different characteristics because of their different environmental conditions. Due to belong to different units of the city, central city and its suburb have different natural conditions and different degree of human activities; therefore, PM2.5 concentration has also different characteristics. In this paper, the selected suburbs monitoring spots include Yuhua District Environmental Protection Bureau and Hunan Normal University in Changsha, Zhuzhou City Environmental Protection Bureau and Zhuzhou Railway Station in Zhuzhou, Xiangtan City Environmental Protection Bureau and Jianglu in Zhuzhou City Environmental Protection Bureau and Zhuzhou Railway Station in Zhuzhou. And selected central city monitoring spots include ShaPing, Hunan University of Chinese Medicine, Zhuzhou smelter hospital, Fourth Middle School of Zhuzhou City, Hunan University of Science and Technology and Zhaoshan.

PM2.5 concentration of the central city was higher than that of the suburb in Changsha. The maximum difference between the highest and the lowest values of the PM2.5 concentration is 5μg/m³. However, for the Zhuzhou city, the PM2.5 concentration of the central city is lower than that of the suburbs only except for 20 o'clock. And the maximum difference in the PM2.5 concentration is 5μg/m³ at 24 o'clock. To Xiangtan city, the PM2.5 concentration distribution is similar to that of Changsha. The difference of PM2.5 concentration between central city and suburbs is relatively high at each time except 18 o'clock. And the maximum difference in the PM2.5 concentration is 11μg/m³ at 24 o'clock.

4.3. Analysis of meteorological factors affecting PM2.5 concentration variation

PM2.5 has a number of natural sources and human sources. In fact, the dust produced by vehicle exhaust, construction and traffic, industrial and agricultural production, the boiler combustion, waste incineration, volcano eruption, produced water splash, outdoor barbecues, the burning of straw and firewood, the dust particles produced by chemical reaction things are all important sources of PM2.5 [13-14]. Of course, meteorological factors, such as the wind velocity, rainfall, air temperature, soil temperature, soil humidity and relative air humidity, are also important factors, which affect the changes of PM2.5 concentration.

There are relationships with different degrees between the meteorological factors of each monitoring station and the variation of the PM2.5 concentration, especially the air temperature, soil temperature, soil moisture and relative air humidity. The number of days which the correlation coefficient between each meteorological factor of air temperature, soil temperature, soil humidity and PM2.5 concentration reached the confidence level is all above 15 days in Bantang, Yuetang, Jianglu, Hunan University of Science and Technology and Zhaoshan. The results showed that the effects of these meteorological factors on PM2.5 concentration variation were significant, and the results were also in good agreement with the previous studies [15-16]. Due to the distance from the city, the number of the correlation coefficient, which reached confidence levels between the meteorological factors and the PM2.5 concentration in Shaoshan, is significantly less. But overall, the correlation between meteorological factors and the changes of PM2.5 concentration is higher.

For the relationship between the meteorological factors and PM2.5 concentration, the meteorological factors, such as wind velocity, rainfall, air temperature, soil temperature and soil humidity was negatively related to PM2.5 concentration, but the relative air humidity was positively related to PM2.5 concentration. In fact, it has been found that the precipitation process is an important mechanism, which removes particles from the atmosphere and the rain, is effective for the settlement of atmospheric fine particles especially [15]. As well known, the role of wind is to transport ground air pollutants by advection. Generally, larger wind velocity will more benefit to the dilution and dispersion of pollutants. In fact, the changes of air temperature and soil temperature will cause the atmospheric pressure changes at some local area. Then, the air will flow among different regions and cause the dispersion and aggregation of the atmospheric particulate matter. So, PM2.5 concentration will be changed. At the same time, rising temperature will increase the chemical activity of gaseous compounds in the atmosphere to benefit the secondary ions' generation. As the result, PM2.5

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concentration is increased. Obviously, diffusion, which is generated by rising temperature in Xiangtan in May, plays a leading role. And the results showed that the correlation between soil relative humidity and PM2.5 concentration was in direct contradiction to the correlation between air relative humidity and PM2.5 concentration. Air humidity increasing will lead to enhanced adsorption of atmospheric particulate matter and thereby increase the concentration of atmospheric particulate matter. At the same time, the area with relatively large air relative humidity is easy to form an inversion layer and hinders the diffusion and dilution of atmospheric particulate matter. As the underlying surfaces of air, the soil moisture increasing will enhance its adhesion, so the soil can absorb more atmospheric particulate matter near the ground. Meanwhile, fine particles, which dispersed over the soil surface, are also less easy to spread. So, soil humidity and air humidity play an opposite role during this process. The correlation from high to low is relativity air humidity > soil temperature > air temperature > soil humidity> wind velocity> rainfall. Under less wind and rain condition, temperature and humidity are the key influence factors.

5. Conclusion

The spatial-temporal change of PM2.5 in Chang-Zhu-Tan area has its specific characteristics, and the meteorological factors are important factors, which affects PM2.5 concentration. The results showed that:

(1) Monthly mean value of PM2.5 concentration in Chang-Zhu-Tan area is below the extremes 75μg/m^3 limited by “Ambient Air Quality Standard” (GB 3095-2012). And the daily mean values are mostly lower than the limited value. So, it showed the air quality was good.

(2) Viewed from the temporal distribution point, the 24-h PM2.5 concentration varied with the two peaks and two valleys styles in Chang-Zhu-Tan area. And the PM2.5 concentration represents the changing trend of “high-low-high” in morning, noon and evening respectively. And the variation trends of the daily mean values of PM2.5 concentration appeared multi-peaks and multi-valleys styles.

(3) Viewed from the spatial distribution point, PM2.5 concentration value of the three cities from high to low was Zhuzhou > Xiangtan > Changsha.

(4) PM2.5 concentration of the central city of Changsha and Xiangtan is higher than that of the suburbs, but the PM2.5 concentration of the central city of Zhuzhou is slightly lower than the suburbs. Meanwhile, the deviation of PM2.5 concentration of Xiangtan is higher than that of Changsha and Zhuzhou.

(5) The meteorological factors have a strong correlation with the PM2.5 concentration variation. Relativity between PM2.5 concentration and meteorological factors from high to low is: relative air humidity > soil temperature > air temperature > soil humidity> wind velocity> rainfall. Among the meteorological factors, wind velocity, rainfall, air temperature, soil temperature and soil humidity are negatively correlated with PM2.5 concentration, but the relationship between relative air humidity and PM2.5 concentration is a positive correlation.

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References

[1] Chang Yanping,Geng Chao,Li Chunlei et al., Current situation analysis and new thinking of PM2.5 in air, Environmental Science & Technology, 35 (2012) 151-154.
[2] Yan Qingqian, Zhao Xue-bin, Yang Li, et al., Comparative experiment of lung injury in rats induced by PM2.5 collected from different cities of China, Journal of Environment and Health, 29 (2012) 7-11+97.
[3] Yang Chunxue, Acute effects of fine particulate matter and ozone on daily mortality in China, Fudan University, 2012.
[4] Shao Min, Haze & PM2.5 World Environment, 1 (2012) 12-13.

IOP Conf. Series: Earth and Environmental Science **108** (2018) 042047 doi:10.1088/1755-1315/108/4/042047

[5] Twomey S, Atmospheric aerosol, Translated by Wang Mingxin, Wang Gengchen, Science Press, 1984.
[6] Li Binlian, Guan Feng, Jiang Jianhua, Analysis of PM2.5 current situation and the prevention control measures, 81 (2012) 54+71.
[7] Yang Hongbin, Zou Xudong, Wang Hongyu, et al., Study progress on PM2.5 in atmospheric environment, Journal of meteorology and environment, 28 (2012) 77-82.
[8] Hu Luhua, Zhang Hong, The capacity of the atmospheric environment in the core area of Changsha-Zhuzhou-Xiangtan agglomeration, Sichuan environment, 28 (2012) 31-35.
[9] Xiao Yan, The air pollution in Chang-Zhu-Tan area and its prevention, Journal of Hunan college of finance and economics, 25 (2009) 94-96.
[10] Sun Zhenquan, Shao Longyi, Huang Yuting, et al., Pollution characteristics of PM10 and PM2.5 in the atmosphere in Beijing, Journal of Beijing vocational & technical institute of industry, 5 (2006) 29-34.
[11] Yu Jianhua, Yu Tong, Wei Qiang, et al., Characteristics of mass concentration variations of PM10 and PM2.5 in Beijing area, Research of environmental sciences, 17 (2004) 45-47.
[12] Tan Ronghua, Zhang Yuanmao, Zheng Yefei, et al., Pollution research on PM2.5 in typical urban resident area in Shanghai, Journal of environmental & occupational medicine, 21 (2004) 226-229.
[13] YANG Chunxue, KAN Haidong, CHEN Renjie, Research on level, composition, source and pollution characteristics of ambient fine particles in China, Journal of environment and health, 28 (2011) 735-738+753.
[14] Zhu Xianlei, Zhang Yuanhang, Zeng Limin, et al., Source Identification of Ambient PM2.5 in Beijing, Research of environmental sciences, 18 (2005) 1-5.
[15] Meng Zhaoyang, Zhang Huaide, Jiang Xiaoming, et al., The characteristics of PM2.5 and its influencing factors during winter and spring in Taiyuan, Journal of the Graduate School of the Chinese Academy of Sciences, 24 (2007) 648-656.
[16] Huang Hong, Zeng Baoqiang, Cao Junji, et al., Level of PM2.5 and affecting factors in higher education mega centre,Guangzhou, Environmental Science & Technology, 32 (2009) 103-106.