Temporal Distribution Characteristics of PM2.5 in Beijing and Its Influencial Factors

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Abstract: With the development of China, the environmental problems become serious and attract much concern. Among all the problems, the air pollution caused by PM 2.5 is one of the most serious one. Therefore, this study focus on this problem and analyzes the season series distribution characteristics and influencing factors of PM2.5 through statistical analysis and Spearman and Pearson correlation coefficient method. According to the research result of this paper, the concentration of PM2.5 varies from low to high in spring, summer, winter and autumn. On the whole, PM2.5 concentration in Beijing is negatively correlated with temperature difference, relative humidity and precipitation. Besides, the PM2.5 concentration in Beijing shows a strong correlation with the local wind speed.

1. Introduction
In recent years, with the rapid development of China's economy, atmospheric environmental problems are becoming increasingly serious. Among them, PM2.5, as one of the core environmental problems, has been widely concerned in recent years [2]. More and more studies have shown that compared with large particles, PM2.5 is more harmful to human body, and large particles are more likely to lurk in the respiratory tract and alveoli [3]. Therefore, the study of PM2.5 is very important.

Existing studies show that the lack of understanding of spatial correlation and structural characteristics of atmospheric environmental governance performance at different regional scales makes it difficult to form an efficient and orderly cooperation mechanism for pollution prevention and control, which is one of the important reasons for the steady improvement of regional air pollution control performance in China [4].

Ma Jingnan et al. [5] analyzed the seasonal and daily variation characteristics of PM2.5 and gaseous precursors (SO2, O3, NO2, CO) concentration in Beijing urban area in 2018 and meteorological factor data. The results showed that the average PM2.5 concentration in Beijing urban area was 50.6 μg / m³ in 2018, and haze pollution events occurred frequently in spring, autumn and winter.

Tang Yingyin et al. [6] used the air quality data of a natural year (March 1, 2016, February 28, 2017) in the urban area of Bazhong City, analyzed the pollution characteristics and temporal and spatial variation law of PM2.5 in Bazhong City. The results show that the logarithm of PM2.5 daily average concentration is close to normal distribution, and there is a significant correlation between PM2.5 and other major air pollutants. The concentration of PM2.5 was in the order of winter > autumn > spring > summer, which reflected that the pollution of PM2.5 was the most serious in winter, moderate in spring and autumn, and the least in summer.

According to the PM2.5 pollution monitoring data of Beijing in recent six years from January 1, 2010 to December 31, 2015, this paper classifies and processes the data according to the seasonality
and year. In addition, the data are calculated by Pearson and Spearman coefficients, thus discussing the PM2.5 pollution status and its seasonal changes in Beijing. Besides, the spatial and temporal distribution characteristics of the pollution gases and their seasonal changes and its influencing factors are discussed. It is of great scientific significance to study the spatial-temporal pattern, transport evolution and deposition removal of regional air pollution sources.

This data set includes hourly air pollutants data from 4 nationally-controlled air-quality monitoring sites. The data come from the study of [1]. This study aims to provide a reference for air pollution control in Beijing and even in the whole country.

2. Research Methods
The Pearson correlation coefficient is usually used to describe the correlation between two variables[7]. The calculation formula is as follows, where n is the number of samples; X - and y- are the sample mean:

\[
R_p = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}
\]

(1)

The Pearson correlation coefficient requires the data to be normal distribution and can only describe the linear correlation. Spearman correlation coefficient is used to analyze the rank size of two variables. It does not require the data to satisfy the normal distribution or can describe the nonlinear relationship. The calculation formula is as follows:

\[
R_s = 1 - \frac{6 \sum_{i=1}^{n}d_i^2}{n(n^2-1)}
\]

(2)

In this formula, \(d_i = X_i - Y_i\) represents the rank difference of two variables, and \(X_i\) and \(Y_i\) are the positions of data in the list after sorting from large to small.

The value range of the two correlation coefficients is [-1, 1]. The higher the absolute value of the value is, the higher the correlation level of the two variables is; otherwise, the lower the correlation level is.

3. Results and Analysis

3.1. PM2.5 Pollution Level
According to the ambient air quality standard (GB 3095-2012), the secondary standard limit of the annual average concentration of PM2.5 is 35 μg/m³, and the daily average concentration limit is 75 μg/m³ [8]. The over standard rate represents the proportion of days in the whole year when the average daily concentration of PM2.5 exceeds the limit of level II standard.

According to the calculation, the annual average PM2.5 concentration in the six years from 2010 to 2015 is 107.09365804 μg/m³, 97.88569895 μg/m³, 87.42239455 μg/m³, 90.80263363 μg/m³, 89.15264168 μg/m³ and 76.05268464 μg/m³ respectively. All of them exceed the standard, indicating that PM2.5 pollution in Beijing is serious. However, the highest annual average concentration is in 2010, the lowest is in 2015, and the annual average concentration is decreasing from 2010 to 2015, indicating that the PM2.5 pollution situation in Beijing is gradually improving.

3.2. PM2.5 Seasonal Variations

| Year | Spring mean(μg/m³) | Summer mean(μg/m³) | Autumn mean(μg/m³) | Winter mean(μg/m³) |
|------|--------------------|--------------------|--------------------|--------------------|
| 2010 | 87.03465804        | 110.5642317        | 126.7299893        | 104.0457298        |
See Table 1 for the pollution situation of different cities in different seasons. In the past six years, the average concentration of PM2.5 in autumn is the highest, which is 80.92-126.73 μg/m³, 7.89% - 68.97%. The second is winter and summer, 14.48% ~ 38.73% and 12.61% ~ 47.41% respectively. The lowest in spring is 4.45% - 22.43%. The concentration of PM2.5 fluctuated slightly in different years, but it showed a downward trend, which was closely related to the attention and control of air pollution in China in recent years.

In different years, PM2.5 concentration decreased from 107.09 μg/m³ to 76.05 μg/m³, showing a downward trend year by year, which is closely related to the attention and control of air pollution in China in recent years.

### 3.3. Factors Affecting PM2.5 Concentration

When the Pearson coefficient is larger than the Spearman coefficient, it refers mainly to a linear correlation. Otherwise, it represents mainly a nonlinear relationship.

Pearson correlation coefficient and Spearman correlation coefficient of PM2.5 concentration and temperature difference, relative humidity, wind speed, and rainfall were calculated. Table 2 and Table 3 show the calculation results. The calculation were processed by excel based on the original data from X. Liang, S. Li, S. Zhang, H. Huang, and S. X. Chen (2016)[1].

#### Table 2. Pearson Correlation coefficient between PM2.5 and other air pollutants

| Year | Temperature difference (°C) | Relative humidity (%) | Wind speed (m/s) | Precipitation (mm) |
|------|-----------------------------|-----------------------|-----------------|-------------------|
| 2011 | -0.434832195                | -0.72078882           |                 | 0.013967371       |
| 2012 | -0.434832195                | -0.72078882           | -0.22172127     | 0.013967371       |
| 2013 | -0.434832195                | -0.72078882           | -0.22172127     | 0.013967371       |
| 2014 | -0.434832195                | -0.72078882           | -0.22172127     | 0.013967371       |
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This paper is based on the annual scale PM2.5 Correlation analysis with other meteorological factors. The calculation results of concentration and other meteorological correlation coefficients are shown in Table 2 and Table 3, 2010-2015 in Beijing PM2.5. The concentration is negatively correlated with temperature difference, relative humidity and precipitation. This is because precipitation and humidity can make some particles settle, thus decreasing the concentration of PM2.5. There is a significant positive correlation between the PM2.5 concentration and wind speed. Because the wind can spread pollutants in the surrounding areas, the increase in wind speed will lead to the increase of the PM2.5 concentration.

On the whole, the PM2.5 concentration has a strong linear correlation with wind speed, while it has a negative correlation with temperature difference, relative humidity and precipitation.
4. Conclusion
From 2010 to 2015, the annual average concentration of PM2.5 in Beijing exceeded the limit value of the national secondary standard, and the pollution level was relatively heavy. In 2010, the pollution level was the most serious, then decreased year by year (except 2013), and in 2015, the pollution level was the least. The concentration of PM2.5 was from low to high in spring, summer, winter and autumn. In the autumn with the most serious pollution, the rate of exceeding the standard is as high as 68.97%. The calculation results show that PM2.5 concentration in Beijing has a negative correlation with temperature difference and relative humidity, a strong positive correlation with wind speed, and no significant correlation with precipitation. PM2.5 pollution can be improved by increasing air humidity and reducing daily temperature difference.

According to the above research results, it can be seen that PM2.5 pollution in Beijing is very significant in autumn and winter, which is due to the low temperature in autumn and winter and a large amount of coal-fired heating in northern China, resulting in a sharp increase in particulate matter emissions. On the other hand, PM2.5 is negatively correlated with relative humidity and precipitation. The climate of Beijing is temperate monsoon climate. In winter, it is cold and dry, with little precipitation and low humidity. As a result, PM2.5 in the air cannot be settled and eliminated, and a large amount of PM2.5 stays in the air, resulting in high concentration of PM2.5 in winter. However, in summer, it is hot and rainy, with high relative humidity and precipitation, and PM2.5 can be effectively settled, so PM2.5 can be effectively settled in summer. The concentration is low.

Different strategies can be formulated according to the seasonal variation of PM2.5 pollution in Beijing. For example, when autumn and winter are approaching, we should focus on the treatment, strengthen the inspection and control of coal-fired plants, control the emission of particulate matter, and at the same time use artificial rainfall and artificial snowfall to increase the relative humidity of the air and reduce the concentration of PM2.5. In spring and summer, natural conditions are conducive to the decrease of PM2.5 concentration. Therefore, it is necessary to strictly monitor the exhaust emission of factories and automobiles to reduce the pollution emission from the root.

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