CHEMICAL ENGINEERING TRANSACTIONS

VOL. 66, 2018

A publication of AIDIC

The Italian Association
of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Songying Zhao, Yougang Sun, Ye Zhou

ISBN 978-88-95608-63-1; **ISSN** 2283-9216

DOI: 10.3303/CET1866092

Spatial-temporal Change of PM2.5 in Z City and Influencing Factors Analysis

Pengfei Zhang, Ming Yu*, Yu Tian, Yue Yang, Minfei Shi, Wenlong Li

School of Information and Computer Engineering, Haerbin Northeast Forestry University, Harerbin 150040, China
zhangpengfei@nefu.edu.cn

In this paper, 24-hour real-time monitoring data of 17 state-controlled monitoring stations in Z City of year 2016, including air quality and meteorological data, are used to analyze the spatial-temporal change trend of PM2.5 in Z City and its influencing factors. The results showed that: 1)a, the average annual concentration of PM2.5 in Z city was 51.31 □g·m-3, winter (68.5 □g/m3) > autumn (54.25 □g/m3) > spring (35.68 □g/m3) > summer (47.54 □g/m3), and winter has the highest degree of differentiation; b, on a monthly basis, the monthly histogram at each monitoring station showed a "U" type distribution; c, on a daily basis, the annual trend of PM2.5 concentration appears triple-peak and double-valley sawtooth-shaped fluctuation. 2) PM2.5 was positively correlated with CO, NO_2, SO_2, PM10 and was negatively correlated with O_3. 3) PM2.5 was negatively correlated with temperature, humidity, rainfall, wind speed, and was positively correlated with the air pressure.

1. Introduction

In recent years, the problem of air pollution has become increasingly prominent. Its main component is fine particulate matter (PM2.5), and Tang (2016) has reported that long-term inhalation of air containing higher concentrations of particulate matter can cause damage to the respiratory and cardiovascular systems of the human body. The harm of air pollutants to the human health cannot be ignored and it is of great significance to study the source, aggregation and proliferation of PM2.5. Liu et al. (2016) showed that the concentration of PM 2.5 in Z city was obviously non-uniformly distributed in time series. Jiang et al. (2016) pointed out that PM 2.5 pollution in Z city was the most significant in winter, which is closely related to average low wind speed near the ground, higher frequency of static small winds, and less and weaker rainfall; Li et al. (2016) think that atmospheric pollutants are related to meteorological elements and are affected by meteorological elements in different months; Based on the analysis of the above scholars, this paper makes a comprehensive analysis of the air quality status of Z city in 2016, studies in-depth on the spatial-temporal change trend of PM2.5 in Z city and further analyzes its influencing factors, thus providing some theoretical support for urban air pollution prevention and control.

2. Materials and Methods

2.1 Data source

The meteorological data and air quality data of this paper are from ******** (WEB ******), which summarizes the 24-hour real-time data of a complete year of 2016 in Z City, PM2.5 and the concentration of each factor in the time series mean are obtained. If missing data in a day is more than 8h, then this day’s data is deleted; whereas or abnormal value (> 2σ) occurs, then use interpolation method to supplement. There are 7% data missing in total, and we use Office 2010 to conduct data processing analysis.

2.2 Regional Overview

Z City is located in southwestern China, belonging to the edge of the basin mountains. It has a tropical humid monsoon climate of central Asia, hot in summer and warm in winter, with a long frost-free period; annual

Please cite this article as: Zhang P., Yu M., Tian Y., Yang Y., Shi M., Li W., 2018, Spatial-temporal change of pm2.5 in z city and influencing factors analysis, Chemical Engineering Transactions, 66, 547-552 DOI:10.3303/CET1866092

rainfall is of 1000 mm or more; cloudy and mist in winter, has less sunshine hours and frequent temperature inversion led to weak winds on the surface ground, once air pollutants gathered it is difficult to spread.

3. Results and analysis

3.1 PM2.5 concentration time series changes

(1) PM2.5 concentration seasonal changes

As Table 1, the quality of air in Z City was generally good in 2016 with an annual compliance rate of 79.80 %. Table 2 and Figure 2 show the PM2.5 concentrations: winter> autumn> spring>summer, each season the mean concentration value reaches GB Secondary air quality standards (75 mg/m^3); In all monitoring stations, the winter PM2.5 concentration reaches a highest level of 81μg/m³, and a lowest level of 56.71μg/m³ (excluding the control point), the summer PM2.5 concentration reaches a highest level of 42.04μg/m³, and a lowest level of 29.29 mg/m^3, we can see that, the highest concentration in summer is lower than the lowest in winter. Yang et al. (2017) think that the degree of spatial differentiation is the highest in winter and the lowest in summer, it's because the unstable weather conditions in spring and summer has weakened the impact of regional geography on the environmental pollution in some areas; at the same time, the concentration of fine particles affected by the regional topography is more obvious [5], thus causing the accumulation of pollutants in Z City.

Table 1: Z City air quality profile

year	Air quality condition					
	excellent	good	mild	moderate	serious	severe
2016	101d	191d	59d	11d	4d	0d
2016	27.72%	52.08%	16.10%	2.98%	1.12%	0.00%

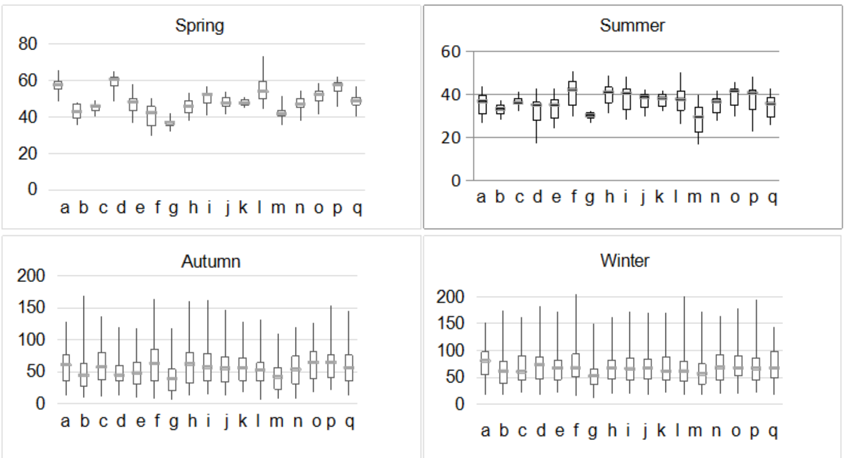

Figure 1: 2016 Z City PM2.5 concentration seasonal box-plot

Table 2: Z City PM2.5 average concentrations of each season and September

season/month	Spring	Summer	Autumn	Winter	Sep	year
average(mg/m^3)	47.54	35.68	54.25	68.95	69.52	51.31

(2) PM2.5 concentration monthly changes

As Figure 2, the concentration of PM2.5 in Z City shows monthly "U" type distribution, and the concentration of PM2.5 in each area reaches the highest in February, September and December (abnormal: huge upsurge occurs in September and even reaches the highest average of the whole year, which is related to the month rainfall degree and the special weather). The lowest value usually occurs in July and the difference between the monthly average of each monitoring station is twice as much, this may be due to the unstable summer meteorological conditions that are easier for the diffusion and sedimentation of the fine particles, meanwhile, Wang et al. (2016) showed that the increase of vegetation coverage made the spring and summer concentrations relatively low.

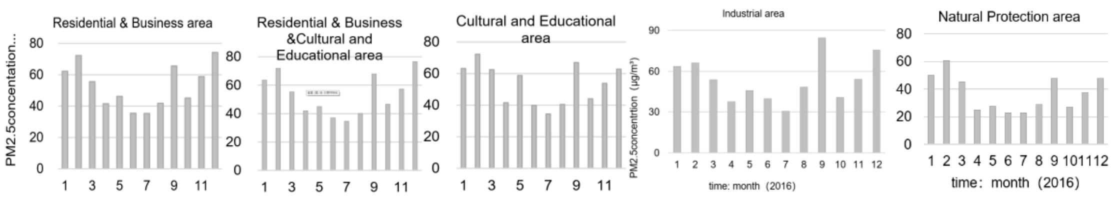

Figure 2: Monthly average concentration of PM2.5 in Z City in 2016

(3) PM2.5 concentration daily changes

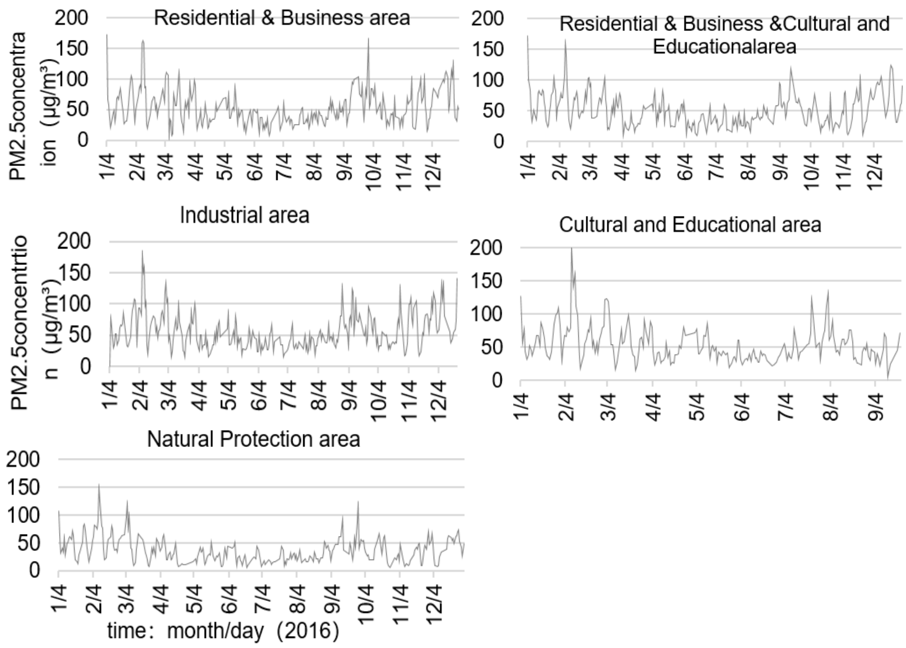

Figure 3: 2016 Z City PM2.5 concentration daily changes

Select five representative areas to represent the overall state of Z City, from Figure 3, we can see that there is a lot of volatility in the PM2.5 concentration values throughout the year, the daily overall curve showed a sawtooth shape with triple peaks, and the peak values generally occurred in February, September and December, and the peak and valley values varied widely. Except for the nature reserves, all the peaks in all regions exceeded twice the GB secondary air quality standard (75 mg/m^3), in most of the year, the PM2.5 concentrations fluctuate around 50 mg/m^3, and the air pollution index is in good condition for a long time.

3.2 The correlation of PM2.5 and air quality factors

Table 3: PM2.5 and the air pollutants correlation coefficient

correlation coefficient	AQI	PM10	CO	NO_2	O_3(1hour)	O_3(8hour)	SO_2
Annual average	0.992	0.957	0.578	0.619	-0.226	-0.210	0.567
Spring average	0.981	0.952	0.561	0.749	-0.036	-0.021	0.578
Summer average	0.933	0.906	0.509	0.395	0.190	0.175	-0.004
Autumn average	0.998	0.966	0.501	0.498	0.427	0.423	0.491
Winter average	0.998	0.977	0.496	0.624	0.038	0.044	0.496

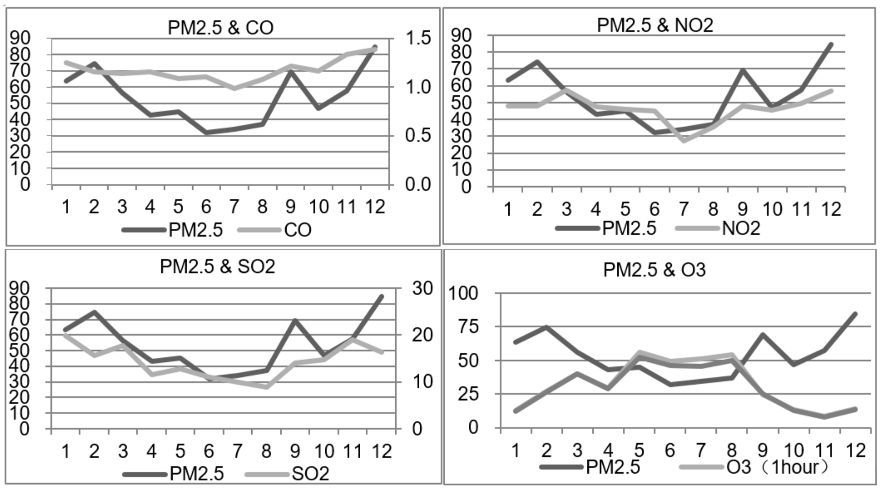

Figure 4: Comparison of PM2.5 and the monthly air pollutant concentration changes

From the correlation coefficient Table 3 and the trend of each factor Figure 4, it can be seen that the correlation coefficients between PM2.5 and CO, NO2 and SO2 are all greater than 0.5 and have a strong correlation. Among them, PM2.5 had the strongest correlation with NO_2, and had obvious seasonal characteristics, high in spring and winter, low in summer and autumn; the concentrations of SO_2 and PM2.5 tended to be the same; the effect of CO on PM2.5 was stable and not much; however, the correlation between O_3 and PM2.5 is weak. The formation principle of the two compounds is quite complicated, and they are mutually inhibitory factors during the reaction, showing a negative correlation as a whole.

3.3 The correlation of PM2.5 and air pollutants

(1) The correlation of PM2.5 with the and rainfall, and relative humidity
From Table 4 and Figure 5, we can see that the PM2.5 is generally negative correlated with the rainfall and the relative humidity. As Table 4, the correlation coefficient between the rainfall and the PM2.5 is greater than 0.5, which is a strong correlation. As water vapor can combine with PM2.5 to form sedimentation, PM2.5 plays a role of scrubbing. However, the negative correlation between the humidity and PM2.5 is very weak and the fluctuation range is relatively small. Since the city of Z belongs to the subtropical humid monsoon climate, the annual air is relatively humid and the humidity is very stable with no major fluctuations.
(2) The correlation of PM2.5 and temperature
As Table 4 and Figure 5, there is a clear negative correlation between temperature and PM2.5. The higher temperature will make the atmosphere more active, and the vertical rise of the atmosphere will accelerate the spread of PM2.5. Therefore, the average concentration of PM2.5 will be lower in the spring, summer and early autumn when the temperature is higher. In late autumn and winter, the temperature is low, prone to thermal inversion phenomenon, the surface wind is very weak, pollutants gathered on the surface, so that the average concentration of PM2.5 is higher.
(3) The correlation of PM2.5 and air pressure
As Table 4 and Figure 5, there is a significant positive correlation between air pressure and PM2.5 concentration. In the relationship chart between the two, the effect of air pressure on PM2.5 mainly depends on the precipitation. When the air pressure is low, the air flow rises, the rainfall increases, the water vapor in the air combines with the PM2.5 particles to form a sedimentation, thus reducing the concentration of PM2.5. When the air pressure is higher, the atmospheric structure is stable, thus reducing the scattering speed of PM2.5.

Table 4: PM2.5 and weather factors monthly average correlation coefficient table

	wind speed	Rainfall	temperature	humidity	atmospheric pressure
Full year	-0.407	-0.626	-0.815	0.349	0.888
Spring	0.761	-0.629	-0.721	-0.891	0.922
Summer	-0.971	-0.520	0.521	-0.428	0.363
Autumn	0.176	0.989	0.270	-0.321	-0.258
Winter	-0.739	-0.928	-0.817	0.923	0.757

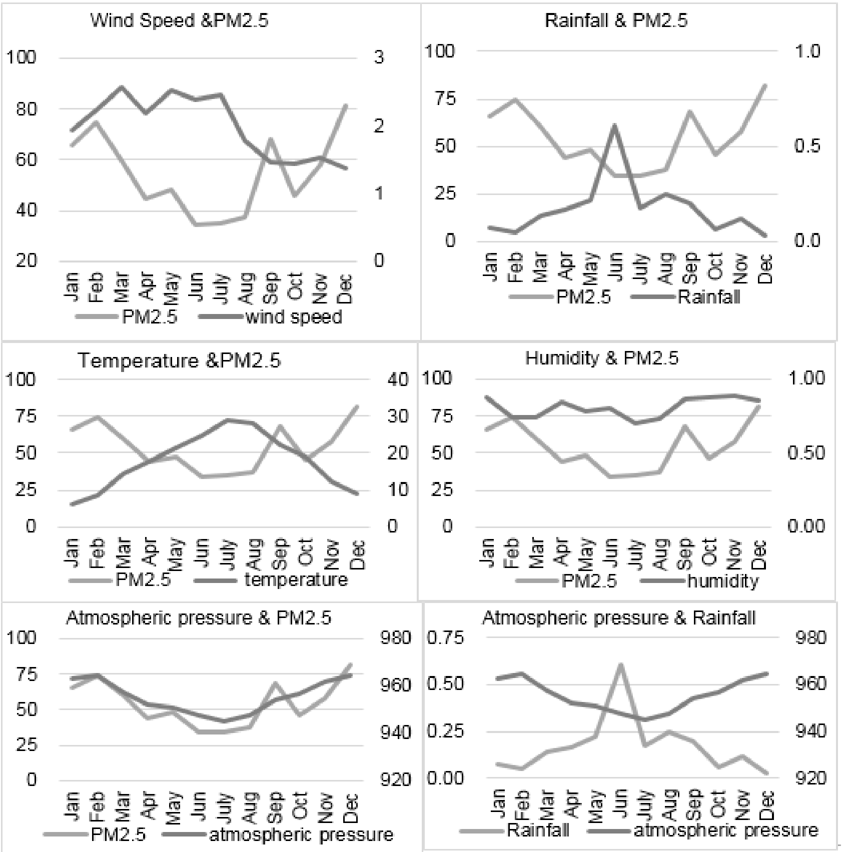

Figure 5: Monthly mean concentration of PM2.5 and meteorological factor changes

(4) The correlation of PM2.5 with wind direction, and wind speed

As Table 5, about 87 % of the time in the year, Z City is in the state of static winds and light breeze, the average annual wind speed reaches 1.97 m/s, available from Figure 5, PM2.5 and wind speed was negatively correlated, due to low wind speed grade, and special geography position, the showing correlation is not obvious;

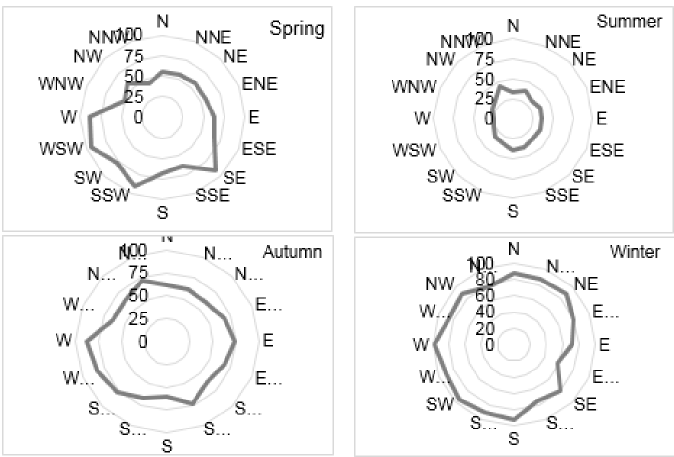

Figure 6: PM2.5 concentration rose diagram in all seasons in 2016

As Figure 6, the wind direction with the highest concentration of PM2.5 in spring, autumn and winter was WSW, NNW and W, respectively. The PM2.5 concentration in the summer wind directions is the lowest and without major fluctuations. Overall, in the range of S~W, the concentration of PM2.5 is the highest. Except summer, the PM2.5 concentration in these wind directions is 80~100 mg/m^3 in each season. The effect of wind direction on the pollution is mainly manifested in the horizontal wind transport of pollutants [13] The special mountainous terrain of the city is not conducive to the circulation of wind in the southwest, so that the degree of diffusion and transfer of PM2.5 is small and the concentration is high.

Table 5: Annual wind speed and frequency

Wind speed (m/s)	Count	Ave
≤1.5	2970	0.95
1.5~3.3	3993	2.13
3.4~5.4	845	4.06
5.5~7.9	115	6.3

4. Conclusion and discussion

This paper analyzes the change of PM2.5 concentration in Z City in spatial-temporal changes, studies its changing rules and the correlation with the influencing factors, and obtains following conclusions:

PM2.5 has certain regularity in time series change. According to the season, the difference between autumn and winter was higher than that in spring and summer, and the concentrations were: winter> autumn> spring> summer; the mean value of summer maximum concentration was lower than that of the lowest average in winter;

According to the monthly observation, the monthly histogram at each monitoring station showed "U" type distribution. The highest PM2.5 concentration appeared in February, September and December and the lowest was in July, but a sudden increase occurred in September which is related to the climate change; and the difference between the extremes of the monthly average of monitoring stations is twice as much;

The overall daily curve was sawtooth-shaped with triple-peaks, all peak values of the monitoring stations exceeded twice the GB secondary air quality standard (75 mg/m^3), however, during most time of the year, the PM2.5 concentration fluctuates around 50 mg/m^3.

There was a significant positive correlation between PM2.5 and CO, NO_2, SO_2 and PM10, and PM2.5 is negatively correlated with O_3. In the precursors which formed the PM2.5, except for PM10, NO_2 has the greatest impact on PM2.5 and the NO_2 concentration shows obvious seasonal variations of high in winter and low in summer.

PM2.5 is negatively correlated with temperature, humidity, rainfall and wind speed, and is positively correlated with air pressure. When wind direction is in the range of S~W, the concentration of PM2.5 is the highest, except for summer, the concentration of the other winds in all seasons are in the 80~100mg/m^3.

Acknowledgements

This work was supported by the National College Students Innovation and entrepreneurship training program (201710225136).

Reference

Jiang W.H., Chen D.J., 2016, Analysis of air quality and meteorological conditions in Chongqing city in 2015, Sichuan Environment, 35(3), 90-92, DOI: 10.14034/j.cnki.schj.2016.03.017.

Li, Q., Ji L., Ma J., He S., Zhang S., Si, Y.Y., 2016, Correlation analysis of atmospheric pollutants and meteorological elements in Beibei district, Chongqing, Journal of Southwest china Normal University, 41(8), 64-72, DOI: 10.13718/j.cnki.xsxb.2016.08.012.

Liu, Y.L., Sun, Q.M., Zhong, M.Y., Zhong, N.Q., Luo, K.L., 2016, The spatial and temporal distribution characteristics of PM2.5 in downtown Chongqing, Environmental science, 37(4), 1219-1229, DOI: 10.13227/j.hjkx.2016.04.005.

Tang, J.Y., 2016, Study on the pollution of atmospheric particulates in the main urban area of Chongqing and the impact on children's respiratory system, Chongqing Medical University, Master's thesis.

Wang Y.R., Zhao J.Y., Jang, Q.O., 2016, Study on the relationship between the PM and vegetation coverage in Beijing area in 2013 and 2014, Ecology and Environmental Science, 25(1), 103-111, DOI: 10.16258/j.cnki.1674-5906.2016.01.015.

Yang W.T., Yao S.Q., Deng M., Wang Y.J., 2017, Spatial and temporal variation characteristics of PM2.5 in Beijing and its relationship with PM10, China Environmental Science, 22(6), 506-510. DOI: 10.13227//j.hjkx.201703222.