A simple analysis of the relationship between Taiyuan pollutant concentration and time

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Abstract: In the context of today's growing emphasis on environmental issues, the paper analyses 2018 pollutant data from eight sites in Taiyuan. The relationship between PM$_{2.5}$ concentration and time (season, month, week) was analyzed by the R language, and the reason for PM$_{2.5}$ concentration variation was inferred. Air Pressure, wind speed, precipitation, and vehicle restrictions all affect the concentration of pollutants.

1. Introduction

Air pollution in China receives increasing attention by the general public as well as scientific researchers. A classic example is PM$_{2.5}$. It is found out to be a major source of haze pollution in urban areas in China. As a result, air pollution has an adverse impact on people's life. There is a consistent statistical correlation between exposure to PM$_{2.5}$ and human health hazards, and PM$_{2.5}$ has many potential hazards to human health. (Dai & Song, 2001) So Studies have shown that many pollutants pose a serious hazard to the human respiratory system. In order to protect people's health, the content of pollutants needs to be monitored timely and more accurately. Since 2014, the government has introduced many policies. Following these policies, many PM$_{2.5}$ monitoring stations were built across the country. Such monitoring stations have provided a large number of air pollution data. The availability of these air pollution led to numerous academic studies on air pollution. For example, air pollution studies have been done in a few urban regions such as the Pearl River Delta (PRD) (Louie et al., 2005) and the Beijing metropolitan area (Zhang et al., 2012b). However, it is difficult to extrapolate these data to other regions due to complex terrain, meteorological conditions, and emission distributions (Li et al., 2014). More studies are needed for the city-scaled urban areas in China.

With the continuous development of the economy and the continuous advancement of China's urbanization process, the emissions of various pollutants have increased. Taiyuan, the capital city of Shanxi province, is a city with heavy industrial as its pillar industry (Yu, et al., 2010), so the air pollution in this area has always existed, and in 2006, air pollution in Taiyuan was moderate, reaching alarming levels (Wen, 2008). With the continuous progress of urbanization in China, Taiyuan has witnessed an increasing number of cars, resulting in more emissions emitted into the atmosphere.

In order to better understand the relationship between the concentration of pollutants in the air and time, the data of pollutants PM$_{2.5}$ in one year at eight sites in Taiyuan was collected, collated and analyzed. The aim of this study is to know the temporal trend of pollutants in Taiyuan urban areas and hope to be able to help Taiyuan formulate appropriate measures to prevent and control air pollution.
2. Methods

We chose PM2.5 as the representative pollutant and collected data from eight monitoring sites over the course of a year. We have done a preliminary collation of these data, through them using the R language to analyze the data from eight sites, we've got some signature data (mean, median, max, min, so) which is shown in Table 1 below. Data on all the products are downloaded from public websites (https://www.aqistudy.cn/#). All measurements were conducted at national air quality monitoring sites in each region. The map we downloaded from the site (https://map.baidu.com/mobile/webapp/search/search?q=taiyuan&c=176&newmap=1&from=alamap&tpl=mapcity) shows that of the eight sites (ShangLan, NanZhai, JianCaoPing, TaoYuan, WuCheng, JinSheng, XiaoDian, JinYuan), TY is in the middle of Taiyuan, and the other seven are a little more remote, which means that the flow of people and cars in TY is more intensive, also with the lives of the general population more closely. So, in order to make our data analysis more representative and characteristic, the following analysis will take its TY site data as a representative. I then used R language to analyze the PM2.5 data monitored from TY and processed them by month, season, and week to get three individual charts.

3. Result and Discussion

3.1. Overview of air pollutants

At present, the 24-hour average concentration of PM2.5 in China is less than 75 μg/m3. However, this figure is far from the international standard of PM2.5. According to the World Health Organization (WHO), the PM2.5 standard is less than 10 μg/m3. When PM2.5 reaches an average concentration of 35 μg/m3, the risk of illness and death increases dramatically. And the average secondary standard of PM2.5 is 35 μg/m3. From the table below we can see the characteristic values of PM2.5 from eight monitoring stations in Taiyuan. Looking at the mean, we can see that the annual averages of PM2.5 are all more than 35 μg/m3 (JY's annual average is the highest), which means that, levels of PM2.5 in Taiyuan have reached levels that affect people's health. Also, according to the maximum and minimum values and the standard deviation that we have collated from the eight monitoring sites, we can see that the levels of PM2.5 have fluctuated greatly, with the minimum being only single digits and the maximum generally being above 200 μg/m3.

The distribution and variation of the pollutants are related to many factors, such as geographical location. From the table, we can see that PM2.5 concentrations are higher in JY and JS which were in the southwest, other researchers have studied the changing characteristics of air pollutants in Taiyuan and their relationship with meteorological factors (Guo et al., 2017).
Table 1. Characteristic values of PM$_{2.5}$ concentration in 8 different places

|   | SL  | NZ  | JCP | TY  | WC  | JS  | XD  | JY  |
|---|-----|-----|-----|-----|-----|-----|-----|-----|
| mean | 41.4 | 55.9 | 58.1 | 57.4 | 59.1 | 59.4 | 57.8 | 70.8 |
| medium | 36   | 47.5 | 50  | 47  | 50  | 49  | 48  | 59  |
| min  | 4    | 2   | 0   | 9   | 8   | 8   | 4   | 3   |
| max  | 190  | 247 | 264 | 277 | 256 | 289 | 225 | 261 |
| sd   | 29.9 | 35.8 | 38.6 | 36.3 | 37.7 | 42.0 | 39.8 | 46.1 |

3.2. Relationship between pollutant concentration and time

Using the R language, I analyzed the data and came up with the following three box-plots.

![Figure 2. Variation of PM2.5 concentration with time](image)

3.2.1. Month and season in relationship to PM$_{2.5}$

In order to analyze the relationship between the pollutant and the month, first of all, from the change of the median line (which represents the average level of the sample data), we can see that the concentration of PM2.5 from June to September is small, and the data shows an upward trend to both sides, but it fell in February and December. Looking at the Q3 and lower Q1, we can see that the width of the box tends to be narrow in the middle and wide on both sides, with July and September being the narrowest, meaning they fluctuate the least. And November and January are the biggest, which means they're the most volatile.

Looking at the seasonal chart, it is clear from the median that PM2.5 concentrations are lower in summer and autumn, and higher in Spring and winter. From the observations of Q3 and Q1, we can see that the variation range is the smallest in summer and the largest in winter.

Meteorological factors play a significant role in aerosol concentration to the extent that local emission sources are identified, as PM2.5 mainly accumulates in the boundary layer during heavy pollution weather (Deng et al., 2011), therefore, the meteorological factors such as wind speed, temperature, and humidity in the atmosphere below 850hpa are of vital importance. In general, serious pollution occurs under conditions such as light wind or calm wind, inversion layer in the lower troposphere and so on. (Zhang et al., 2012). The stronger and lower the inversion layer, the more disadvantageous to aerosol concentration diffusion. In addition, some aerosol particles are highly hygroscopic and dry aerosol particles also increase in hygroscopicity in humid weather (Birgitta et al., 1994).
Generally speaking, the higher the concentration of air pollutants before precipitation, the greater the proportion of the time when the concentration of air pollutants decreases after precipitation, and the greater the value of the concentration reduction, there are also many cases of elevated concentrations after rainfall (An et al., 2018). In other words, there is a significant nonlinear negative correlation between precipitation and particulates concentration (Jin, 2012). And because Taiyuan has more precipitation in summer and autumn, and less precipitation in winter and spring, (Ren et al., 2012) the pollutant content in summer and autumn is significantly less than that in winter and spring.

Furthermore, the horizontal and vertical movements of the ground air have a significant effect on the diffusion of pollutants. PM2.5 is negatively correlated with wind speed. The higher the wind speed, the lower the concentration of pollutants, and the more favorable the diffusion (Guo et al., 2017).

In addition, PM2.5 concentration in Taiyuan is negatively correlated with sea level pressure over north China and positively correlated with sea level pressure over the Korean Peninsula and the Sea of Japan. The distribution of these two correlations is closely related to the evolution of the atmospheric active centers in the middle and high latitudes in winter, while the 500 HPA height field over eastern China in the corresponding period is abnormally high and the sea level pressure is relatively low, the weakening of near-surface wind speed is one of the background factors for the persistent high PM2.5 concentration in Taiyuan in winter (Zhou, et al., 2018).

3.2.2. Weekdays in relationship to PM2.5.
By looking at the third chart, we can see that the Sunday median is the highest, and by looking at Q1 and Q3, we can see that the Monday, Tuesday, and Sunday data fluctuate a lot. It is known that Taiyuan has a policy of restricting traffic on weekdays with odd and even numbers. Therefore, the traffic volume on weekdays is relatively smaller than that on weekends. Therefore, the pollution emission at weekends will be higher.

4. Conclusions
In today's increasingly serious international air pollution, to find effective monitoring and management of pollutants is crucial. Through the analysis of PM2.5 concentration, we have a certain understanding of its changing law and influencing factors. Of course, this article has its drawbacks, because it uses only one pollutant from a single location as an example, and it doesn't cover enough ground and doesn't take into account all the factors. But it is hoped that these conclusions can provide Taiyuan government with some effective information, so that more reasonable and effective policies can be put in place to improve the air quality in Taiyuan City.

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