Effect of rainfall intensity on PM\textsubscript{10} and PM\textsubscript{2.5} scavenging in Guangzhou at night

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Abstract: The Lingnan area is a region where frequent rainfall occurs in mainland China. In addition to the special occurrence period, the nighttime rainfall has obvious seasonal characteristics, which is different from the climatic boundary conditions during the daytime, and has a great influence on the migration and transformation process of atmospheric pollutants. By counting the observations of atmospheric particulate matter (PM\textsubscript{2.5}, PM\textsubscript{10}) before and after rainfall in the Pearl River Delta region, the average clearance rate of PM\textsubscript{10} and PM\textsubscript{2.5} for the whole region was 2.36% and 1.41%, and the average clearance rate of night rainfall was calculated 6.44%, 4.22%. The results show that the rainfall can effectively remove atmospheric particulate pollutants through wet deposition, and the nighttime rainfall is more effective than the daytime rainfall on the atmospheric particulate matter. Through classification discussion, it is found that the greater the rainfall intensity, the longer the rainfall time, the larger the particle size, and the more obvious the advantage of night rain.

Keywords: Nighttime rainfall; Atmospheric particulate pollutants; Scavenging coefficients.

1. Introduction
The Pearl River Delta region is an area where ash identification, research and treatment were carried out earlier in China. A large number of automatic air quality monitoring stations were established as early as the beginning of the 21st century, and the air monitoring of the Guangdong-Hong Kong (Australia) Pearl River Delta region was established in 2006. The network began a relatively complete air pollution record. The domestic research on the pollution characteristics of various air pollutants in the Pearl River Delta has carried out rich research. By studying the distribution characteristics of pollutants such as PM\textsubscript{2.5} and ozone, it is proved that the high pollution weather in the Pearl River Delta is caused by primary pollution and secondary pollution, and in the context of regional transmission of urban agglomeration, pollution is more likely to be aggravated and more difficult to control; the trend analysis of pollutants shows that all kinds of pollutants show obvious seasonal characteristics, and ozone is the primary The proportion of pollutants has increased year by year, and other pollutants such as inhalable particulate matter have been decreasing year by year.

Meteorological factors are considered to be direct impact factors of atmospheric pollution, including atmospheric boundary characteristics such as wind speed, wind direction and temperature, which have
different effects on the generation, formation, propagation, diffusion, transformation and sedimentation of atmospheric pollutants. Rainfall has obvious wet deposition effects on atmospheric pollutants, especially atmospheric particulate matter; the Pearl River Delta is humid and warm all year round, and rainfall is abundant. The role of rainfall is particularly important. In precipitation, the special nature of night rain is often mentioned: night rainfall refers to rainwater that naturally falls between 20:00 and 8:00 on the day. The Pearl River Delta region is rich in night rain resources. The average annual night rainfall is 722mm, and the average annual rain rate has reached 41.44%. Many scholars have found that atmospheric pollutants exhibit different characteristics between day and night. In order to find out the special effects of nighttime rainfall on atmospheric particulate matter, this paper uses the observed meteorological and atmospheric particulate matter pollution data to quantitatively analyze the effects of different levels of rain intensity, rainfall duration of night rain and daily rain on atmospheric particulate matter, and reveals the hysteresis effect of rainfall removal to further explore the superiority of night rain removal capability.

2. Study area and method

2.1. Study area and Source of raw data

The data used herein includes rainfall observation data and atmospheric particulate matter monitoring data. The complete set of meteorological data including rainfall data is the hourly observation data of the China Ground Meteorological Station released by the National Meteorological Information Center on the China Meteorological Data Network (http://data.cma.cn). The direct data source is national level. The hourly data files of the basic station, the meteorological elements data have undergone strict quality control, the data real rate is over 99.9%, and the data correct rate is close to 100%. There are 18 national-level basic weather stations in the Pearl River Delta region, as shown in Figure 1. The time series of rainfall data is from 2014 to March 2019, with a minimum observation interval of 1 hour and a data accuracy of 0.1 mm.

The atmospheric particulate matter studied in this paper includes two categories: PM$_{2.5}$ and PM$_{10}$. The data comes from the National Urban Air Quality Real-Time Release Platform of China Environmental Monitoring Station (http:///.106.37.208.233:20035/), which includes monitoring data of atmospheric pollutants in 338 urban areas across the country. In 2012, the Ministry of Environmental Protection established the platform on the basis of the “Eleventh Five-Year” National Environmental Air Monitoring Network. The data is directly from the 1436-point urban environmental air automatic monitoring station in the National Ambient Air Monitoring Network. The main contents of the monitoring include Reference values for data such as SO$_2$, NO$_2$, CO, O$_3$, PM$_{10}$, and PM$_{2.5}$. The data is authentic and has been used in many studies. There are 56 automatic monitoring stations in 9 prefecture-level cities in the Pearl River Delta, which are evenly distributed among the urban areas with frequent urban pollution. The urban ambient air automatic monitoring station observes once a minute, and the instrument automatically processes the hourly data and uploads it to the platform. Among them, the data unit of PM$_{2.5}$ and PM$_{10}$ is micrograms/m$^3$.

2.2. Method

2.2.1. Scavenging coefficients. The rate of precipitation of atmospheric particulate matter by rainfall refers to the efficiency of rainfall on the wet deposition of atmospheric particulate matter. The removal rate of atmospheric particulate matter may be affected by other meteorological elements such as wind speed, humidity and pollution source characteristics, but there are large differences.

$$r = \frac{(\rho_{before} - \rho_{after}) \rho_{before}}{\rho_{before}} \times 100\% \quad (1)$$

Among them, the concentration of atmospheric particulate matter before rainfall represents the concentration of atmospheric particulate matter after rainfall; $r$ is the clearance rate, $r$ is positive, which represents the decrease of atmospheric particulate matter concentration after rainfall, and $r$ is negative, which represents the increase of atmospheric particulate matter concentration after rainfall.
The content of this study corresponds to hourly data of rainfall data and atmospheric particulate matter concentration, starting with 20:00 every day and ending at 19:00. According to the definition of night rain, rainfall is divided into night rain and daily rain. According to past studies, when the water stop interval exceeds 1 h, it is regarded as the secondary rainfall process, and each rainfall has a corresponding clearance rate. According to the classification of precipitation grade by the China Meteorological Administration, when the hourly rainfall is 0.1-2.5mm, 2.6-7.6mm, or more than 7.6mm, the rainfall is divided into light rain, moderate rain and heavy rain, and then studied at different rainfall intensities. Under the conditions, night rain and daily rain are effective in scouring and removing atmospheric particulate pollutants.

3. Scavenging effects of night rain with different rainfall intensities on atmospheric particulate pollutants

The relationship between different rainfall intensity and PM$_{2.5}$ and PM$_{10}$ removal rate in Guangzhou during the observation period is shown in Fig. 1 and Fig. 2. In order to facilitate the comparison discussion, the frequency of rainfall in different time periods is uniformly expressed as the proportion of the frequency corresponding to different clearance rates to the rainfall level, that is, the proportion of the rainfall frequency. The removal rate is positive, which means that the mass concentration of atmospheric particulate pollutants decreases after rainfall; while the removal rate is negative, which means that the mass concentration of atmospheric particulate pollutants increases after precipitation. When PM$_{2.5}$ is the primary pollutant, as shown in Figure 4, the sample of light rain is the largest of all samples, the distribution of clearance rate is more discrete, and the main clearance rate is between 0%-20%, indicating that the rain is The removal efficiency of PM$_{2.5}$ is not high, the impact of raindrops on aerosol particles is low, and it is greatly affected by other factors, but it can still be found that the clearance rate corresponding to night rain is slightly higher than the clearance rate corresponding to daily rain. In the process of moderate rain and heavy rain, most of the events of rainfall removal of atmospheric particulate pollutants are distributed in the interval where the clearance rate is positive, and in the interval of high clearance rate, the occurrence probability of night rain is significantly greater than that of daily rain. When night rain occurs, the average clearance rate of PM$_{2.5}$ for light rain, moderate rain and heavy rain is 1.56%, 22.11%, and 22.08%, which is greater than the situation when the rain occurs -5.51%, 5.04%, 15.84%. This indicates that the night rain has a higher probability of clearing PM$_{2.5}$ than the rain, and as the rainfall intensity increases, the removal effect is better.

[Figures and diagrams are not provided in the text.]
Comparing the clearance rate of PM$_{10}$ corresponding to different rainfall levels, we can find that the law of yield is similar to the law of PM$_{2.5}$ corresponding clearance rate. The greater the rain intensity, the more the PM$_{10}$ removal rate is concentrated in the high value section, that is, the rainfall to PM$_{10}$. The removal effect is better, and the rain intensity increases accordingly. The superiority of night rain and daily rain to remove atmospheric particulate pollutants is also more obvious. When night rain occurs, the average clearance rate of PM$_{10}$ for light rain, moderate rain and heavy rain is 5.16%, 27.34%, 25.73%, which is greater than the average clearance rate for PM$_{2.5}$.

**Fig. 2 Relationship between different rainfall intensities and PM$_{10}$ scavenging rate in Guangzhou**

**4. Conclusion**

In this paper, we compare the nighttime rainfall and daytime rainfall of different rainfall intensities to the removal of atmospheric particulate matter, and basically obtain the following conclusions:

(1) By studying the cleaning effect of rainfall on atmospheric particulate pollutants in the Pearl River Delta region, it is found that rainfall can effectively remove atmospheric particulate pollutants, and the removal rate of PM$_{10}$ is greater than the removal rate of PM$_{2.5}$.

(2) In Guangzhou, the effect of night rain on the removal of atmospheric particulate pollutants is generally better than that of daily rain, and the removal rate of PM$_{10}$ is significantly better than that of the same rain intensity and the same rainfall duration. As the rain intensity increases, the rainfall duration increases, and the night rain is more effective in removing PM$_{10}$ and PM$_{2.5}$ than the rain.

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