Analysis of Temporal and Spatial Variation Characteristics of Air Quality in the Pearl River Delta during 2015-2019

Huang Chuntao*, Liao Qifeng, Lu Jifu

1Huali College Guangdong University of Technology, Guangzhou, Guangdong, 511300
2Guangdong Kedilong Technology Co., Ltd., Guangzhou, Guangdong, 510000
*Corresponding author: hualikyc@163.com

Abstract: Based on the history monitoring data of Air Quality Index (AQI) during 2015-2019, we conducted a contrastive analysis of the temporal and spatial variation characteristics of air quality in the Pearl River Delta. Results showed that the variation trends of AQI annual averages in the Pearl River Delta were basically the same. The AQI annual averages rose after decline and the variation curves were W-shaped. In the Pearl River Delta, Shenzhen and Huizhou enjoyed better air quality. In this region, AQI quarterly averages were high in autumn and winter but low in summer, and in a same year, the variation trends of the nine cities were basically the same. In autumn, the ozone concentration increased dramatically and therefore ozone became a major pollutant in ambient air. In winter, Guangzhou, Shenzhen and Dongguan saw a double-peak phenomenon in AQI hourly values, which rose at rush hours.

1. Introduction
With the constant urban development in recent years, ambient air quality has become a public concern. The national government and environmental protection agencies at all levels proactively advanced the governance of ambient air, released real-time air quality data and forecasted future air quality data. As Guangdong’s economic development center, the Pearl River Delta covers nine cities in Guangdong, which are Guangzhou, Foshan, Shenzhen, Dongguan, Huizhou, Zhuhai, Zhongshan, Zhaoping and Jiangmen. With the proposal of the goal of “making China’s skies blue again” and improving ambient air quality, all municipal governments in the Pearl River Delta have in recent years made proactive efforts to improve air quality.

Researchers [1-3] have studied the change rules and influencing factors of air pollutants in the Pearl River Delta. There have also been many researches on air pollution in an individual city. Studies have been conducted on the relationship between the change rules and meteorological factors of major air pollutants such as PM2.5 and ozone in Guangzhou [4-5], Shenzhen [6-7], Dongguan [8], Foshan [9] and other major cities. So far, there have been quite a lot of researches [10-12] on the relationship between the variation characteristics and influencing factors of ambient air quality in the Pearl River Delta but few studies on the temporal and spatial distribution characteristics of AQI in this region in the past several years.

Based on the history monitoring data of air quality during 2015-2019, this research studied the temporal and spatial variation characteristics of AQI in the nine cities in the Pearl River Delta, hoping to offer basis for improving ambient air quality and for prevention and control of haze in this region.
2. Data Sources and Methods

2.1 Data Sources
The history data of air quality in the nine cities from 2015 to February 2020 were sourced from the air quality history data search website (www.aqistudy.cn/historydata). We selected daily averages and monthly averages of the nine cities. The hourly monitoring data from January 1 to June 30, 2019 were derived from the official website of Guangdong Provincial Department of Ecological Environment. The data statistics is subject to *Ambient Air Quality Standards (GB 3095-2012)* and the AQI pollution level evaluation standard is subject to *Technical Regulation on Ambient Air Quality Index (On Trial) (HJ 663-2013)*.

2.2 Research Methods and Data Processing
The data of the nine cities in this research were quarterly averages and annual averages calculated based on AQI monthly averages. Spring is from March to May; Summer is from June to August; Autumn is from September to November; and Winter is from December to February of next year. We calculated the over-standard rate of air quality according to AQI daily averages. The quality level of light pollution or above refers to over-standard air quality.

3. Results and Discussion

3.1 AQI Temporal and Spatial Variation Characteristics

3.1.1 Variation Characteristics on an Annual Basis
The variations of AQI annual averages in the Pearl River Delta during 2015-2019 are shown in Table 1. AQI variation trends of the nine cities were basically the same. All averages rose after decline and the variation curves were W-shaped. From 2015 to 2016, the AQI annual averages presented a decline in various degrees. From 2016 to 2017 and from 2018 to 2019, all AQI annual averages increased. From 2017 to 2018, on the contrary, all AQI annual averages decreased. In both 2017 and 2019, the air quality in the Pearl River Delta became worse than one year earlier. In 2017, generally, the AQI annual averages were relatively high, and four cities, including Foshan, Guangzhou, Jiangmen and Zhaoqing, demonstrated an annual average of over 75. Shenzhen and Huizhou enjoyed better air quality in this region and had AQI annual averages below 60 during 2015-2019.

| Year | Dongguan | Foshan | Guangzhou | Huizhou | Jiangmen | Shenzhen | Zhaoqing | Zhongshan | Zhuhai |
|------|----------|--------|-----------|---------|----------|----------|----------|-----------|--------|
| 2015 | 70       | 65     | 68        | 54      | 59       | 53       | 65       | 57        | 56     |
| 2016 | 66       | 70     | 70        | 53      | 66       | 55       | 70       | 61        | 58     |
| 2017 | 73       | 78     | 76        | 57      | 77       | 56       | 78       | 72        | 61     |
| 2018 | 65       | 68     | 70        | 55      | 66       | 51       | 68       | 61        | 58     |
| 2019 | 74       | 73     | 74        | 57      | 72       | 58       | 73       | 70        | 60     |

3.1.2 Variation Characteristics on a Quarterly Basis
In the Pearl River Delta, the AQI quarterly averages during 2015-2019 were high in autumn and winter but low in summer, and in a same year, the variation trends of the nine cities were basically the same, which was shown in Figure 1. The meteorological conditions in summer and winter, mainly with south wind, were in favor of diffusion. The concentration of PM2.5 and PM10 dropped quickly. As a result, the AQI values in summer were relatively low. In autumn, the temperature was high and the humidity was low. Oxynitrides and volatile organic compounds (VOCs) had strong second-order
reactions, leading to a sharp increase in the ozone concentration. This made ozone a major pollutant in ambient air. In autumn, the concentration of PM2.5 and PM10 was low but the ozone concentration went up remarkably, resulting in an overall rise in AQI in this season. As the meteorological conditions in winter hindered the diffusion of pollutants and due to the discharge of pollution sources in all regions at the year end, particulate matter (PM) and oxynitriles became major pollutants. Therefore, the AQI values were relatively high.

In 2019, Jiangmen’s and Zhongshan’s AQI averages in autumn were higher than 110. The days with light pollution or above accounted for a half of the whole autumn. During 2015-2019, Shenzhen’s and Zhuhai’s AQI averages in summer were below 50, indicating excellent air quality.

3.1.3 Variation Characteristics on a Daily Basis

Figure 2 displayed the variations of AQI values on an hourly basis in the Pearl River Delta on January 1, 2019. AQI values of Guangzhou, Shenzhen and Dongguan presented a double-peak phenomenon. Their AQI increased at 7:00 and reached the first peak during 8:00-9:00. Again, it rose at 18:00 and amounted to the second peak after 20:00. These three cities had a large flow of people and heavy traffic and their AQI values increased at rush hour. In Zhuhai, the significant peak showed up at 18:00. In Jiangmen, AQI peaked at 2:00 and then gradually declined, which might be related to local weather conditions.
Figure 2 Variations of AQI values on an hourly basis in the Pearl River Delta on January 1, 2019.

Figure 3 demonstrated the variations of AQI values on an hourly basis in the Pearl River Delta on June 30, 2019. In Guangzhou, Foshan, Dongguan and Jiangmen, the remarkable AQI peak appeared at 14:00, when the temperature was highest in the day. It was in summer and the ozone concentration soared. Ozone became the major pollutant in ambient air, causing a rapid rise in AQI values. On that day, AQI values of Shenzhen and Zhuhai were lower than 25, suggesting excellent air quality. In Zhongshan and Zhaoqing, the remarkable AQI peak showed up at 12:00.

Figure 3 Variations of AQI values on an hourly basis in the Pearl River Delta on June 30, 2019.

3.2 Variation Characteristics of Air Quality Pollution Levels
AQI pollution levels include five tiers: excellent, good, light pollution, moderate pollution and serious pollution, among which the light pollution or above refer to over-standard air quality. Based on Table 2, during 2015-2019, the excellent and good rate of AQI daily averages of Shenzhen and Huizhou exceeded 90%. In 2017 and 2019, the excellent and good rate of AQI daily averages of Foshan, Jiangmen and Zhongshan was under 80% and the over-standard rate was over 20%, implying poor air quality. In 2016, the excellent and good rate of AQI daily averages of Zhuhai was 94.8%, which was at...
the highest level in the past five years. Compared with that of 2016, the excellent and good rate of AQI daily averages of Zhuhai dropped to 82.2% in 2019, showing a remarkable decline in days with excellent or good air quality. During 2015-2019, the excellent and good rate of AQI daily averages of Zhaoqing ranged from 81.9% to 87.9%, indicating stable air quality.

| Cities     | AQI in 2015 | AQI in 2016 | AQI in 2017 | AQI in 2018 | AQI in 2019 |
|------------|-------------|-------------|-------------|-------------|-------------|
|            | Excellent and good rate (%) | Over-standard rate (%) | Excellent and good rate (%) | Over-standard rate (%) | Excellent and good rate (%) | Over-standard rate (%) | Excellent and good rate (%) | Over-standard rate (%) | Excellent and good rate (%) | Over-standard rate (%) |
| Dongguan   | 85.2        | 14.8        | 86.9        | 13.1        | 80.8        | 19.2        | 87.9        | 12.1        | 78.6        | 21.4        |
| Foshan     | 85.2        | 14.8        | 84.4        | 15.6        | 77.3        | 22.7        | 86.3        | 13.7        | 79.2        | 20.8        |
| Guangzhou  | 87.9        | 12.1        | 84.7        | 15.3        | 79.2        | 20.8        | 85.5        | 14.5        | 80.3        | 19.7        |
| Huizhou    | 97.8        | 2.2         | 96.7        | 3.3         | 94.5        | 5.5         | 96.2        | 3.8         | 95.3        | 4.7         |
| Jiangmen   | 87.9        | 12.1        | 83.9        | 16.1        | 75.6        | 24.4        | 84.9        | 15.1        | 76.7        | 23.3        |
| Shenzhen   | 96.4        | 3.6         | 96.7        | 3.3         | 93.4        | 6.6         | 95.9        | 4.1         | 91.0        | 9.0         |
| Zhaoqing   | 85.5        | 14.5        | 87.3        | 12.7        | 81.9        | 18.1        | 87.9        | 12.1        | 84.4        | 15.6        |
| Zhongshan  | 90.3        | 9.7         | 88.5        | 11.5        | 77.5        | 22.5        | 89.0        | 11.0        | 78.9        | 21.1        |
| Zhuhai     | 90.1        | 9.9         | 94.8        | 5.2         | 87.9        | 12.1        | 91.0        | 9.0         | 82.2        | 17.8        |

4. Conclusion

(1) During 2015-2019, the variation trends of AQI annual averages in the Pearl River Delta were basically the same. The AQI annual averages rose after decline and the variation curves were W-shaped. In both 2017 and 2019, the air quality in this region became worse than one year earlier. In 2017, generally, the AQI annual averages were relatively high, and four cities, including Foshan, Guangzhou, Jiangmen and Zhaoqing, demonstrated an annual average of over 75. Shenzhen and Huizhou enjoyed better air quality in this region.

(2) During 2015-2019, the AQI quarterly averages in the Pearl River Delta were high in autumn and winter but low in summer, and in a same year, the variation trends of nine cities were basically the same. In autumn, the ozone concentration increased dramatically and therefore ozone became a major pollutant in ambient air.

(3) AQI values of Guangzhou, Shenzhen and Dongguan presented a double-peak phenomenon on January 1, 2019 and their AQI values rose at rush hour. On June 30, 2019, in Guangzhou, Foshan, Dongguan and Jiangmen, the remarkable AQI peak appeared at 14:00. At that moment, the ozone concentration soared and ozone became the major pollutant in ambient air. On that day, AQI values of Shenzhen and Zhuhai were lower than 25, suggesting excellent air quality.

Acknowledgments

The paper is supported by the key platform and scientific research of Guangdong Provincial Education Department in 2016-the young Innovative Talents project (natural science): Simulation of urban shallow lake ecosystem and application of eutrophication management (Project Code: 2018KQNCX354), and the"2016 Key Discipline Training Project of Guangdong Province" of Guangdong Provincial Department of Education (Yue Jiao Yan Han [2016] No.19).

References

[1] Shen, J, Liu, YF, & Yan, PZ.(2020)Analysis of ozone formation rate in Guangdong based on three-dimensional air quality model. Environmental Monitoring in China,36:157-164.
[2] Liu, JZ.(2020)Effects of measures for surface atmospheric particulate pollution control in urban
roads. Journal of Green Science and Technology, 12:102-104.

[3] Shen, J, He, L, Cheng, P, Xie, M, et al. (2019) Characteristics of ozone concentration variation in the Northern Background Site of the Pearl River Delta. Ecology and Environment Sciences, 28:2006-2011.

[4] Zhou, MD, Kuang, YQ, & Yun, GL. (2020) Analysis of driving factors of atmospheric PM2.5 concentration in Guangzhou City based on geo-detector. Research of Environmental Sciences, 33:271-279.

[5] Chen, Y, Zhang, JP, & Huang, ZZ. (2017) Spatial-temporal variation of surface ozone in Guangzhou and its relations with meteorological factors. Environmental Monitoring in China, 33:99-109.

[6] Sun, TL, Zou, BB, Huang, XF, et al. (2019) Analysis of the sources of atmospheric PM2.5 in Shenzhen. China Environmental Science, 39:13-20.

[7] Mou, JF, Fan, JJ, Yan, ZN, et al. (2018) Analysis on the pollution characteristics and influence factors of PM2.5 in Shenzhen in 2016. Journal of Hygiene Research, 47:407-412.

[8] Guo, SS, Li, MM, Fang, HB, et al. (2019) Analysis on the formation mechanism of an air pollution process. Environmental Monitoring and Forewarning, 11:17-20.

[9] Bu, QL, Gan, Q, & Huang, XX. (2020) Variation characteristics of surface ozone in Foshan and its relations with meteorological factors. Guangdong Meteorology, 42:46-49.

[10] Wang, Y, Wang, ZC, Ji, P, et al. (2017) Spatial distribution types and weather background of air quality in the Pearl River Delta area. Environmental Engineering. 2017;35:77-81.

[11] Wu, M, Luo, Y, Wu, D, et al. (2019) Effect of dry season boundary layer vertical temperature structure in the Pearl River Delta on air quality. Environmental Science & Technology, 42:189-195.

[12] Yu, KY, Huang, ZJ, Shi, BW, et al. (2020) Identification of key uncertainties of air quality simulation in the Pearl River Delta. Acta Scientiae Circumstantiae, 40:2952-2961.

[13] Liu, J, Wu, D, Fan, SJ, et al. (2017) Impacts of precursors and meteorological factors on ozone pollution in Pearl River Delta. China Environmental Science, 37:813-820.