Analysis of the Spatial and Temporal Variation Characteristics of Ozone in the Pearl River Delta Region from 2016 to 2020

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Abstract: Based on the historical data of air ozone monitoring of Pearl River Delta from 2016 to 2020, the temporal and spatial variation characteristics of ozone in the Pearl River Delta were analyzed. The results showed that the mean change curves of Q_3 in the seven cities in the Pearl River Delta region from 2016 to 2020 were M-shaped, and the change trend was basically the same, except Huizhou and Zhuhai. The over standard rate of daily mean value of Q_3 in Jiangmen City from 2016 to 2020 was more than 10%, and the over standard situation of daily mean value of Q_3 was serious. In the Pearl River Delta region, the change trend of the monthly mean value of Q_3 in the same year was basically the same. On the whole, the mean value from August to November was higher, and the mean value in June was lower. The peak of Q_3 concentration appeared between 12:00 and 16:00 in the daytime, and it was generally low at night.

1 Preface

Ozone (Q_3) is an important component of the atmosphere, about 90% of which is distributed in the stratosphere and 10% in the troposphere. Q_3 in stratosphere can absorb solar short-wave ultraviolet radiation and protect all kinds of biological materials on earth. Although the content of Q_3 in troposphere is small, it plays an important role in the atmospheric chemical reaction and air quality change because of its strong oxidation. In recent years, atmospheric photochemical pollution, represented by Q_3 pollution, has become increasingly serious in China. Especially in summer, Q_3 is the main pollutant instead of PM_{2.5}. Higher concentration of Q_3 near the ground will cause damage to human respiratory system, nervous system and eyes, especially to children ^[1]. In addition, Q_3 can reduce crop yield and damage plant leaves ^[2]. Therefore, the research on Q_3 pollution has become a hot spot. A lot of research work mainly focused on the relationship between Q_3 and precursors ^[3-6], meteorological factors of Q_3 ^[7-10], numerical simulation of Q_3 ^[11-12], etc.

As the economic development center of Guangdong Province, the Pearl River Delta region includes nine cities in Guangdong Province, namely Guangzhou, Shenzhen, Dongguan, Foshan, Zhuhai, Huizhou, Zhongshan, Jiangmen and Zhaoqing. In recent years, the municipal governments have been actively committed to improving the ambient air quality. The haze pollution represented by PM_{2.5} has been effectively improved, while the Q_3 pollution is becoming more and more obvious. At present, there are many studies on the relationship between the variation characteristics of Q_3 in the Pearl River Delta and its precursors and influencing factors ^[13-15], but few

studies on the spatial and temporal distribution characteristics of Q_3 in the Pearl River Delta in recent years.

Based on the historical data of air Q_3 monitoring in the Pearl River Delta from 2016 to 2020, this paper studies the temporal and spatial variation characteristics of Q_3 in nine cities in the Pearl River Delta, in order to provide relevant basis for the prevention and treatment of ozone pollution in the Pearl River Delta.

2 Data resource and methods

2.1 Data resource

The historical data of Q_{3-8h} monitoring of the nine cities in the Pearl River Delta region from January 1, 2016 to December 31, 2020 were from the air quality historical data query network (www.aqistudy.cn/historydata). The daily and monthly mean values of Q_3 in the nine cities were selected. The hourly monitoring data on June 30, 2019 and December 31, 2019 were from the website of Department of Ecology and Environment of Guangdong Province.

2.2 Research methods and data processing

Concerning the data of the nine cities in the Pearl River Delta used in this study, the annual mean value of Q_3 was based on the monthly mean value, and the annual over standard rate of Q_3 was calculated by the daily mean value.

According to the Technical Regulation for Ambient Air Quality Assessment (Trial) (HJ 663-2012), Q_{3-8h} is divided into five grades: excellent ($1\sim100\mu\text{g}\cdot\text{m}^{-3}$), good

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(101~160 $\mu\text{g}\cdot\text{m}^{-3}$), mild pollution (161~215 $\mu\text{g}\cdot\text{m}^{-3}$), moderate pollution (216~266 $\mu\text{g}\cdot\text{m}^{-3}$) and severe pollution and above (more than 266 $\mu\text{g}\cdot\text{m}^{-3}$). Mild pollution or above is the Q_3 concentration exceeding the standard.

3 Results and discussion

3.1 Annual variation characteristics of Q_3

The variation of the annual mean value of Q_3 in the Pearl River Delta from 2016 to 2020 is shown in Figure 1. The change curves of seven cities are M-shaped, except Huizhou and Zhuhai. The change trend of the seven cities

is basically the same. In 2016-2017, the annual mean value of Q_3 increased. In 2017-2018, the average annual value of Q_3 decreases to varying degrees. In 2018-2019, the average annual value of Q_3 increases, and in 2019-2020, the average annual value of Q_3 decreases. However, the annual mean value of Q_3 in Zhuhai decreases from 2016 to 2017 and then increased for two consecutive years from 2017 to 2019. The annual mean value in Huizhou City increased for three consecutive years from 2016 to 2019, and decreased from 2019 to 2020. In 2019, the annual mean value of Q_3 in the Pearl River Delta region is generally higher. Zhaoqing city has the lowest annual mean value of Q_3 , which is 93. Dongguan, Foshan, Guangzhou, Jiangmen, Zhongshan and Zhuhai are cities with the annual mean value of more than 100.

Figure 1 Variation of annual mean value of Q_3 in the Pearl River Delta region from 2016 to 2020

3.2 Monthly variation characteristics of Q_3

The variation of the monthly mean value of Q_3 in the Pearl River Delta from 2016 to 2020 is shown in Figure 2, in which the change trend of the nine cities in the same year is basically the same. In May, July, August and September, 2016, the monthly mean value of Q_3 in Pearl River Delta was higher than that from January to April. The monthly mean value of Q_3 in Dongguan City in August was the highest, which was 134 $\mu\text{g}\cdot\text{m}^{-3}$. The variation of the monthly mean value of Q_3 in the Pearl River Delta in 2017 is similar to that in 2016. The monthly mean value of Q_3 in Jiangmen City in October was the highest, which was 151 $\mu\text{g}\cdot\text{m}^{-3}$. The variation of the monthly mean value of Q_3 in 2018 is relatively gentle. The value of nine cities in October was relatively high, of which Zhuhai had the highest, 144 $\mu\text{g}\cdot\text{m}^{-3}$. From January to July in 2019, the monthly mean value of Q_3 was low, and the minimum value in February in Foshan was 46 $\mu\text{g}\cdot\text{m}^{-3}$. The monthly mean values from September to November were higher, and the biggest change was in Jiangmen City, and the

monthly mean value in Jiangmen City in September was as high as 190 $\mu\text{g}\cdot\text{m}^{-3}$. In 2020, the monthly mean value of Q_3 in the Pearl River Delta region changed greatly, and the monthly increase and decrease were obvious. The monthly mean value of Q_3 in Jiangmen City in November was the highest, 132 $\mu\text{g}\cdot\text{m}^{-3}$.

Compared with the monthly mean values of Q_3 from 2016 to 2020, the values from August to November is higher. The main reason is that the temperature is relatively high, the humidity is low, and the photochemical reaction is violent. From September to November in 2019, more cities exceeded the standard of monthly mean value of Q_3 . In September, Dongguan, Foshan and Jiangmen exceeded the standard. The cities with a higher monthly mean value than the standard in October are Dongguan, Jiangmen and Zhongshan, and Jiangmen and Zhongshan in November. Affected by the South China Sea monsoon climate in the southwest direction, although the temperature in the Pearl River Delta is high in June, the Q_3 concentration is relatively low

Figure 2 Variation of monthly mean value of Q_3 in the Pearl River Delta region from 2016 to 2020

3.3 Daily variation characteristics of Q_3

The hourly variation of Q_3 value in the Pearl River Delta on June 30, 2019 is shown in Figure 3. It can be seen that the variation of Q_3 concentration in the Pearl River Delta region shows a typical single-peaked type. The peak of Q_3

concentration appeared between 12:00 and 16:00 in the daytime, and the Q_3 concentration reached $215 \mu\text{g} \cdot \text{m}^{-3}$ at 14:00 in Guangzhou. The photochemical reaction was weak at night, and the emission of precursors such as CO , NO_x and VOCs decreased. Therefore, the Q_3 concentration was generally low at night, most of which were below $40 \mu\text{g} \cdot \text{m}^{-3}$.

Figure 3 Variation of hourly Q_3 value in the Pearl River Delta region on June 30, 2019

The hourly change of Q_3 value in the Pearl River Delta on December 31, 2019 is shown in Figure 4. Most cities in the Pearl River Delta showed a typical single-peaked variation of Q_3 , including Guangzhou, Foshan, Zhongshan, Jiangmen, Dongguan and Zhaoqing, and the peak of Q_3 concentration appeared between 14:00 and 16:00. The

curve of period change of Q_3 concentration in Huizhou City was M-shaped, with peak values at 7:00 and 14:00 respectively. The peak of Q_3 concentration in Shenzhen and Zhuhai appeared at 22:00, which may be related to the local weather conditions.

Figure 4 Variation of hourly Q_3 value in the Pearl River Delta region on December 31, 2019

3.4 Analysis of cities exceeding the standard of Q_3 concentration

It can be seen from Table 1 that the over standard rate of daily mean value of Q_3 in Jiangmen City from 2016 to 2020 is more than 10%, and that of 2017 and 2019 is as high as 20.3% and 20.5% respectively. The exceedance probability of daily mean value of Q_3 in Huizhou from 2016 to 2020 is below 5%, and that of 2020 is only 2.2%.

In 2019, the Pearl River Delta has a relatively high rate of exceeding the standard of daily mean value of Q_3 . The rate of Dongguan City, Foshan City, Jiangmen City, Zhongshan City and Zhuhai City is over 15%. In 2016 and 2020, the excellent rate of daily mean value of Q_3 in the Pearl River Delta region is higher. In 2016, only Dongguan City and Jiangmen City had the excellent rate below 90%, and in 2020, there is only one city with an excellent rate below 90%, namely Jiangmen City.

Table 1 Excellent rate and over standard rate of Q_3 in Pearl River Delta region from 2016 to 2020

City	Q ₃ in 2016		Q ₃ in 2017		Q ₃ in 2018		Q ₃ in 2019		Q ₃ in 2020	
	Excellent rate (%)	Over standard rate (%)	Excellent rate (%)	Over standard rate (%)	Excellent rate (%)	Over standard rate (%)	Excellent rate (%)	Over standard rate (%)	Excellent rate (%)	Over standard rate (%)
Guangzhou	90	10	90	10	90	10	90	10	90	10
Shenzhen	90	10	90	10	90	10	90	10	90	10
Zhuhai	90	10	90	10	90	10	90	10	90	10
Foshan	90	10	90	10	90	10	90	10	90	10
Zhongshan	90	10	90	10	90	10	90	10	90	10
Jiangmen	90	10	90	10	90	10	90	10	90	10
Dongguan	90	10	90	10	90	10	90	10	90	10
Huizhou	90	10	90	10	90	10	90	10	90	10
Zhaoqing	90	10	90	10	90	10	90	10	90	10

Dongguan city	88.5	11.5	84.7	15.3	91.2	8.8	80.6	19.5	91.5	8.5
Foshan city	90.2	9.8	83.0	17.0	90.1	9.9	82.2	17.8	91.3	8.7
Guangzhou city	91.5	8.5	86.9	13.1	90.1	9.9	85.2	14.8	90.4	9.6
Huizhou city	97.3	2.7	95.1	4.9	96.4	3.6	95.3	4.7	97.8	2.2
Jiangmen city	88.8	11.2	79.7	20.3	87.7	12.3	79.5	20.5	88.0	12.0
Shenzhen city	97.0	3.0	93.2	6.8	96.4	3.6	91.0	9.0	97.3	2.7
Zhaoqing city	91.3	8.7	88.5	11.5	93.7	6.3	89.0	11.0	97.5	2.5
Zhongshan city	91.3	8.7	82.1	17.9	90.7	9.3	81.9	18.1	91.0	9.0
Zhuhai city	95.4	4.6	89.9	10.1	91.5	8.9	83.4	16.6	93.2	6.8

4 Conclusion

(1) From 2016 to 2020, the change curve of annual mean value of Q_3 in seven cities in the Pearl River Delta region shows an M shape, except Huizhou and Zhuhai. In 2019, the annual mean value of Q_3 in the Pearl River Delta region is generally high. Zhaoqing is the city with the lowest average value in Q_3 , which is 93. Dongguan, Foshan, Guangzhou, Jiangmen, Zhongshan and Zhuhai are cities whose annual mean value are more than 100 in Q_3 . The over standard rate of daily mean value of Q_3 in Jiangmen City from 2016 to 2020 is more than 10%, which is relatively severe.

(2) From 2016 to 2020, the change trend of annual mean value of Q_3 in the nine cities in the Pearl River Delta region in the same year is basically the same. On the whole, the monthly mean value of Q_3 from August to November is rather high. Influenced by the South China Sea monsoon climate in the southwest direction, although the temperature in the Pearl River Delta is high in June, the Q_3 concentration is comparatively low. From September to November in 2019, more cities exceeds the monthly mean value.

(3) On June 30, 2019, the hourly variation of Q_3 in the Pearl River Delta region shows a typical single-peaked variation. The peak of Q_3 concentration appears between 12:00 and 16:00 in the daytime, and it is generally low at night. On December 31, 2019, the variation of Q_3 concentration in most cities in the Pearl River Delta shows a typical single-peaked change, including Guangzhou, Foshan, Zhongshan, Jiangmen, Dongguan and Zhaoqing. The variation curve of Q_3 concentration in Huizhou City is M-shaped. The peak of Q_3 concentration in Shenzhen and Zhuhai appears at 22:00, which may be related to the local weather conditions.

Project fund

This paper is one of the phased achievements of the Key Discipline Cultivation Project "Civil Engineering" of Guangdong Province in 2016 (Guangdong Teaching and Research Notice [2016] No. 19) and the undergraduate teaching quality and teaching reform construction project

"Engineering Cost" of Guangdong Provincial Department of Education (Guangdong Teaching and Research Notice [2018] No. 179).

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