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Original Research Paper

The Relation Analysis Between Meteorological Factors and $PM_{2.5}$ in Xi'an

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ABSTRACT

In order to analyse the relationship of the change of $PM_{2.5}$ with each meteorological factor, the $PM_{2.5}$ was collected in eight monitoring sites of Xi'an, and the data of meteorological factors was provided by NOAA. The paper analyses daily changing trend of $PM_{2.5}$, and studies its relevancy with air visibility, air speed, temperature and relative humidity. Results show that $PM_{2.5}$ density has negative correlation with air visibility and speed, good positive correlation with temperature, and when relative humidity is lower than 60%, the relation is positive, while relative humidity is within the range of 61%~100%, the relation is strongly negative. The article provides a reference for fine particulate matter control and its prevention in Xi'an.

INTRODUCTION

$PM_{2.5}$ are fine particles, which refer to the atmospheric particulates whose particle size is smaller than 2.5μm. They are now generally considered to be main cause of affecting the air quality (Fu et al. 2011). As the $PM_{2.5}$ enters easily through the respiration, it deposits in alveolar region and enters the blood circulation. It contains a lot of toxic and harmful substances, so it can cause very serious harm to human beings (Fu et al. 2011). The research in the field of epidemiology in United States and Europe has shown that there is a close relationships between urban air fine particles and pollution level resulting in many adverse health effects (Bao et al. 2010). At the same time, because of their long term suspension in the air, $PM_{2.5}$ is not only affecting air quality and ecological environment, it is also destroying historical artifacts and harm the human health. It is also diffusing and absorbing solar radiation to affect climate directly, and change the optical properties and cloud distribution to affect climate indirectly by the cloud condensation. Currently, the $PM_{2.5}$ mass concentration has become one of the indicators to evaluate air pollution.

The changes of $PM_{2.5}$ concentrations have an extremely close relationship with meteorological conditions (Xu & Jiang 2011). In recent years, overseas and domestic scholars have conducted a number of studies on changes in $PM_{2.5}$ concentration and meteorological conditions. Akpinar & Akpinar (2008) have researched in winter the relationship of air pollutants concentration and meteorological parameter in Turkey. Richmond-Bryant & Kalin (2009) have studied the relationship of $PM_{2.5}$ concentration and traffic etc. on a school around. Deng et al. (2011) have researched the relationship of atmospheric fine particles and the features of related gas pollution in the northeast of Beijing. Li (2011) has analysed the causes for the changes of air quality during 2006-2010. Xu & Jiang (2011), Zhang et al. (2008) and Li & Yang (2011) respectively studied the relationship of pollutants and meteorological factors in Xuzhou, Pingdingshan and Guiyang.

Xi'an is located in the land of China Center and the junction of two major economic regions in central and western China. It is the transportation hub that northwest approach to the cities in southwest, central China, north China and east China. With the accelerated urban process of industrialization in recent years, dumping large amounts of pollutants into the atmosphere is making significant impact on the atmosphere of the city, in which $PM_{2.5}$ is one of the basic pollutants. The study has collected $PM_{2.5}$ concentration at 8 stations in Xi'an from April 20 to August 1, 2013, and in accordance with the meteorological data provided by the National Oceanic and Atmospheric Administration, it has analysed the relationship of fine particulate matter concentration and meteorological factors (visibility, wind speed, temperature, humidity). It provides a reference for the in-depth study and fine particulate air pollution prevention.

DATA ACQUISITION

The sampling area includes Xingqing residential district, textile town, Xiaozhai, Xi'an People's Stadium, Yanliang, Lintong, Caotan and Qujiang cultural industry groups. It contains the business district, residential areas, industrial zones, and the leisure activities. The area was sampled every two-hour by United States Kaimidi K168 automatic monitoring instrument. Table 1 shows the average daily values for $PM_{2.5}$.

ANALYSIS RESULTS

Daily variation characteristics of $PM_{2.5}$ in each monitoring site: During sampling period, putting April 26, April 28, May 27 and June 5 as typical days, variation trend of $PM_{2.5}$ at each monitoring site in a day is shown in Figs. 1, 2, 3 and 4. Seen from the figures, the variation trend of $PM_{2.5}$ concentration in a day is basically same, rising from 06:00, achieving the highest value of the day at 10:00. From 14:00 to 20:00, the change is relatively flat and remaining at the same level, in which, a trough will appear about 17:00, and rising again from 20:00, with a peak occurring at 23:00.

Overall, concentration of $PM_{2.5}$ in Xi'an at each monitoring site is basically rendered obvious bimodal dual vale. The period from 06:00 to 08:00 is peak for work, school and transport, which estimated that peak traffic may cause pollution increase, coupled with the impact of industrial activities , so at 10:00, $PM_{2.5}$ emissions will reach a peak. While the temperature at noon and afternoon is higher, solar radiation is stronger; the atmosphere is in a relatively unstable state, the vertical turbulent exchange and diffusion ability is also stronger, so $PM_{2.5}$ decreased. When the evening is coming, wind speed is high, the lower atmosphere is the most unstable within a day, air purification ability is strong, which is good for the spread and migration of $PM_{2.5}$, and therefore, there will be a trough around 17:00. At night, the atmosphere is relatively stable, pollutants are not easy to diffuse, particulate matter will gradually accumulate and $PM_{2.5}$ concentration will increase in the atmosphere near the ground, so the second peak occurs around 23:00. At midnight, human activities reduce, suspended particles also reduce, and therefore $PM_{2.5}$ concentration will increase again.

Canonical correlation analysis of $PM_{2.5}$ and comprehensive meteorological factors: Typically, both, the sources of pollution and meteorological factors will affect the concentration of $PM_{2.5}$ values. In certain circumstances of pollution, climate conditions will determine the mass concentration of $PM_{2.5}$. Putting wind speed, temperature and relative humidity as typical meteorological factors, we analysed the comprehensive relationship of $PM_{2.5}$ concentrations and these three meteorological conditions by canonical correlation analysis

The variable *Var* represents the daily mean $PM_{2.5}$ concentration value subtracts the value at 0:00, variable *Zva* represents daily $PM_{2.5}$ concentration value at 0:00, *Spd* represent daily mean wind speed, *Temp* represents the mean daily temperature, and *Rhx* represents the daily average relative humidity. Attaining the correlation coefficient of variables *Zva, Spd, Temp and Rhx* by using the canonical correlation analysis method, the results are given in Table 2.

By analysing the comprehensive correlation of the change of *Var* and *Zva, Spd, Temp, Rhx*, the correlation coefficient is given in Table 3.

By this method, when the constant vector is [-7.96 0.11 0.91 1.02], the correlation coefficient of linear combination reach a maximum value of 0.78, that is to say, the correlation coefficient of *Var* and -7.96 * *Zva* + 0.11 * *Spd* + 0.91 * *Temp* +1.024 * *Rhx* is 0.78.

The results showed that there is a close relationship between the changes of $PM_{2.5}$ concentration and synthetic conditions of wind speed, temperature and relative humidity.

Analysis of the relationship of $PM_{2.5}$ concentrations and each meteorological factor: There is a close relationship between air pollutant concentration and meteorological conditions. The relevance of $PM_{2.5}$ concentration values and meteorological factors is good, in which, it has negative correlation with visibility and wind speed, and positive correlation with temperature, when humidity is lower than 60% the correlation is positive, or the correlation is negative. The

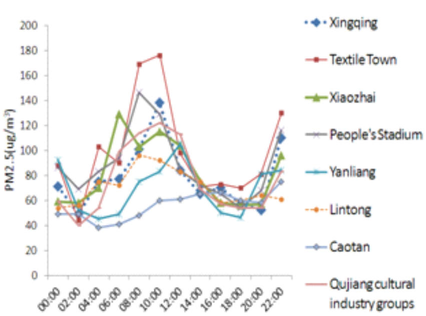

Fig.1: The variation trend chart of $PM_{2.5}$ on April 26.

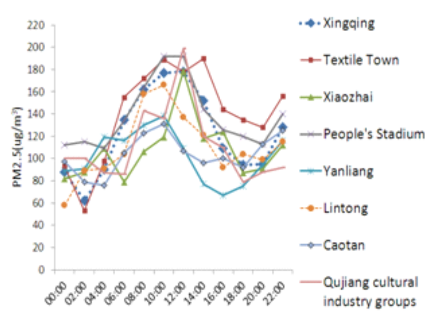

Fig. 2: The variation trend chart of$PM_{2.5}$ on April 28.

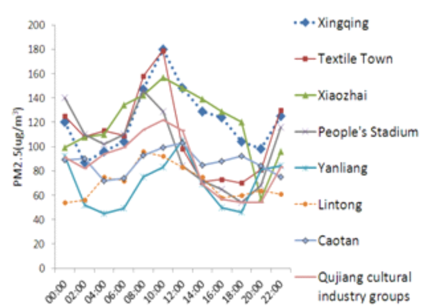

Fig. 3: The variation trend chart of $PM_{2.5}$ on May 27.

Table 1: The average daily values of $PM_{2.5}$.

Date	$PM_{2.5}$ ($\mu g/m^3$)	Date	$PM_{2.5}$ ($\mu g/m^3$)	Date	$PM_{2.5}$ ($\mu g/m^3$)	Date	$PM_{2.5}$ ($\mu g/m^3$)
Apr 20	64	Apr 21	111	Apr 22	156	Apr 23	155
Apr 24	135	Apr 25	113	Apr 26	78	Apr 27	104
Apr 28	85	Apr 29	77	Apr 30	42	May 1	37
May 2	45	May 3	57	May 4	61	May 5	68
May 6	47	May 7	46	May 8	21	May 9	42
May 10	50	May 11	60	May 12	73	May 13	57
May 14	50	May 15	27	May 16	33	May 17	39
May 18	64	May 19	70	May 20	83	May 20	71
May 21	59	May 22	57	May 23	56	May 24	51
May 25	34	May 26	49	May 27	43	May 28	15
May 29	29	May 30	31	June 1	37	June 2	54
June 3	42	June 4	37	June 5	42	June 6	37
June 7	30	June 8	69	June 9	8	June 10	19
June 11	20	June 12	32	June 13	22	June 14	37
June 15	51	June 16	60	June 17	67	June 18	75
June 19	133	June 20	78	June 21	11	June 22	20
June 23	52	June 24	63	June 25	41	June 26	28
June 27	33	June 28	30	June 29	25	June 30	35
July 1	41	July 2	42	July 3	52	July 4	35
July 5	31	July 6	69	July 7	74	July 8	50
July 9	21	July 10	11	July 11	20	July 12	55
July 13	38	July 14	89	July 15	86	July 16	25
July 17	50	July 18	31	July 19	42	July 20	50
July 21	93	July 22	41	July 23	44	July 24	98
July 25	120	July 26	74	July 27	51	July 28	23
July 29	15	July 30	39	July 31	60	August 1	35

Table 2: The correlation coefficient between variables.

	Zva	Spd	Temp	Rhx
Zva	1.00	0.22	0.29	-0.36
Spd	0.22	1.00	0.52	-0.37
Temp	0.29	0.52	1.00	-0.89
Rhx	-0.36	-0.37	-0.89	1.00

Table 3: The comprehensive correlation of Var and Zva, Spd, Temp, Rhx.

	Zva	Spd	Temp	Rhx
Var	0.67	0.05	-0.07	0.31

Table 4: The correlation of each meteorological factor and $PM_{2.5}$ density (sample size n = 104).

	$PM_{2.5}$	Visiby	Spd	Temp	Rhx
PM2.5	1				
visiby	-0.64	1			
Spd	-0.68	0.30	1		
Temp	0.49	-0.37	-0.42	1	
Rhx	-0.20	-0.69	-0.35	0.86	1

correlation coefficients are given in Table 4.

The relationship between Xi'an $PM_{2.5}$ pollution index, and visibility, wind speed, temperature and relative humidity using Xi'an daily observation data of pollution index and meteorological data provided by NOAA is given in Figs. 5, 6, 7, 8 respectively.

Fig. 5 shows that the visibility is low when $PM_{2.5}$ pollution index is high, while visibility is high when $PM_{2.5}$ pollution index is low, so there is an opposite relationship between Xi'an $PM_{2.5}$ pollution index and visibility.

Fig. 6 shows the relationship between Xi'an $PM_{2.5}$ and wind speed. It can be seen clearly that the relationship is negatively correlated. The two functions of wind speed for pollutant diffusion are transmission and dilution. First, turbulent development determines the diffusion of pollutants in the atmosphere, turbulent mixing status also determines the change of the wind, and the wind will transfer the atmospheric pollutants to other regions. With the increase of wind speed, movement speed of pollutants also increases, and the pollutants will be further transferred per unit time, so the pollutant concentration will be lower. Second, in the process of the wind blow away the pollutants, pollutants are constantly mix and get diluted with the surrounding air. When the wind speed is high, mixed capacity is strong, so air quality is good. When the wind speed is down, the horizontal transmission capacity and diffusion ability is poor, so that the pollutant concentration is increased.

As shown in Fig. 7, $PM_{2.5}$ concentrations and temperatures show the same changing trend. High temperature often corresponds to the sunny weather condition, the pressure is relatively high, and under the action of high pressure, the air sinks and suppresses turbulence upward development, thus $PM_{2.5}$ concentrations will rise. While low temperature generally corresponds to the rainy day and low atmospheric pressure, and the air will be moving up, if wind speed high again, the atmosphere is more neutral or unstable, which is good for the spread of pollutants. In addition, the rainfall is the main cause of the temperature decrease, with the occurrence of rainfall, the temperature is reduced. The rain has a profound effect on the removal of the particles, so the particle concentration also decreases.

The relationship between Xi'an air humidity and $PM_{2.5}$ concentration is shown in Fig. 8. As can be seen from it, when the relative humidity is lower than 60%, the correlation is positive. On analysing the causes, the increase of air humidity makes pollutants easy to strand, which lead to increase in pollutant concentration. When the air humidity increased to 61% and continue gradually increasing, $PM_{2.5}$ pollution index has gradually declined. This is because high

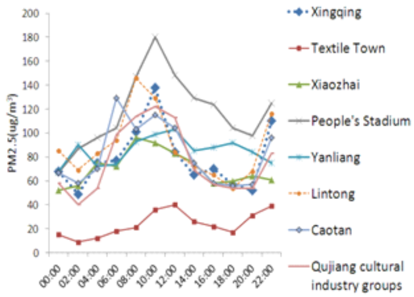

Fig. 4: The variation trend chart of $PM_{2.5}$ on June 5.

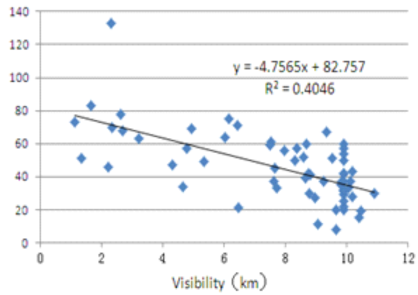

Fig. 5: The correlation between $PM_{2.5}$ pollution index and visibility.

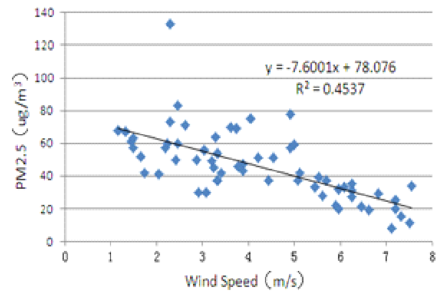

Fig. 6: The correlation between $PM_{2.5}$ pollution index and wind speed.

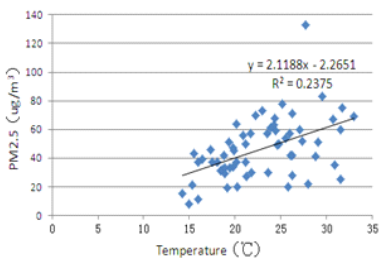

Fig. 7: The correlation between $PM_{2.5}$ pollution index and temperature.

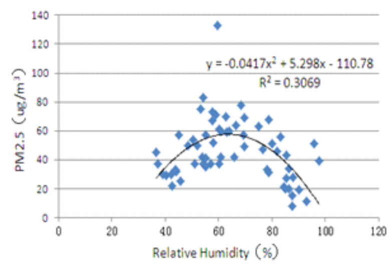

Fig. 8: The correlation between $PM_{2.5}$ pollution index and relative humidity.

humidity condition is usually accompanied by rainfall and after rain, the concentration of pollutants will be greatly reduced with washing by rain.

CONCLUSIONS

The diurnal variation of the $PM_{2.5}$ shows double peak and double trough with peaks occurring at 10:00 and 23:00.

The spread of $PM_{2.5}$ depends on a combination of various meteorological factors. Canonical correlation analysis showed that there is a close relationship between the changes of $PM_{2.5}$ concentration and the conditions of wind speed, temperature and relative humidity. $PM_{2.5}$ density has negative correlation with air visibility and speed and good positive correlation with temperature. However, when relative humidity is lower than 60%, the relation is positive, while relative humidity is within the range of 61%~100%, the relation is strongly negative.

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