A research on the seasonal difference of air pollution in Chengdu

Chenwei Ma¹ and Lijin Ding

School of Public Administration, Sichuan University, Chengdu, Sichuan, 610065, China

¹Email: cxm782@163.com

Abstract. With the rapid development of Chengdu's economy, the problem of air pollution has gradually drawn attention by scholars. Based on the time series data covers 2014 through 2019 of Chengdu, this research investigates the seasonal difference in air pollution and the possible influence of six pollutants on air pollution. The results indicated that there is a significant seasonal difference of air pollution in Chengdu and air pollutants are mainly fine particulate matter and ozone. Based on the findings, the government might consider achieve precise emission reductions for the pollution sources of PM2.5 and O3.

1. Introduction

In the past ten years, China has been in a period of rapid economic growth and rapid urbanization. The rapid development of economy has greatly improved people's material living standards. But at the same time, it has also exacerbated air pollution to some extent. As the city that has ranked first in China's Happiest Cities for 11 consecutive years, Chengdu has five aspects of happiness: life, security, liveability, development and harmony. According to data from the Chengdu Statistical Yearbook, Chengdu’s resident population in 2017 was 16.05 million, private cars were 3.982 million, the entire society consumed 57 billion kWh, and the comprehensive energy consumption standard coal of industrial enterprises above designated size was 13.176 million tons. The above four indicators have increased by 12.24%, 75.34%, 28.09% and 37.91% respectively compared with five years ago. Due to factors such as increasing population, vehicles, industrial enterprises and energy consumption, Chengdu has experienced severe regional air pollution many times. Combined with Chengdu's unique two-sided mountain topography, Chengdu's winter haze is very serious. This is reminiscent of the foggy city of London in the 1970s. In each winter from 2014 to 2017, Chengdu's air quality index (AQI) exceeded standards severely. Severe air pollution is not conducive to the establishment of a liveable city and the land of abundance in Chengdu, nor is it conducive to enhancing the people's sense of gain and happiness, and it is even more detrimental to the people's health.

With the progress of society and economic development, the concept of green development and green governance has become more and more popular. People's awareness of environmental protection is growing, and the need to improve the atmospheric environment is becoming stronger. The Nineteenth National Congress of the Communist Party of China further pointed out that "We must realize that lucid waters and lush mountains are invaluable assets and act on this understanding, implement our fundamental national policy of conserving resources and protecting the environment, and cherish the environment as we cherish our own lives. (http://www.xinhuanet.com/english/download/Xi_Jinping's_report_at_19th_CPC_National_Congress.pdf)."
Therefore, solving the air pollution problem is not only a livelihood project to improve people's sense of gain and improve people's health, but also an important way to promote sustainable development and implement basic national policies. Based on the above, this paper focuses on the case study of Chengdu, the happiest city, hoping to analyze the air pollution status and the seasonal difference in Chengdu to accurately identify the characteristics of air pollution changes, so as to provide basis for controlling air pollution in Chengdu and make Chengdu more attractive.

2. Literature reviews and research hypotheses

For a long time, air pollution index (API) has played a role in monitoring and measuring air pollution, filling a gap in my country where there is no quantitative index to measure air pollution. However, with the changes in air pollution, API has become increasingly unsuitable for practical needs, so it is gradually replaced by AQI. Air quality index (AQI) is a dimensionless index used to quantitatively describe the status of air quality. Table 1 shows the classification of AQI. When \( \text{AQI} \leq 100 \), air pollution has little effect on people. When \( \text{AQI} \geq 101 \), air pollution is unhealthy for people. In general, a larger AQI numerical value means more serious air pollution.

| AQI numerical value | AQI levels of health concern               |
|---------------------|------------------------------------------|
| 0-50                | Good                                     |
| 51-100              | Moderate                                 |
| 101-150             | Unhealthy for Sensitive Groups           |
| 151-200             | Unhealthy                                |
| 201-300             | Very Unhealthy                           |
| 300-500             | Hazardous                                |

Both API and AQI combine air pollutants into a single dimensionless index and use it as the basis for air quality classification to indicate the degree of air pollution. The biggest difference between the two indexes is the different pollutant items involved. API contains inhalable particulate matter (PM10), sulphur dioxide (SO2) and nitrogen dioxide (NO2). While on the basis of API, AQI incorporates fine particulate matter (PM2.5), ozone (O3) and carbon monoxide (CO). Especially when PM2.5 and O3 are becoming important air pollutants, AQI more accurately reflects the air pollution than API. Through comprehensive consideration, AQI is taken as an indicator to measure air pollution in this paper.

In terms of the seasonal difference, Wang Bin et al used cluster analysis to divide cities into three types: north, east and south. Among them, the eastern and southern cities are affected by factors such as monsoon and precipitation, which have produced obvious the seasonal difference [1]. Li Xiangyang et al studied the nine typical cities in the north and the frequent sand and dust storms in spring are important factors affecting the air quality of the northern cities in spring [2]. Li Wenjie et al analyzed the data from 2001 to 2010 and pointed out that Beijing, Tianjin and Hebei have the best air quality in summer and the worst in winter and spring [3].

Zhang Jianzhong et al found that the air pollution in January was heavier than in February, and the AQI numerical value in southern Beijing was even more than 201 in January. They also pointed out that humidity and barometric pressure have a significant correlation with AQI [4]. Jiang Lei et al used AQI as an indicator to measure air pollution, and their research showed that the increase in SO2 emissions and PM2.5 concentration will exacerbate air pollution [5]. Li Yunzhen et al found that the main source of AQI is particulate matter through their research on the relationship between AQI and haze. They also found that the average visibility in Chengdu is poor in autumn and winter [6]. Thus, this research puts forth the following research hypothesis:

H1: There is a seasonal difference in air pollution in Chengdu.

In terms of air pollutants. Wang Shulan et al found that the sources of PM10 in total suspended particulate in Chengdu are mainly fossil energy combustion, catering industry emissions, metallurgical
construction industry emissions and natural dust [7]. Zhang Caiyan et al also studied the source of particulate matter in Chengdu through the CMB model. They used winter particulate matter as the research object. Their results indicate that the main sources of PM2.5 are secondary pollutants, dust, coal dust and motor vehicle exhaust dust, and the ratio of PM2.5 to PM10 has increased year by year from 2010 to 2012. Based on this, they speculated that the type of pollution in Chengdu has shifted from primary pollutants to secondary pollutants [8]. Wu Kai et al found that the ozone pollution in Chengdu was becoming increasingly serious and the average annual O3 concentration was increasing [9]. Thus, this research puts forth the following research hypothesis:

H2: The air pollutants in Chengdu are mainly fine particulate matter and ozone.

3. Data
The China Air Quality Index has been included in the statistics since 2013. Therefore, air quality index and the six pollutant indexes of Chengdu used in this paper are from January 28, 2014 to November 6, 2019. The daily data during the period comes from the AiryMap Platform collecting and sorting out the data of China's environmental monitoring station. A total of 2108 days before and after, missing 7 days, there are 2101 days of data. Since time data is used, this paper carries out ADF test to avoid spurious regression. The results show that air quality index and the six pollutants are stationary time series.

4. Data analyses and results
4.1. Seasonal difference in AQI
On an annual basis, the number of healthy days (i.e., when AQI ≤ 100) in Chengdu increased from 139 days in 2013 to 287 days in 2019, and air pollution has been largely controlled. But looking at the seasons, the air pollution in Chengdu is not optimistic. Table 2 shows the air pollution of Chengdu in different seasons. Based on the number of healthy days, the standard-reaching rate in winter is less than 60% and the standard-reaching rate in spring is only 67.82%. Taking the average of AQI numerical value as the standard, AQI in winter is much larger than that in other seasons, up to 121.

Table 2. Air pollution status of Chengdu.

| season  | standard-reaching rate | AQI  |
|---------|------------------------|------|
| spring  | 67.82%                 | 89.70|
| summer  | 70.29%                 | 84.65|
| autumn  | 83.88%                 | 73.80|
| winter  | 45.19%                 | 121.28|

It can be seen from the descriptive statistics that there is the seasonal difference in air pollution in Chengdu. On this basis, this paper further carries out regression analysis. Table 3 shows the regression results with AQI as the dependent variable.

Table 3. Regression results of seasonal difference in Chengdu.

| variable | coef  | SE   | t     | Sig.  |
|----------|-------|------|-------|-------|
| summer   | -5.042| 2.526| -2.000| 0.046 |
| autumn   | -15.894| 2.563| -6.200| 0.000 |
| winter   | 31.588| 2.622| 12.050| 0.000 |
| constant | 89.696| 1.788| 50.170| 0.000 |

Because season is a categorical variable, this paper sets season as a dummy variable for regression. And spring is selected as the reference item. Therefore, spring does not appear in regression. From the regression results, all variables are significant at the confidence level of 0.05. This indicates that there is a significant seasonal difference in AQI in Chengdu. It can be seen from the regression coefficients
in Table 3 that Chengdu has the best air quality in autumn, followed by summer, spring and winter. This is consistent with the results in Table 2. The research hypothesis H1 have been testified.

Furthermore, according to the results demonstrated through Table 4 and Figure 1, it is shown that the impact of six pollutants on air pollution in Chengdu varies with seasons. Taking particulate matter and ozone with greater pollution degree as examples, particulate matter (mainly PM2.5) has greater influence in autumn, winter and spring, and less influence in summer; ozone has a greater influence in summer and less influence in autumn, winter and spring. This further testifies hypothesis H1.

### 4.2. The impact of six pollutants on AQI

According to “Technical Regulation on Ambient Air Quality Index (on trial)” issued by the Ministry of Environmental Protection of China, six pollutants monitored by AQI are PM2.5, PM10, NO3, SO2, CO and O3. The calculation formula of AQI is as follows:

\[
AQI = \max\{IAQI_1, ..., IAQI_n\} 
\]

(1)

Among them, IAQI is the individual air quality index; n is different pollutant items. This shows AQI can be regarded as the individual air quality index of the primary pollutant. In other words, AQI measures the concentration of the primary pollutant rather than the concentration of all pollutants exceeding the standard. Therefore, this paper can find out main air pollutants by regression analysis with AQI as the dependent variable. Table 4 shows the regression results with AQI as the dependent variable in different seasons.

#### Table 4. Regression results of six pollutants.

|          | (1) Year | (2) Spring | (3) Summer | (4) Autumn | (5) Winter |
|----------|----------|------------|------------|------------|------------|
| PM2.5    | 0.815*** | 0.521***   | 0.098      | 0.656***   | 0.826***   |
|          | (0.0419) | (0.0618)   | (0.118)    | (0.0746)   | (0.0589)   |
| PM10     | 0.067*   | 0.135***   | 0.011      | 0.214***   | 0.063      |
|          | (0.0289) | (0.0368)   | (0.0776)   | (0.0541)   | (0.0423)   |
| O3       | 0.362*** | 0.378***   | 0.880***   | 0.200***   | -0.000     |
|          | (0.00741)| (0.0129)   | (0.00924)  | (0.0120)   | (0.0286)   |
| CO       | 0.114*** | -0.010     | 0.013      | 0.021      | 0.066***   |
|          | (2.122)  | (3.494)    | (4.042)    | (2.581)    | (3.334)    |
| NO2      | -0.007   | 0.117***   | 0.103***   | 0.088***   | 0.046***   |
|          | (0.0380) | (0.0557)   | (0.0624)   | (0.0633)   | (0.0622)   |
| SO2      | -0.038***| 0.065***   | -0.024     | -0.017     | -0.004     |
|          | (0.0780) | (0.122)    | (0.118)    | (0.110)    | (0.116)    |
| N        | 2101     | 550        | 552        | 521        | 478        |
| R²       | 0.864    | 0.863      | 0.925      | 0.912      | 0.935      |

Standardized beta coefficients; Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Standardized beta coefficients have better comparability than unstandardized coefficients because standardized beta coefficients exclude the influence of dimension and independent variable deviation. Therefore, main air pollutants can be found by comparing the standardized beta coefficients. The result of Breusch-Godfrey test shows that the random error terms have autocorrelation. For the sake of robustness, this article uses Prais-Winsten regression to avoid autocorrelation. After the re-estimation of Prais-Winsten regression, the transformed Durbin-Watson statistic is closer to 2 than the original Durbin-Watson statistic. Comparing the two regression results, this paper found that the results are almost the same. This shows that the regression results are robust.
As can be seen from Table 4, PM2.5 and O3 are main air pollutants in the whole year. And depending on the season, the standardized beta coefficients of the six pollutants will also change greatly. To facilitate the observation of the impact of the six pollutants on AQI in different seasons, standardized beta coefficients are displayed by bar graph. Figure 1 shows the impact of six pollutants on air pollution in different seasons.

![Figure 1. Beta coefficients of six pollutants.](image)

It can be seen from Figure 1 that PM2.5 is the primary pollutant in spring, autumn, winter and ozone is the primary pollutant in summer. The beta coefficients of the remaining four pollutants is less than fine particles matter and ozone. The research hypothesis H2 have been testified.

5. Discussion and conclusions
There is the seasonal difference in air pollution in Chengdu. Based on the research results of this paper, it is speculated that the reason why Chengdu's summer AQI is higher than that of autumn is that the summer O3 concentration is extremely high. In summer, the sunshine duration is long and the degree is strong. The high temperature is conducive to the production of O3. Therefore, AQI increases with the rapid increase of O3 concentration. PM2.5 is lower in summer because of the strong airflow diffusion and heavy rainfall. The trend of PM10 is similar to that of PM2.5. SO2 and CO only constitute significant pollutants in spring and winter respectively. These two seasons are when pollution is serious. This is because more temperature inversion, low wind speed and less precipitation between spring and winter in Chengdu are conducive to the accumulation of air pollution. NO2 is significant in all seasons. From the perspective of the beta coefficient, NO2 is the fourth largest pollutant after particulate matter and ozone.

The annual pollutants in Chengdu are mainly PM2.5 and O3. Among them, PM2.5 is the primary pollutant in winter, autumn, spring and O3 is the primary pollutant in summer. This shows that the type of air pollution in Chengdu has been transformed into a compound type of pollution mainly composed of ozone and fine particles. The generation of PM2.5 is mainly caused by pollution from
moving sources such as motor vehicles, coal-fired sources, and urban dust. Because PM2.5 is the primary pollutant, it is necessary to strengthen the control of moving source pollution and urban dust and accelerate the transformation of energy structure in the process of air pollution control in Chengdu in the future. The production of O3 is mainly caused by nitrogen oxides and volatile organic compounds produced by industrial source pollution and mobile source pollution under strong light and high temperature. The reason why ozone became the primary pollutant in Chengdu in summer may be because the high temperature and strong ultraviolet rays in summer are conducive to the generation of ozone by nitrogen oxides and volatile organic compounds. In response to this, Chengdu can carry out precise emission reductions to reduce the emission of nitrogen oxides and volatile organic compounds through the supervision of some industrial enterprises and auto repairs. At the same time, Chengdu should encourage green travel to reduce pollution from moving sources of roads and strengthen the management of mechanical vehicles on construction sites.

**Prospect**

AQI can reflect air pollution more accurately than API. But in some cases, AQI cannot reflect the comprehensive impact of pollutants included. Therefore, we intend to consider and collect more data to prove in future research.

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**References**

[1] Wang B, Gao H W 2008 Characteristics of air pollution index in coastal cities of China *Ecology and Environmental Sciences* 02 542

[2] Li X Y, Ding X M, et al 2011 Characteristics of air pollution index in typical cities of North China *Journal of Arid Land Resources and Environment* 25 96

[3] Li W J, Zhang S H, Gao Q X, et al 2012 Relationship between Temporal-Spatial Distribution Pattern of Air Pollution Index and Meteorological Elements in Beijing, Tianjin and Shijiazhuang *Resources Science* 34 1392

[4] Zhang J Z, Sun J, et al 2014 Relation Between the Spatial-temporal Distribution Characteristics of Air Quality Index and Meteorological Conditions in Beijing *Meteorological and Environmental Sciences* 37 33

[5] Jiang L, Zhou H F, et al 2018 The analysis of socio-economic factors of air quality index (AQI) based on the perspective of the exponential decay effects *Acta Scientiae Circumstantiae* 38 390

[6] Li Y Z, Zhou P, et al 2016 The Relational Study of Chengdu AQI and Haze *Ecology and Environmental Sciences* 25 1760

[7] Wang S L, Cai F H, Zhang Y H, et al 2004 Analysis on the Sources and Characters of Particles in Chengdu *Scientia Geographica Sinica* 24 488

[8] Zhang C Y, Wu J H, Zhang P, et al 2014 Particulate Composition and Source Apportionment Trends in Winter in Chengdu *Research of Environmental Sciences* 27 782

[9] Wu K, Kang P, Wang Z H, et al 2017 Ozone temporal variation and its meteorological factors over Chengdu City *Acta Scientiae Circumstantiae* 37 4241