

Analysis on the Temporal and Spatial Characteristics of Air Quality in the Main Urban Area of Jinan City

Qian Gao, Qiang Zhao, Chunhui Zou and Dan Xiong

School of Water Conservancy and Environment, University of Jinan, Jinan 250022, China

Qiang Zhao, zhaoqiang8827@sina.com

Abstract. According to the monitoring data of air pollutants in Jinan City and Jinan Statistical Yearbook from 2005 to 2016, the space-time variation characteristics of mean concentration were analyzed. Although the overall air pollution in Jinan City was relatively serious, there was a generally lowering tendency in recent years. Firstly, the average concentration of SO₂ increased from 2005 to 2016, and then decreased, with the maximum concentration of 93ug/m³ appearing in 2013. The average concentration of PM₁₀ showed a slow decline during 2005-2012. At the turning point in 2013, the average concentration increased suddenly, reaching a maximum of 191ug/m³. As far as NO₂ is concerned, its annual change trend is analogous to that of SO₂. The average monthly concentration presented a serious seasonal variation, with severe pollution in winter and light pollution in summer. Secondly, on the part of the spatial distribution, the concentration of pollutants in the central and northern parts of the main urban area of Jinan was higher, while that in the south was lower. Last but not least, correlation analysis shows that there is a significant negative correlation between SO₂, PM₁₀, NO₂ and temperature. The maximum correlation coefficient is -0.868, and the correlation is strong. PM₁₀ is positively correlated with atmospheric pressure, with a correlation coefficient of 0.701, which is negatively correlated with relative humidity and precipitation.

1. Introduction

With the rapid development of China's economy, the air quality is under enormous pressure [1]. Atmospheric particles especially inhalable particles and fine particles play a significant role in the quality of atmospheric environment [2-3]. Air pollution not only leads to increasingly serious environmental pollution in cities, but also further exacerbates the harm to human health and ecological balance [4]. Nowadays, air quality is increasingly a focal point of concern for citizens. Since 2000, many scholars have taken up research into PM₁₀ pollution status, health assessment, source analysis, transboundary pollution [5-7] and other achievements, but most of researches focus on the single pollution factor in the air. There are few studies on multiple air pollution factors. This article quantitatively analyzed the air quality in the main urban area of Jinan City through the scaling exponents and air pollution index. Only by understanding the current status of environmental quality and clearly identifying the influences, can we propose a creative solution on environmental governance.

2. Study area overview and data sources

Jinan City is located in the middle of Shandong Province, between 36° 01' ~37° 32' N and 116° 11' ~117° 44' E[8]. The space structure of Jinan is “one city and two districts”, representing the



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

main urban area and the western and eastern urban areas respectively. The main urban area is located in east of Yufu River, west of the highway east ring, and between the Yellow River and the southern mountainous area [9]. It is determined as the four districts of Huaiyin, Lixia, Tianqiao and Shizhong. The air quality indicators for this study were inhalable particles (PM_{10}), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). The monitoring points for these three indicators were located in the main urban area of Jinan City (Figure 1). The data of pollutant concentration and meteorological for 2005-2016 were gained from the China Meteorological Data Network and Statistics Bureau of Jinan City.

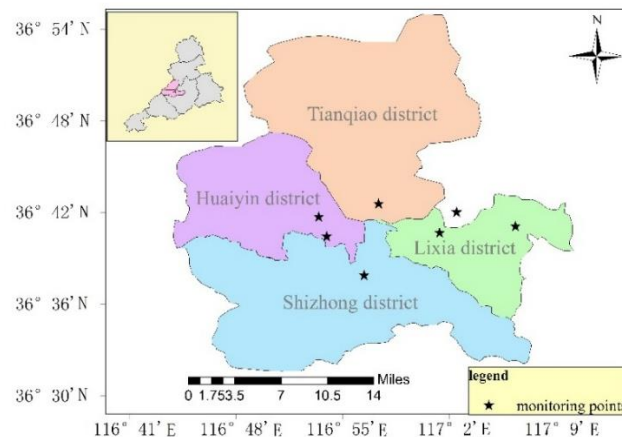


Figure 1. The distribution map of the monitoring points in the main city of Jinan

3. Research Methods

Pearson correlation is used in correlation analysis. Its value range is -1 to 1, and the greater the absolute value, the stronger the correlation, conversely, the closer the correlation coefficient is to 0, the weaker the correlation. Consequently, it is applicable to the correlation analysis of meteorological data and has a significant correlation. The specific formula is as follows:

$$\rho_{X,Y} = \frac{cov(X,Y)}{\sigma_X \sigma_Y} = \frac{E((X - \mu_X)(Y - \mu_Y))}{\sigma_X \sigma_Y} = \frac{E(XY) - E(X)E(Y)}{\sqrt{E(X^2) - E^2(X)}\sqrt{E(Y^2) - E^2(Y)}} \quad (1)$$

Where E is the mathematical expectation; COV represents covariance; X and Y are the corresponding elements, and this paper is the concentration of atmospheric pollutants and meteorological data respectively.

4. Analysis of Time Distribution Characteristics of Air Pollutants

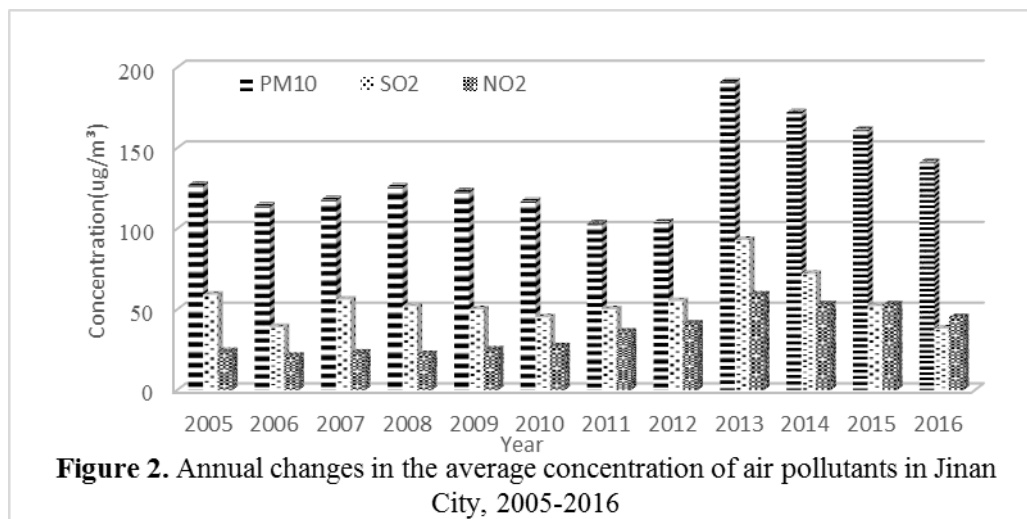
4.1. Analysis of inter-annual variability in major pollutants

By analyzing the concentration of pollutants, an interannual variations of the main urban area of Jinan City was obtained (Figure 2). From 2005 to 2016, the SO_2 concentration increased first and then decreased. The concentration presented an increasing trend before 2013, and showed a decreasing trend after 2013. In 2016, the minimum concentration reached $38\mu g/m^3$. The largest increase occurred in 2013, reaching the maximum concentration of $93\mu g/m^3$ within 11 years.

On the whole, the PM_{10} concentration showed a slow downward trend from 2005 to 2012, reaching a minimum annual average concentration of $104\mu g/m^3$. However, in 2013, the annual average concentration suddenly increased to a maximum of $191\mu g/m^3$, and then decreased gradually in 2014-2016.

The analysis of NO_2 showed that the average annual concentrations had no pronounced changes, and the tendency of change was similar to that of SO_2 . The minimum and maximum concentrations appeared in 2006 and 2013 separately.

In general, the annual PM_{10} pollution level was relatively high, both exceeding the national secondary standard of $100\mu g/m^3$, especially in 2013, the concentration reached $191\mu g/m^3$. The

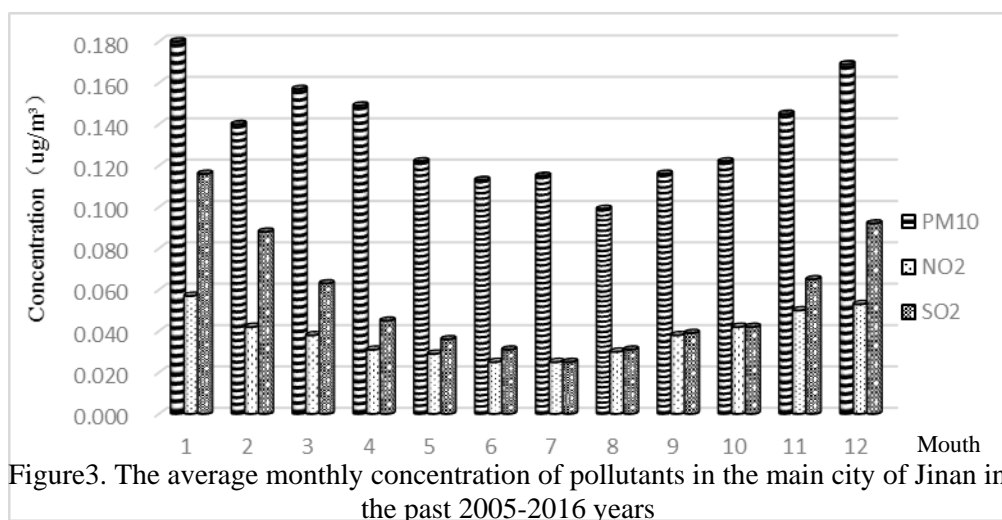


concentration of SO_2 in the period from 2005 to 2016 was generally volatile, showing a trend of increasing first and then decreasing. NO_2 pollution in 2005-2016 has no obvious variations. Through analysis, PM_{10} was the main pollutant in Jinan City, and NO_2 pollution was lighter.

4.2. Analysis of inter-monthly variation of major pollutants

Results from monthly analysis revealed that concentration of SO_2 peaked in January, exceeding the national secondary standard of $60 \mu g/m^3$ (Figure 3). By contrast, the trend of SO_2 from January to July was gradually decreased. After August, SO_2 pollution began to gradually increase. The pollution of SO_2 was relatively serious during the heating period, while the summer pollution with light precipitation was light.

From the perspective of various indicators, the pollution of PM_{10} was relatively serious. In November of each year to April of the following year, the pollution was relatively severe, and in the 5-10 months of each year, the pollution was lighter. The extremes of concentration occurred in January and August. According to the change data of NO_2 in the period from 2005 to 2016, it can be seen that NO_2 pollution was relatively light, and the trend of change was the same as that of SO_2 .



5. Spatial distribution characteristics of atmospheric pollutants in Jinan

This paper opts the air quality of the last three years as the object, using the ARCGIS software from the inverse distance weighting method for the concentration of SO_2 ($\mu\text{g}/\text{m}^3$), PM_{10} ($\mu\text{g}/\text{m}^3$) and NO_2 ($\mu\text{g}/\text{m}^3$) to analyze spatial interpolation and spatial distribution research of Jinan urban area atmospheric pollutants. The pollution of SO_2 showed an increasing distribution from south to north (Figure 4). A maximum area was formed in the north with a concentration of more than $120\mu\text{g}/\text{m}^3$, which was closely related to the topography. The SO_2 concentration decreased overall in 2014-2016, and the change in the central urban area of Jinan City was more obvious.

In spatial analysis, PM_{10} had serious pollution in the northwest and relatively low pollution in the southeast. There was a maximal center in the middle and the difference between the maximum values was 1.7 times. This spatial differentiation might be the consequence of both wind direction and topographic effects (Figure 5). Interannual changes showed that the concentration of PM_{10} decreased year by year, the area where the maximum occurred shifts from the middle to the north, and the pollution in the west has improved.

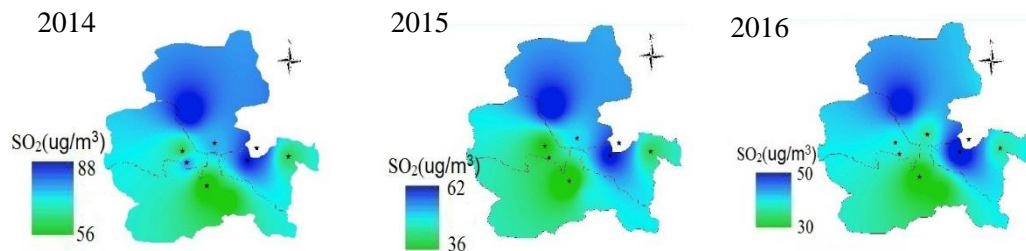


Figure 4. The spatial distribution of SO_2 in the main city of Jinan for 2014-2016 years

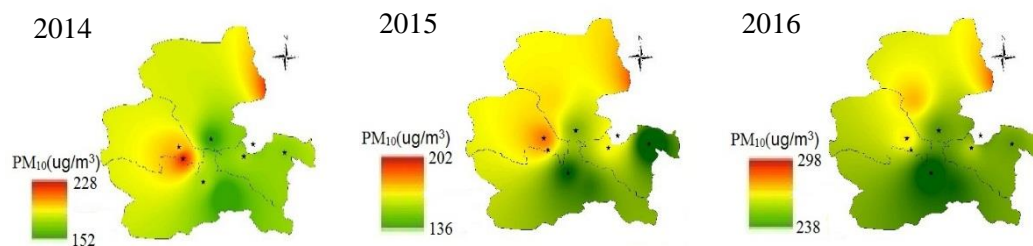


Figure 5. The spatial distribution of PM_{10} in the main city of Jinan for 2014-2016 years

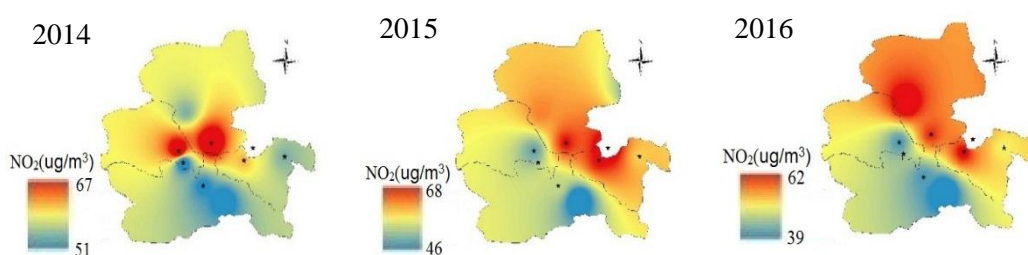


Figure 6. The spatial distribution of NO_2 in the main city of Jinan for 2014-2016 years

The concentration of NO_2 exceeded the secondary standard of ambient air quality of $40\mu\text{g}/\text{m}^3$. Within three years, the concentrations were not much different, but the transfer occurred in areas with severe pollution. In 2014, it appeared in the central part of the study area, and in 2015 it changed to the northeast, and 2016 turned to the north (Figure 6). The appearance of this situation might be related to industrial production.

In general, the pollution in the southern part of Jinan City was light, while the pollution in the north and central parts was serious. From 2014 to 2016, the concentration of pollutants has been significantly reduced, and the environmental quality has improved.

6. Correlation Analysis of Air Pollutants and Meteorological Factors in Main Urban Area of Jinan City

Through Pearson correlation coefficient analysis, the correlation between atmospheric pollutants and meteorological factors in the main urban area of Jinan City was obtained. The results are shown in Table 1. The table shows that SO₂ and NO₂ have a significant correlation ($p < 0.01$ or $p < 0.05$) with the average temperature, the maximum temperature, and the minimum temperature, with the largest correlation coefficient being -0.748. However, there is a significant correlation between PM₁₀ and air pressure, average temperature, maximum temperature, minimum temperature, relative humidity, and maximum precipitation ($p < 0.01$ or $p < 0.05$). The largest correlation coefficient was -0.868.

Table 1. Analysis of atmospheric pollutants and meteorological factors in the main city of Jinan

	Atmospheric pressure	Average temperature	Maximum temperature	Minimum temperature	Relative humidity	Maximum precipitation
PM ₁₀	0.701*	-0.867**	-0.866**	-0.868**	-0.605*	-0.738**
SO ₂	0.612	-0.748**	-0.743**	-0.748**	-0.468	-0.569
NO ₂	0.622	-0.721**	-0.716**	-0.721**	-0.430	-0.545

*, $p < 0.05$ **; $p < 0.01$

Average temperature, maximum temperature, minimum temperature and three pollutants are negative correlation, and the correlation of PM₁₀ is strongest, maintaining near 0.86, shows that with the increase of the temperature, the concentration of PM₁₀ presents downward trend. The relationship between NO₂ and SO₂ is also negatively correlated with temperature, and the correlation coefficient is near -0.7. Temperature is the dominant meteorological factor on affecting air pollutants. The concentration of PM₁₀ is positively correlated with air pressure and negatively correlated with precipitation and relative humidity. The relation between PM₁₀ and relative humidity is consistent with the conclusion of Tan [12], while NO₂ and SO₂ have no significant correlation with these meteorological factors.

7. Conclusions

This paper analyzed the temporal and spatial characteristics of major pollutants SO₂, NO₂ and PM₁₀ in the main urban area of Jinan City. Based on the data collected from 2005 to 2016, we can conclude that:

(1) PM₁₀ pollution was relatively serious throughout the year and was the main pollutant in Jinan City.

(2) In 2005-2016, the average concentration of SO₂ in the main urban area of Jinan City increased first and then decreased, with the maximum concentration of 93ug/m³ occurring in 2013. The average concentration of PM₁₀ showed a slow downward trend in 2005-2012. In 2012, it reached an annual average concentration of 104ug/m³, which suddenly increased after 2013, reaching a maximum of 191ug/m³. The average annual concentration of NO₂ was similar, and the inter-annual variation was similar to that of SO₂.

(3) The monthly variation of atmospheric pollutant concentration in the main urban area of Jinan city has obvious seasonal characteristics. In winter, the pollution was the most serious, especially in January, the most serious pollution was in the summer, and the pollution was lighter in summer.

(4) In recent years, air pollutants in Jinan had obvious spatial and temporal variation characteristics. The concentrations of pollutants in the south were relatively low, while the concentrations in the central and northern parts were relatively high. The concentration in 2014-2016 years had been reduced to varying degrees.

(5) SO₂, PM₁₀ and NO₂ have a significant negative correlation with the highest temperature, minimum temperature and average temperature, and the maximum correlation coefficient was -0.868. PM₁₀ was positively correlated with air pressure, with a correlation coefficient of 0.701, but negatively correlated with relative humidity and precipitation.

Acknowledgments

This study was financially supported by the Natural Science Foundation of China (NO.41471160)

References

- [1]Wang S X, Zhao B, Cai S Y, Klimont Z and C Nielsen 2014 Emission trends and mitigation options for air pollutants in East Asia *Atmos. Chem. Phys.* **14** 13 pp 2601-74.
- [2]Ren Z, Wan B, Su F, Gao Q and Zhang Z 2004 *Research of Environmental Sciences* **17** 1 pp 1-6.
- [3]Zhao Y, Pan Y, Zhang H, Guo J, Wei Q and Shi J 2004 Analysis of the current pollution status of inhalable particulate matter in Beijing *Research of Environmental Sciences* **17** 1 pp 67-69.
- [4]Lewis A C 2001 Public health and air pollution: The Lancet *Lancet* **357** 9249 p70.
- [5]Biancofiore F, Busilacchio M, Verdecchia M, Tomassetti B and Aruffo E 2017 Recursive neural network model for analysis and forecast of PM₁₀ and PM_{2.5} *Atmos. Pollut. Res.* **8** 4 pp 652-9.
- [6]Shi G, Tian, Y, Ma T, Song D and Zhou L 2017 Size distribution, directional source contributions and pollution status of PM from Chengdu, China during a long-term sampling campaign *J Environ. Sci-China* **56** 6 pp 1-11.
- [7]Shi G, Wang J, Fu F and Xue W 2017 A study on transboundary air pollution based on a game theory model: cases of SO₂, emission reductions in the cities of Changsha, Zhuzhou and Xiangtan in China *Atmos. Pollut. Res.* **8** 2 pp 244-52.
- [8]Jinan 2010 *Statistical Bureau Jinan Statistical Yearbook*. 2010 (China Statistics Press)
- [9]Anonymous 2016 Jinan will form the spatial structure of "one city and two areas" *Going to the world* 39 p15.
- [10]Sun Y, Zhou X and Wang W. 2016 Aerosol size distributions during haze episodes in winter in Jinan, China *Particuology* **28** 5 pp 77-85.
- [11]He J, Gong S, Yu Y, Yu L, Wu L and Mao H 2017 *Environ. Pollut.* **223** pp 484-96.
- [12]Wang Z and Qin P 2014 Practice and countermeasures of pollution reduction in Yingkou City network model for analysis and forecast of PM₁₀ and PM_{2.5} *Atmos. Pollut. Res.* **8** 4 pp 652-9.