Temporal and spatial distribution characteristics of ozone in Taiyuan City in 2018

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Abstract: To understand the spatial-temporal characteristics of ozone in Taiyuan, the ozone concentration data of Taiyuan National Control Point in 2018 were analyzed. The results show that, in 2018, the data of ozone as the main pollutant in Taiyuan did not exceed the annual average standard. The monthly distribution of ozone was inverted “V” and the highest average concentration appeared in July. The diurnal variation of ozone didn't show an anti-weekend effect. In terms of spatial distribution, the difference between all the eight points was not obvious.

1. Introduction
In recent years, with the rapid development of China’s economy, excessive energy consumption, and rapid progress in urbanization, air pollution in urban areas has become more and more serious. With the increasing geographical scope and frequency of pollutants, air pollutant has gradually affected people’s daily life and gradually threatened human health and survival. Air pollutants are mainly manifested as excessive levels of airborne particles, sulfur-oxygen compounds, and nitrogen-oxygen compounds. In recent years, under the background that more and more concentration has been focused on PM2.5, SO2, NO2 and these atmospheric pollutants’ concentration has been declining year by year, while the O3 concentration has risen instead of falling [1]. And it has become an important air pollutant, after PM2.5 in China [2,3].

Research results have shown that ozone’s health hazards to humans health, which include: irritation and damage to the nasal mucosa and respiratory tract, ranging from chest tightness, coughing, throat swelling and pain, and may also lead to weakened lung function and lung gas Swelling and lung tissue damage; irritating the eyes, reducing visual sensitivity and vision, causing wrinkles and dark spots on the skin. When the ozone concentration is above 200 μg/m3, it will damage the central nervous system, causing headaches, chest pain. It hinders the blood oxygen delivery function, causing tissue hypoxia, and in severe cases, it destroys the body’s immune function and induces chromosomal aberrations in lymphocytes.

China’s "Ambient Air Quality Standard"[4] issued in February 2012(Jingbian County Government Affairs Open Pilot Column,2018) stipulates that the maximum daily 8-hour average secondary concentration limit of ozone is 160μg/m3. As one of the six major pollutants in the air, ozone pollution monitoring is an important part of ozone pollution forecasting and prevention. At present, O3 pollution control faces severe challenges. Scientific understanding of the changing law
of O₃ concentration and its influencing factors is of great significance to the scientific prevention and control of O₃ pollution.

Taiyuan is the capital of Shanxi Province and an important central city in China. By 2018, the permanent population is 4,421,500, the urban population is 3,752,700, and the urbanization rate is 84.88% [5]. It is the political, economic, and cultural center of Shanxi Province and one of China's important energy and heavy industry bases. With the acceleration of the urban development process, Taiyuan's environmental problems once intensified, the situation is not optimistic and even ranked among the top ten cities with the worst air quality in the world. Therefore, the monitoring and analysis of air pollutant data in Taiyuan are particularly important.

This article uses the data released by China's air quality online monitoring and analysis platform (https://www.aqistudy.cn/#) to conduct statistics and analysis, discuss the changing process and development trend of time and space distribution of O₃ in Taiyuan city, to provide a data basis for Taiyuan city air quality control and further improve Taiyuan local air quality.

2. Methods

2.1 Overview of the study area
Taiyuan City is located at 111° 30’—113° 09’ E east longitude and 37° 27’—38° 25’ N north latitude. It is surrounded by mountains in the west, north, and east, with an average elevation of about 800 m. The middle and south are valley plains. The terrain is high in the north and low in the south. The terrain is complex and diverse, and the altitude difference is large. (http://www.taiyuan.gov.cn/doc/2017/12/21/170645.shtml) It belongs to the northern temperate continental climate, with four distinct seasons, sufficient sunshine, the large temperature difference between day and night, concentrated rainfall in summer and autumn, and dry and windy winter and spring. The annual average outdoor wind speed near the ground is 0.3 m·s⁻¹, the annual average atmospheric pressure is 920 hPa, the average annual air humidity is 49%, and the annual average temperature is 9.5°C. Average annual precipitation 468.4 mm [6].

The monitoring site cities for this data are Shanglan (SL), Nanzhai (NZ), Jiancaoping (JCP), Taoyuan (TY), Wucheng (WC), Jinsheng (JS), Xiaodian (XD), Jinyuan (JY). A total of eight stations are scattered in the northwest and southern areas of Taiyuan. (https://www.aqistudy.cn/#)

2.2 Data sources
The air pollution data comes from all the O₃ data from 2018.1.1 to 2018.12.31 released by China's air quality online monitoring and analysis platform. China's air quality online monitoring and analysis platform is a non-profit software platform. It currently collects PM2.5 and weather information data from 367 cities across the country, including AQI, PM2.5, PM₁₀, SO₂, NO₂, O₃, CO, temperature, humidity, wind level, wind direction, satellite cloud image and other monitoring items, all data is automatically updated every one-hour (https://www.aqistudy.cn/#).

2.3 Research methods
Use the R language to perform basic data analysis on all the data of O₃ from 2018.1.1 to 2018.12.31 in eight areas of Taiyuan City, and obtain basic data including mean, median, maximum, minimum, etc., and analysis for a month, season and Analyze separately each year.
3. Result and Discussion

3.1. Overview of air pollutants

The \( \text{O}_3 \) characteristic values of 8 monitoring stations in Taiyuan City can be seen in the table below. From the average value, we can see that the annual average of \( \text{O}_3 \) all exceeds 95\( \mu \text{g/m}^3 \) (the annual average of XD is the highest), but are also all kept below 105\( \mu \text{g/m}^3 \). Compared the concentration of the eight sites, XD > JY > WC > JS > TY > SL > JCP > NZ, but the difference is not very big, basically the same. According to the "Ambient Air Quality Standard" [4], the 90th percentile of \( \text{O}_3 \)-8h within a year is greater than 160\( \mu \text{g/m}^3 \), the annual average value of ozone in Taiyuan City in 2018 did not exceed the standard. In addition, according to the maximum and minimum values and standard deviations we sorted out from the eight monitoring points, we can see that the level of \( \text{O}_3 \) fluctuates relatively smoothly, usually around 50-60\( \mu \text{g/m}^3 \). At the same time, we can also find that the distribution and changes of pollutants are related to geographical locations. It can be seen from the table that the PM2.5 concentration of SL, NZ, and JCP in the northwestern region is lower. Other researchers have studied the change characteristics of air pollutants in Taiyuan and their relationship with meteorological factors [7].

|       | SL        | NZ        | JCP       | TY        | WC        | JS        | XD        | JY        |
|-------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| mean  | 97.35017  | 96.78044  | 96.89139  | 99.54462  | 100.4417  | 99.85735  | 102.2487  | 101.5743  |
| medium| 89.875    | 89.625    | 89.28571  | 88.8125   | 94.875    | 93.125    | 96.47321  | 94.125    |
| min   | 9.875     | 5.75      | 5.125     | 7.125     | 9.375     | 6.25      | 5.714286  | 7.625     |
| max   | 230.75    | 261.125   | 354       | 266       | 443.375   | 487.5     | 254.8333  | 268       |
| sd    | 50.57335  | 56.20768  | 59.14536  | 59.56557  | 59.64008  | 64.51515  | 58.67758  | 61.07203  |

3.1.1. Month and season in relationship to \( \text{O}_3 \)

From the change of the midline (representing the average level of the sample data), we can see that the annual change of \( \text{O}_3 \)-8 h concentration is present Inverted "V" shape. From January to April, there has been a steady upward trend, and the concentration peaked in July, then there was
a significant downward trend from August, and continued to decline until December, of which the down ward trend from August to September and January to November is particularly obvious. It is also worth noting that October had the largest number of outliers. According to the season table, the O₃ concentration is lower in winter and autumn, while the O₃ concentration is higher in spring and summer. The concentration of ozone in spring, summer, autumn and winter is about 70μg/m³, 113μg/m³, 137μg/m³, and 54μg/m³ respectively. It has the characteristics of summer> spring> autumn> winter. It can be seen that the concentration of air pollutants in summer and spring in Taiyuan is also higher, and the air quality is worse than in other seasons.

O₃ undergoes complex photochemical reactions in the atmosphere, including the generation and transfer of free radicals, and its reaction rate is related to many factors such as temperature, humidity, solar radiation, and other meteorological conditions, as well as the concentration of O₃ precursors. The high temperature will directly accelerate the photochemical reaction speed, and with the increase of temperature, biological emissions increase, the concentration of O₃ precursors increases, and it also promotes the increase of O₃ concentration [8].

In summer, the solar radiation is stronger, the temperature is higher, and the photochemical reaction is also stronger, resulting in a higher O₃ secondary generation concentration; in winter, the photochemical reaction is weak, and under certain conditions, the high concentration of particulate matter causes the aerosol optical thickness to increase, which reduces the O₃ photochemistry. And the combination of these two causes the lowest O₃ concentration in winter [9,10].

At the same time, the influence of wind speed on primary pollutants mainly depends on the characteristics of the dilution and transmission of pollutants by the atmosphere, but the influence of wind speed on the secondary pollutant O₃ is not only due to the effect of diffusion but also due to the downward transport of upper ozone effect. When the wind speed is less than or equal to 3 m/s, as the wind speed increases, the O₃ volume fraction increases; when the wind speed is greater than 3 m/s, the O₃ volume fraction decreases. Compared with other seasons, the average wind speed in summer in Taiyuan slowed down significantly, which further affected the temporal and spatial distribution of O₃ concentration [11].

3.1.2. Weekdays in relationship to O₃
Air pollution "weekend effect"[12] means that when the influence of natural factors such as meteorological conditions is random, the situation of air pollution has a remarkable 7-day periodicity. Because natural factors cannot produce periodic phenomena, this periodic change may be related to human activities. According to China’s weekend system, pollutants can be divided into Monday to Friday as the working day concentration, Saturday, and Sunday weekend concentration, which excludes holiday data. But by looking at the chart, we can see that the
working day does not have a particularly large impact on data fluctuations, and the overall maintenance is within the range of 85-100μg/m³. It can be explained that the temporal and spatial distribution of O₃ concentration in Taiyuan is not greatly affected by the weekend effect [13].

4. Conclusion
Ozone, as a product of photochemical reactions, accounts for an increasing proportion of urban air pollution in China. In order to control ozone pollution in a targeted manner, this paper studies the temporal and spatial distribution of ozone in Taiyuan City.

Research and provide theoretical support for the treatment of ozone pollution in Taiyuan.

(1) In 2018, the average ozone concentration of the eight stations in Taiyuan City was 95-105μg/m³, which did not exceed the annual average standard.

(2) The monthly distribution of ozone concentration is in an inverted "V" shape, which is significantly higher in spring and summer than in autumn and winter. At the same time, ozone did not show an anti-"weekend effect" in Taiyuan.

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