

Analysis of urban air quality and pollutant changes in Shandong Province from 2015 to 2019

Zhihao Cui^{1,*}, Meijuan Liu¹, Lichen Xue¹, Yang Sun²

¹Shandong GEO-Surveying & Mapping Institute, Jinan, China

²No.8 Institute of Geology and Mineral Resources Exploration of Shandong Province, Rizhao, China

*Corresponding author

Keywords: Air quality; Air pollutants; Time series analysis

Abstract: In this paper, the heavily polluted cities of Jinan, Zibo, Dongying and Linyi in Shandong Province were taken as the study area. Based on the daily air quality and pollutant concentration data from 2015 to 2019, the change of air quality and pollutant concentration in the study area was analyzed from four time scales of year, month, working day and day by time series analysis, combined with meteorological, industrial and other influencing factors. The analysis showed that: (1) With the implementation of the blue Sky Defense plan in 2018, the air quality in the study area was significantly improved, and the decrease of SO₂, PM_{2.5} and CO was the largest, the percentage reduction was 41.5%, 62.36%, 39.35%; (2): Monthly variation: it shows a "W" -shaped variation, with severe pollution in winter and light pollution in early autumn; (3) Working days and rest days show an "S" -shaped change, with Tuesday as the pollution trough and Saturday as the pollution peak; (4) A "convex" type of fluctuation was observed, with the heaviest pollution in the middle of the month and lighter pollution in the beginning and end of the month.

1. Introduction

Since the reform and opening up in 1978, with the continuous development of industrialization, China's economy has developed rapidly. In 2010, China successfully surpassed Japan to become the world's second largest economy, and people's living standards have improved significantly. With the rapid economic development, environmental problems have become increasingly apparent. A large number of studies worldwide have found that air pollution can have a negative impact on people with chronic cardiovascular and respiratory diseases, and can promote the development of these diseases in healthy people. Air pollution has become the fifth major risk factor for human health 下方^{[1][2]}, at the same time, chemical enterprises have always been an important factor in air pollution. Therefore, The State Council issued the three-year Action Plan for Winning the Blue Sky Defense War^[3], To improve air quality by significantly reducing the total amount of air pollutants discharged.

In recent years, with air pollution into the public view, the study of air quality and air pollutants is increasing day by day. Wang Angyang et al. (2015) analyzed the air quality data of ten major cities in the Yangtze River Delta from 2004 to 2012, and found that although the air quality improved year by year under the influence of the policy, it was still seriously polluted in autumn and winter, and Nanjing

was the most seriously polluted city among the ten cities in the Yangtze River Delta^[4]. Wang Guanlan et al. (2016) studied the daily air quality data of 13 cities in the Beijing-Tianjin area in 2014 and found that the air in the northern part of the region was significantly better than that in the southern part of the region in 2014, and the pollution was the most serious in winter. Beijing and Hebei Province were dominated by vehicle exhaust emissions and coal burning emissions respectively, while Tianjin was dominated by industrial sulfur dioxide emissions and coal burning^{[5][6]}. Mu Jingfeng et al. (2018) found that the air quality of Shenzhen in summer was better than that in winter by using the data of 19 monitoring stations in Shenzhen from 2014 to 2016, and conducted autocorrelation analysis of the 10 administrative districts of Shenzhen by Moran index, and found that there was obvious autocorrelation of AQI values among administrative districts during the study period^[7]. Zeng Ni et al. (2019) analyzed the hourly air quality data and meteorological data of Anshun City from 2015 to 2018 and concluded that precipitation and relative humidity had a certain promotion effect on reducing air pollution, and the wind direction also affected the quality of air quality. The north wind caused pollution in the home, and the south wind reduced pollution. More cloud cover, atmospheric stability is not conducive to the diffusion of pollutants, leading to the accumulation of pollutants in a certain area, aggravating pollution^[8]. However, most of the existing studies focus on the first-tier cities with better development, while there are few studies on the second - and third-tier smaller cities. As the main component of China's urban development at the present stage, it is of great significance for the Chinese government to define the air quality and the change characteristics of the concentration of various pollutants in small and medium-sized cities and the influencing factors of air quality.

2. Study area and data sources

2.1. Overview of the study area

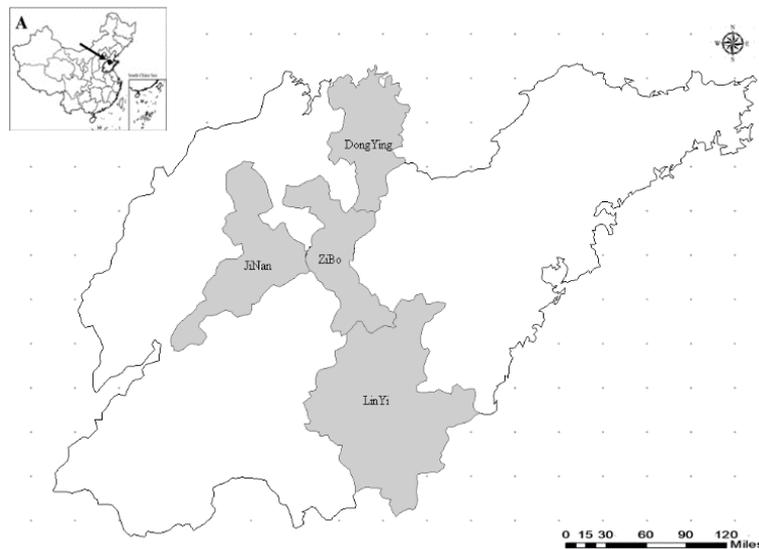


Figure 1: Location of the study area.

Jinan is located in 36°40' N, 117°00' E, located in the central south of Shandong low mountains and alluvium plain in the northwest of Shandong junction zone, the terrain is high in the south and low in the north. Zibo City is located between 35°55'20" N - 37°17'14" N, 117°32'15" E - 118°31'00" E. Linyi is located in the southeast of Shandong Province. It is located between 34°22' N - 36°13' N, 117°24' E - 119°11' E. Dongying City is located in the Yellow River Delta region of northern Shandong Province, with a geographical location of 36°55' N - 38°10' N, 118°07' E - 119°10' E (Figure

1). In terms of climate, they are all warm temperate continental monsoon climate, characterized by cold winter and hot summer, four distinct seasons, and more rainfall in summer. Temperate continental monsoon climate, the climate is characterized by cold winter and hot summer, four distinct seasons, more rainfall in summer.

From the Ministry of Ecology and Environment issued "the Bulletin on the Status of China's Ecological Environment in 2019", Jinan, Dongying, Linyi, Zibo are located in the air quality is relatively poor 20 cities, greatly affecting the daily life of residents, clear Jinan and other cities air quality and pollutants time change characteristics to become an imminent problem.

2.2. Data Sources

The data used in this study are daily air quality and pollutant concentration data from 2015 to 2019, which are sourced from the PM2.5 historical data website (<https://www.aqistudy.cn/historydata/>). According to the research needs, Excel and Node.JS are used to preprocess daily degree data to obtain annual, quarterly, monthly, working rest day and daily degree data, the acquired data are visualized and time series analysis is used to analyze the law of air quality change.

3. Analysis of research results

3.1. Annual Change

The analysis of annual AQI and air pollutant concentrations in the study area from 2015 to 2019 (Figure 2) showed that except for the small variation of O₃ concentration, AQI, PM_{2.5}, PM₁₀, SO₂ and NO₂ concentrations all showed a "V" -shaped change. Before 2018, the pollution peaked in 2015, and with the advance of time, the concentration of each pollutant gradually decreased, and the air quality improved significantly. In 2018, the pollution trough was reached, and the air quality was at the optimal level. Compared with the pollution peak in 2015, the concentrations of all air pollutants had decreased greatly, among which SO₂, PM_{2.5} and CO had the largest reduction, with the reduction percentages of 41.5%, 62.36% and 39.35%. The reasons are as follows: Waste gas of chemical enterprises is an important cause of air pollution. Waste gas emitted by chemical enterprises contains a large amount of SO₂, CO, dust and other air pollution gases. Since the promulation of the "Blue Sky Defense War" plan, municipal governments at all levels in Shandong Province have attached great importance to it and responded positively. Measures such as "transformation of ultra-low emissions of coal-fired units (boilers)" and "comprehensive remediation of volatile organic compounds in key industries and regions" have been taken to strictly control the waste gas emissions of chemical enterprises, and strict standards for the concentration of various pollutants in the waste gas emissions, so as to achieve low pollution and low emission of waste gas and effectively improve air quality.

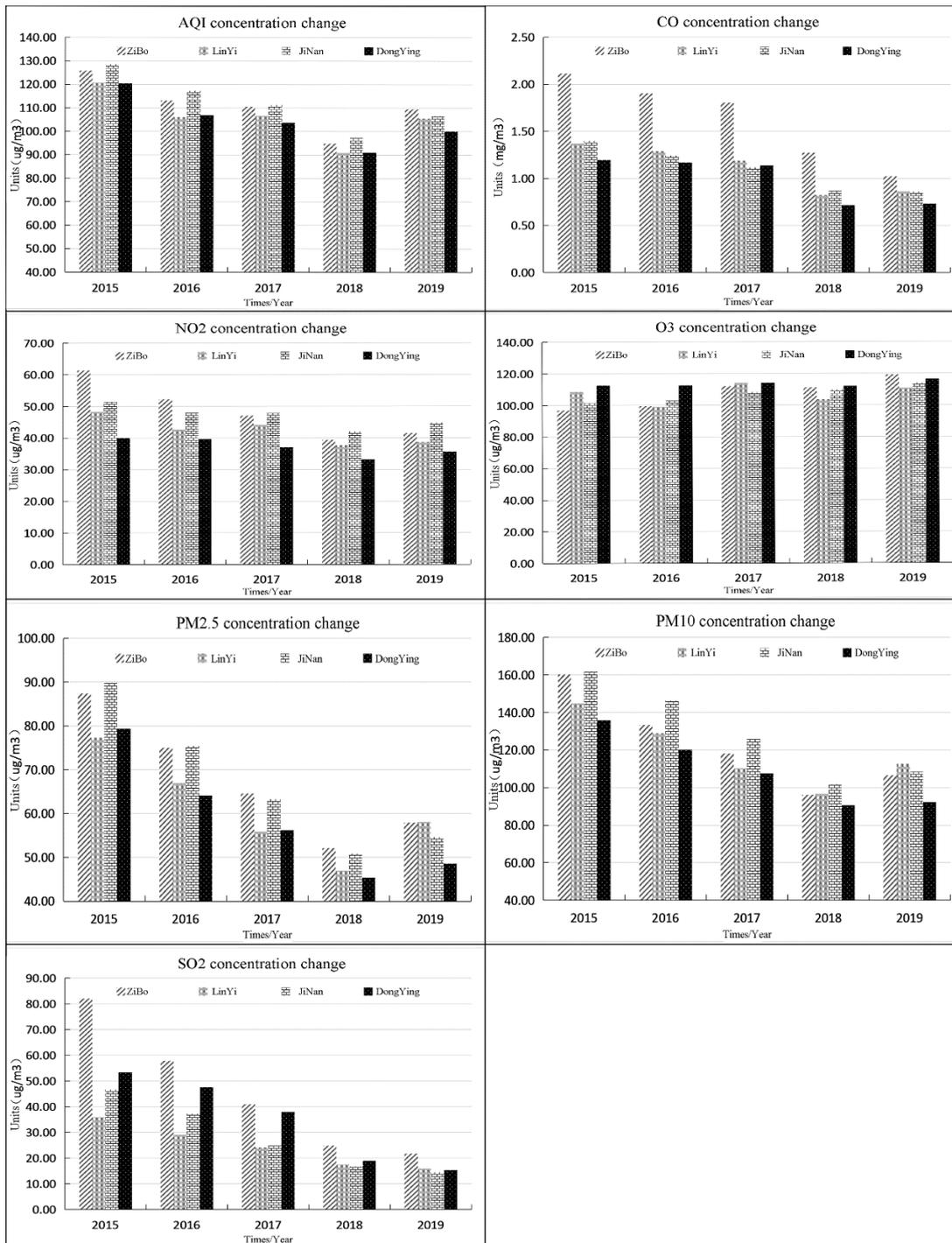


Figure 2: Annual variation of AQI concentration and atmospheric pollutant.

3.2. Monthly Change

Analyzing the change of AQI concentration in the study area from January to December (Figure 3), it can be seen that the monthly change trend of Jinan, Zibo, Linyi, and Zibo is consistent, all of which are "W" type changes. There are "double peaks and double valleys". Winter (November-January) and summer (June) are the peak periods of pollution. April and August are the lightest months of pollution. As spring approaches, pollution decreases, and as winter approaches, pollution

worsens. At the same time, December and January are the most severe months of pollution in the year. This phenomenon is mainly due to: winter chemical enterprises at the end of the year to increase production, Spring Festival car exhaust emissions, heating coal burning increase will release a large number of polluting gases, at the same time, low temperature and lack of rain, resulting in long-term pollutants in the atmosphere sharply, difficult to spread. With the coming of spring, the increase of precipitation and vegetation greening are conducive to the dilution and diffusion of pollutants. In June and July, the peak of summer vacation for students, the increase of human flow, the short and sharp rise of exhaust emissions from private cars, and the pollution is aggravated. This is consistent with the study of Wang Pengfei ^[9] et al., which shows that pollution increases in winter and decreases in spring and autumn. Winter (November-January) and summer (June) are the peak period of pollution, April and August are the lightest months of pollution, with the coming of spring pollution is reduced, with the coming of winter pollution is aggravated, and December and January are the most serious months of pollution.

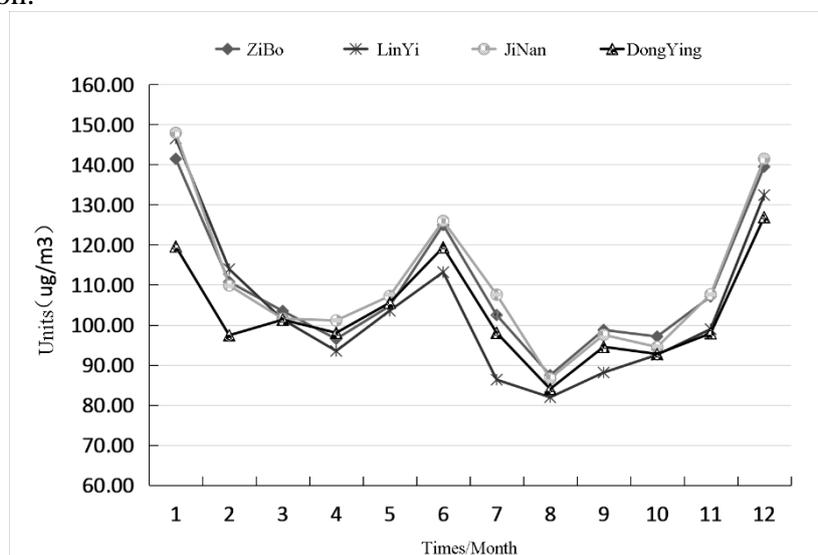


Figure 3: Monthly change of AQI concentration.

3.3. Workday, rest day Change

By analyzing the variation of AQI concentration on working days and rest days in the study area (Figure 3), it can be seen that the monthly variation trend of the four cities of Jinan, Zibo, Linyi and Zibo is consistent, and all of them are inverted "S". The AQI concentration from Monday to Friday is significantly lower than the AQI concentration on the weekend, and the bottom of the AQI concentration in the four cities is Tuesday, the AQI concentration fluctuates from Wednesday to Saturday, and the pollution peak of the week is reached on Saturday. At this time, the AQI concentration in all cities is between 100 and 120. According to the AQI concentration standard, the air quality reaches the light pollution level at this time, the AQI concentration decreased on Sunday. Reasons: (1) The environmental protection supervision of municipal units is mostly on Mondays or Thursdays. At this time, the AQI concentration of factories decreases on Tuesdays and Fridays in order to avoid random inspection by environmental protection departments and reduce exhaust emissions. During the weekend, the environmental protection department has more holidays, and the number of spot checks is very few. Some non-compliance enterprises choose to process and produce on the weekend, increasing waste gas emissions and increasing pollution. (2) Saturday is the first day of rest, and residents go out to play more, and population activities aggravate air pollution, as shown in Figure 4.

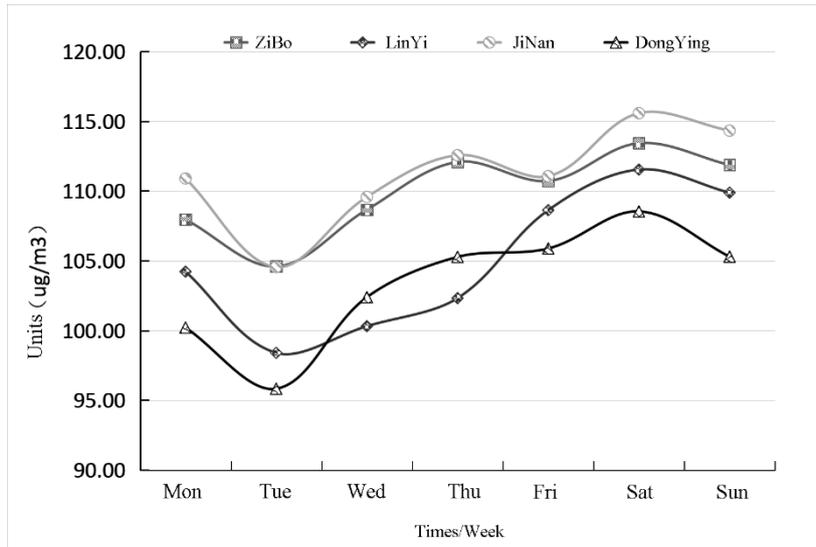


Figure 4: Changes of AQI concentration on working days and rest days.

3.4. Daily Change

By analyzing the change of daily AQI concentration in the study area (Figure 5), it is found that the change of daily AQI concentration in all cities in the study area shows a "convex" change of fluctuation, from the beginning of the month, the AQI concentration fluctuated and decreased. After reaching the middle of the month, the AQI concentration fluctuated and increased, and reached the pollution peak around the 20th day. After the 20th day, the AQI concentration gradually decreased. This is mainly related to the sampling time of the environmental protection department. The environmental protection monitoring time is mostly the sampling inspection at the beginning and end of the month, and the inspection intensity is relatively low during the month. In order to avoid environmental spot checks, most heavily polluting enterprises arrange production plans based on environmental monitoring time, reducing the work plans at the beginning and end of the month, and increasing the tasks in the middle of the month, resulting in a sharp increase in exhaust emissions in the middle of the month, exacerbating pollution in the middle of the month.

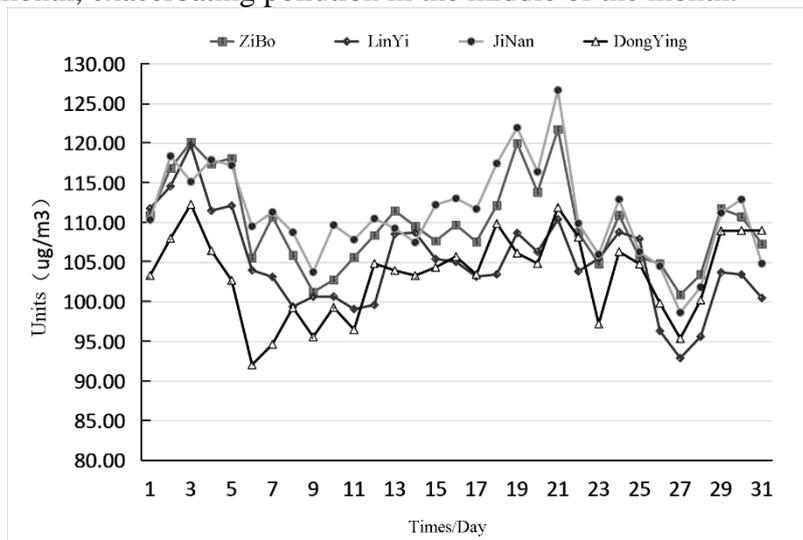


Figure 5: Daily variation of AQI concentration.

4. Conclusions

This article is based on daily air quality and pollutant concentration in 2015-2019, using time series analysis method, to jinan, zibo, linyi in shandong province, dongying four polluted city air quality and pollutant concentration changes were analyzed, and get the following conclusion:

(1) The implementation of the "Blue Sky Battle" plan has effectively reduced the concentration of various atmospheric pollutants and significantly improved the air environment. It shows that it is feasible and effective for the government to control air pollution by formulating corresponding measures and intervening forcefully.

(2) AQI concentration presents a "W" shaped change. In a year, air pollution is the most serious in winter. In June and July, affected by students' holidays, pollution will also rise briefly, pollution is relatively light in spring and autumn, which is related to temperature, precipitation, vegetation and other factors.

(3) "The pollution on rest days is heavier than that on weekdays, with a " S "shaped change. Tuesday is the lowest point of pollution, and Saturday is the highest point of pollution. The average AQI concentration reaches 100-120, indicating a slight pollution state." The reason for the analysis is that enterprises increase their exhaust emissions on weekends, and residents go out to play, resulting in an increase in vehicle exhaust emissions.

(4) The daily AQI concentration fluctuates in a "convex" shape, with the most severe pollution in the middle of the month, and the lighter pollution at the beginning and end of the month.

This study analyzes the temporal variation of air quality in important cities in Shandong Province, and finds that chemical enterprises are discharging waste gas without environmental monitoring. It is recommended that the environmental protection departments of each city increase the intensity of enterprise random inspection and increase the randomness of environmental sampling time to effectively prevent enterprises from illegally discharging waste gas.

References

- [1] Zhang J Y. Discussion on the effect of air pollution on human health [J]. *Jiangxi Chemical Industry*, 2018, (04): 141-142.
- [2] He B Q. What is the impact of air pollution on human health? [N]. *China Environmental News*, 2012-04-24(002).
- [3] The State Council. Notice of The State Council on Printing and Distributing the Three-year Action Plan for Winning the Blue Sky Defense War [Z]. 2018.07.30.
- [4] Wang A Y, Pan Y, Tong Y B. Study on spatiotemporal distribution characteristics of air pollution in major cities in the Yangtze River Delta [J]. *Environmental Protection Science*, 2015, 41 (05): 131-136.
- [5] Wang G L, Xue J J, Zhang J Z. Spatial and temporal distribution characteristics and main causes of air pollution in the Beijing-Tianjin-Hebei region in 2014 [J]. *Meteorological and Environmental Sciences*, 2016, 39(01):34-42.
- [6] Zhang J J, Sun J, Wang G L, et al. Spatial and temporal distribution characteristics of air quality index and its relationship with meteorological conditions in Beijing area [J]. *Meteorological and Environmental Sciences*, 2014, 37(01): 33-39.
- [7] Mu J F, Zhao X, Fan J J, et al. Spatial and temporal distribution characteristics of air pollution in Shenzhen from 2014 to 2016 [J]. *Health Research*, 2018, 47(02):270-276.
- [8] Zeng N, Wu Z H, Fang P, et al. Analysis on the relationship between air quality characteristics and meteorological conditions in Anshun City [J]. *Environmental Science Guide*, 2019, 38(06):38-43.
- [9] Wang P F. Analysis of spatial and temporal distribution characteristics and influencing factors of air quality in Chinese typical cities [D]. Lanzhou University, 2019.