Analysis of Characteristics and Meteorological Influencing Factors of Air Pollution in Luojiang District, Deyang City

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Abstract Based on the monitoring data of ambient air quality and meteorological observation data, the characteristics and meteorological influencing factors of air pollution in Luojiang District of Deyang City from 2018 to 2022 were analyzed. The results show that from 2018 to 2022, the main air pollutants affecting the air quality of Luojiang District of Deyang City were $PM_{2.5}$ and PM_{10}, and the primary pollutant on heavy pollution days was basically $PM_{2.5}$. $PM_{2.5}$ and PM_{10} pollution showed obvious seasonal differences, and $PM_{2.5}$ concentration exceeded the limit mainly in spring and winter, among which it was the most serious in early spring, especially in January and February, followed by December. PM_{10} exceeding the standard had a high seasonal correlation with $PM_{2.5}$ exceeding the standard, mainly in spring and winter, among which it was the most serious in winter, especially in December, followed by January. $PM_{2.5}$ and PM_{10} pollution showed an overall weakening trend. $PM_{2.5}$ and PM_{10} concentration were closely related to meteorological factors such as temperature, relative humidity, wind speed, precipitation and air pressure, and were mainly affected by rainfall.

Key words Luojiang District of Deyang City; Air pollution; Meteorology; Characteristics

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Air quality is closely related to the comprehensive competitiveness of a city and directly affects the investment environment and residents' health, so it is increasingly concerned by the government and the public. The process of urbanization is the only way for developing countries to realize modernization, but this process often leads to the intensification of environmental pollution, industrial concentration, dense population and large consumption of fossil fuels, and high-density buildings are not conducive to the diffusion of air pollutants, so it is easy to cause serious air pollution.

In recent years, air pollution events have occurred in many places of China. Domestic scholars have conducted a lot of research on air pollution characteristics and its influencing factors. The research results show that the spatial and temporal distribution and concentration of air pollutants are not only related to the distribution, type and emission of pollution sources, but also closely related to terrain and meteorological conditions. Located in the northeast edge of Chengdu Plain, Luojiang District of Deyang City, Sichuan Province, occupies an important position in the construction of the dual economic circle in Chengdu and Chongqing. It has a hilly landform, and the terrain is high in the southwest and low in the northeast. Wind is mostly northeaster, and wind speed is small. The water system is developed, and relative humidity is high. Geographical and meteorological conditions are not conducive to the diffusion of air pollutants. There is a certain traditional heavy industry base, so air quality has been widely concerned. Since 2017, Luojiang District, Deyang City has regularly carried out special actions such as "blue sky defense war", "air pollution battle", "eight major projects of blue sky defense war", adhered to the control of "living source, industrial source, dust source, and mobile source", and carried out special remediation of "road dust, food fume, and straw burning ban". As a results, air quality has generally improved. However, there is still a certain gap from the expected, and meteorological factors have a huge impact on air pollution. According to the *Ambient Air Quality Standards* (GB 3095 - 2012) and *Technical Regulation on Ambient Air Quality Index* (on trial) (HJ 633 - 2012), it is meaningful to explore the temporal and spatial distribution of air pollutants such as $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO and O_3, which mainly affect AQI index in Luojiang District, and their correlation with meteorological elements such as wind, pressure, temperature and humidity.

In this paper, based on the monitoring data of ambient air quality from Luojiang Ecological Environment Bureau and the meteorological observation data of Deyang National Meteorological Observation Station (56198) from 2018 to 2022, the characteristics of air pollution in Luojiang District, Deyang City during 2018 - 2022 were analyzed by statistical methods. The influence of conventional meteorological elements on the concentration of major air pollutants in Luojiang District was discussed to provide reference for air quality forecast and air pollution early warning and scientific basis for relevant departments to make decisions on the prevention of air pollution and protection of urban ecological environment.

1 Data and methods

Data included the observation data collected from the auto-

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matic station of Luojiang Ecological Environment Bureau, and the surface meteorological observation data of Luojiang District, Deyang City. The spatial and temporal variation characteristics of air pollutants, distribution characteristics of primary pollutants and secondary pollutants in Luojiang District, Deyang City were analyzed. Combined with statistical analysis, spss was used to analyze the correlation between primary and secondary pollutants and meteorological elements.

Air quality index (*AQI*) is used to quantify the level of air quality, ranging from 0 to 500 (Table 1). There are many types of ambient air pollutants, of which sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and suspended particulate matter ($PM_{2.5}$, and PM_{10}) are common. *AQI* is converted according to the concentration of various pollutants. The *AQI* values of various pollutants are calculated respectively, and the largest one is as the *AQI* value of the final report. Its formula is as follows:

$$IAQI_P = \frac{IAQI_{Hi} - IAQI_{Lo}}{BP_{Hi} - BP_{Lo}}(C_P - BP_{Lo}) + IAQI_{Lo} \quad (1)$$

$$AQI = \max\{IAQI_1, IAQI_2, IAQI_3, \cdots IAQI_n\} \quad (2)$$

In the formula, $IAQI_P$ is the air quality sub-index of pollutant P; C_P is the mass concentration of pollutant P; BP_{Hi} is the high value of pollutant concentration limit similar to C_P, constant; BP_{Lo} is the low value of pollutant concentration limit similar to C_P, constant; $IAQI_{Hi}$ is the air distribution quality index corresponding to BP_{Hi}, constant; $IAQI_{Lo}$ is the air distribution quality index corresponding to BP_{Lo}, constant; *AQI* is air quality index; *IAQI* is air quality sub-index; n is the number of pollutants.

Table 1 Air quality index

AQI	Grade of air quality	Category of air quality	
0 – 50	I	Very good	Green
51 – 100	II	Good	Yellow
101 – 150	III	Light pollution	Orange
151 – 200	IV	Moderate pollution	Red
201 – 300	V	Serious pollution	Purple
>300	VI	Very serious pollution	Maroon

Spring is from March to May, and summer is from June to August; autumn is from September to November, and winter is from December to next January or February.

The 24-hour average data of SO_2, NO_2, CO, O_3, $PM_{2.5}$, PM_{10} and *AQI* from January 1, 2018 to December 31, 2022 were from Luojiang Ecological Environment Bureau, and the daily average temperature, daily maximum temperature, daily minimum temperature, 2-min average wind speed, daily precipitation, daily average relative humidity, and daily pressure from January 1, 2018 to December 31, 2022 were from Deyang National Meteorological Observation Station (56198).

2 Results and analysis

2.1 General overview of air quality As shown in Fig. 1, the air quality of Luojiang District, Deyang City from 2018 to 2022 was mostly very good or good, with a total of 1 687 d, accounting for 92.39%; light pollution days were 116 d, accounting for 6.35%; moderate pollution days were 19 d, accounting for 1.04%; serious pollution days were only 4 d, accounting for 0.22%; there was no very serious pollution.

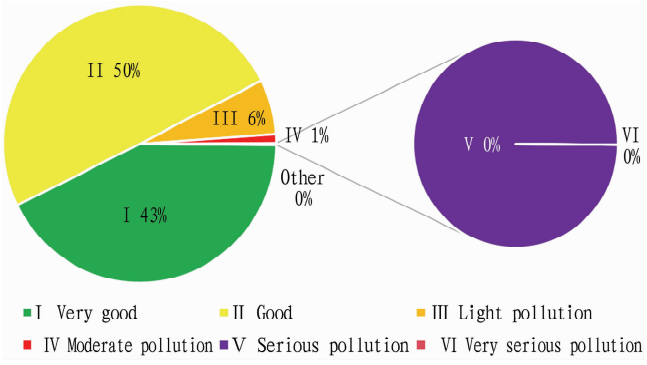

Fig. 1 Proportion of *AQI* days at all levels in Luojiang District, Deyang City

According to the analysis of pollutants, the main air pollutant in Luojiang District, Deyang City from 2018 to 2022 was $PM_{2.5}$, followed by PM_{10}. SO_2, NO_2, CO and O_3 did not exceed the limits (Fig. 2).

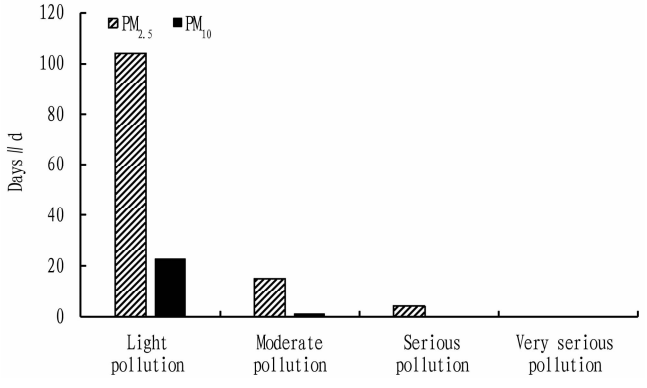

Fig. 2 Distribution of pollutant days in Luojiang District, Deyang City

On pollution days (*AQI* > 100), the primary pollutant was $PM_{2.5}$, followed by PM_{10}, and the primary pollutant on serious pollution days was $PM_{2.5}$. Therefore, the air pollutants affecting the air quality of Luojiang District in Deyang City from 2018 to 2022 were mainly $PM_{2.5}$ and PM_{10}.

2.2 Annual variation characteristics of air pollution As can be seen from Fig. 3, the days of $PM_{2.5}$ and PM_{10} exceeding the limits in Luojiang District of Deyang City generally showed a downward trend. The number of pollution days decreased sharply from 2018 to 2019, and it was slightly larger in 2021 compared with 2020. From 2018 to 2022, the number of days polluted by $PM_{2.5}$ far exceeded that of PM_{10}.

2.3 Seasonal variation characteristics of air pollution As shown in Fig. 4, the days of $PM_{2.5}$ exceeding the limit from 2018 to 2022 in Luojiang District of Deyang City had obvious seasonal

differences, appearing from January to March and from September to December. That is, it gradually weakened and disappeared in late spring, but did not appear in summer, and began to appear in early autumn. The pollution was particularly serious in winter. Among them, the days with moderate and severe pollution were mainly distributed from December to February.

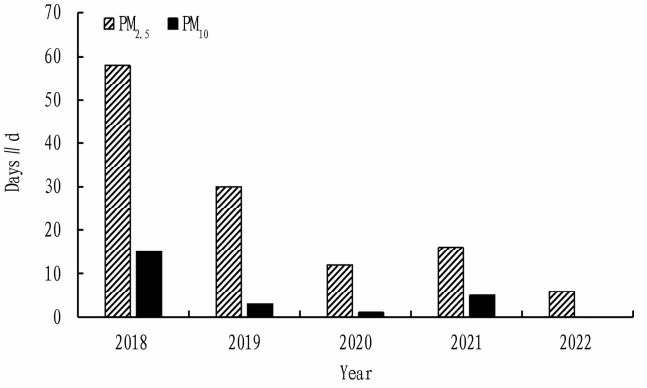

Fig. 3 Annual changes of the days of $PM_{2.5}$ and PM_{10} exceeding the limits in Luojiang District, Deyang City from 2018 to 2022

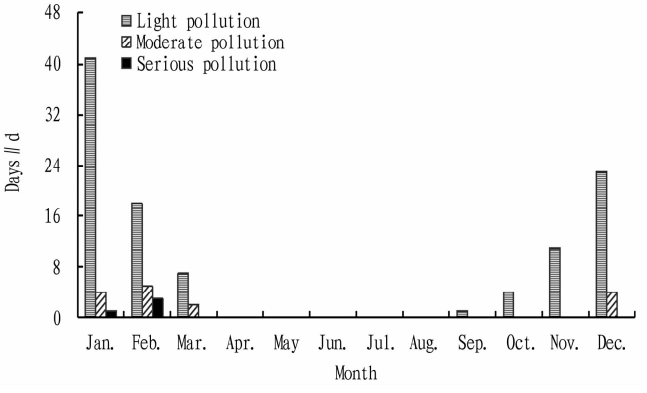

Fig. 4 Monthly distribution of cumulative days with $PM_{2.5}$ exceeding the limit in Luojiang District, Deyang City from 2018 to 2022

Seen from Fig. 5, the distribution of cumulative days with PM_{10} exceeding the limit in Luojiang District, Deyang City from 2018 to 2022 was similar to that of $PM_{2.5}$, with obvious seasonal differences, mainly appearing from January to March and from October to December. That is, it gradually weakened and disappeared in late spring, but did not appear in summer, and began to appear in middle autumn. The pollution was particularly serious in winter. Among them, the days with moderate pollution were mainly distributed in December, and there was no serious pollution.

Secondly, the days with both $PM_{2.5}$ and PM_{10} exceeding the limits were 111 d, accounting for 79.86% of the total number of polluted days, and they were mainly distributed in winter (January, December and next February). Therefore, air pollution in Luojiang District of Deyang City occurred in spring, autumn and winter, and was mainly distributed in winter. The main pollutants were $PM_{2.5}$ and PM_{10}.

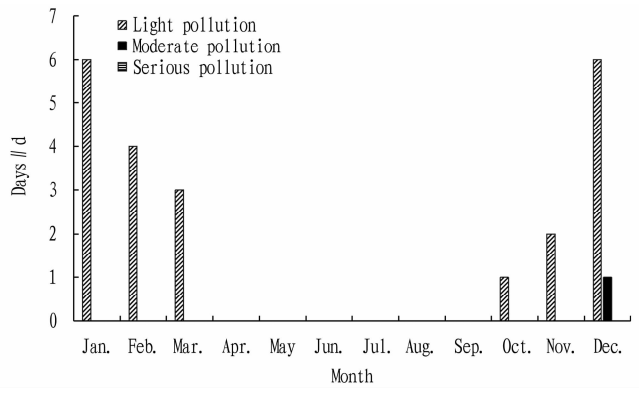

Fig. 5 Monthly distribution of cumulative days with PM_{10} exceeding the limit in Luojiang District, Deyang City from 2018 to 2022

3 Influence of meteorological factors on the concentration of major air pollutants

Air quality is closely related to meteorological conditions. Under different meteorological conditions, the degree of ground pollution caused by pollutants discharged from the same source varies greatly, because air pollution often occurs under unfavorable meteorological conditions.

The main air pollutants in Luojiang District of Deyang City are $PM_{2.5}$ and PM_{10}, and can reduce visibility and damage human health. Besides, they will have adverse effects on other animals and plants in the ecosystem. In particular, $PM_{2.5}$ particles are smaller in size, easier to enter the human body, and have a larger surface area. The longer $PM_{2.5}$ stays in the environment, the more harmful substances it absorbs, and the more likely it is to cause greater health hazards.

3.1 Influence of meteorological elements on $PM_{2.5}$ concentration The correlation between the daily average of $PM_{2.5}$ concentration and meteorological elements (daily average temperature, daily maximum temperature, daily minimum temperature, 2-min average wind speed, daily precipitation, daily average relative humidity, and daily average pressure) in Luojiang District of Deyang City from 2018 to 2022 (precipitation has sedimentation effect on particulate matter, and the air humidity on precipitation days is relatively high, so days with precipitation were excluded) was analyzed. The results are shown in Table 2.

As can be seen from Table 2, $PM_{2.5}$ concentration was positively correlated with daily average temperature, daily maximum temperature, daily average relative humidity and pressure, and negatively correlated with daily minimum temperature, 2-min average wind speed and daily precipitation, and each correlation coefficient was statistically significant at $\alpha = 0.01$ level. It had the most obvious correlation with daily precipitation, because precipitation has sedimentation effect on particulate matter. Therefore, it can be inferred that the daily average of $PM_{2.5}$ concentration in Luojiang District of Deyang City was greatly affected by precipitation, and $PM_{2.5}$ concentration often exceeded the limit in haze

days, which was mainly distributed in winter. Hence, $PM_{2.5}$ pollution in Luojiang District of Deyang City was greatly affected by the season and the topography of Sichuan Basin. In winter, the atmosphere is static and stable, and the diffusion conditions are poor. The basin is prone to fog in the morning and evening, and heating demand is rising, which is easy to cause $PM_{2.5}$ accumulation pollution.

Table 2 Kendall correlation coefficients between $PM_{2.5}$ concentration and meteorological elements in Luojiang District, Deyang City from 2018 to 2022

$PM_{2.5}$	Daily average temperature	Daily maximum temperature	Daily minimum temperature	2-min average wind speed	Daily precipitation	Daily average relative humidity	Daily average pressure
Kendall correlation coefficient	0.213**	0.163**	−0.138**	−0.197**	−0.351**	0.073**	0.144**

Note: ** indicates significant correlation at $\alpha = 0.01$ level.

3.2 Influence of meteorological elements on PM_{10} concentration The correlation between the daily average of PM_{10} concentration and meteorological elements (daily average temperature, daily maximum temperature, daily minimum temperature, 2-min average wind speed, daily precipitation, daily average relative humidity, and daily average pressure) in Luojiang District of Deyang City during 2018 − 2022 (precipitation has sedimentation effect on particulate matter, and the air humidity on precipitation days is relatively high, so days with precipitation were excluded) was analyzed. The results are shown in Table 3.

As shown in Table 3, PM_{10} concentration was negatively correlated with daily average temperature, daily maximum temperature, daily minimum temperature, 2-min average wind speed and daily precipitation, and negatively correlated with pressure. The above correlation coefficients were statistically significant at $\alpha = 0.01$ level. It had no significant correlation with daily average relative humidity. PM_{10} concentration had the most obvious correlation with daily precipitation, because precipitation has sedimentation effect on particulate matter. Besides precipitation, it had the greatest correlation with daily minimum temperature. Therefore, it can be inferred that the daily average of PM_{10} concentration in Luojiang District of Deyang City was greatly affected by precipitation, and PM_{10} was mainly distributed in winter. In winter, there is little precipitation and more dust on the road surface. Moreover, a large amount of PM_{10} is also generated by anthropogenic sources such as burning, heating and power supply. Hence, PM_{10} pollution in Luojiang District of Deyang City is greatly influenced by the season and the topography of Sichuan Basin. In winter, the air is dry, and precipitation is scarce. There is more dust on the ground, and heating demand is rising, which is easy to cause PM_{10} accumulation pollution.

Table 3 Kendall correlation coefficients between PM_{10} concentration and meteorological elements in Luojiang District, Deyang City from 2018 to 2022

PM_{10}	Daily average temperature	Daily maximum temperature	Daily minimum temperature	2-min average wind speed	Daily precipitation	Daily average relative humidity	Daily average pressure
Kendall correlation coefficient	−0.222**	−0.135**	−0.288**	−0.204**	−0.404**	−0.024	0.179**

Note: ** indicates significant correlation at $\alpha = 0.01$ level.

4 Analysis of influencing factors

4.1 Topographic factor Luojiang District, Deyang City, is located on the edge of Sichuan Basin. The terrain is high in the northwest and low in the southeast, and the dam area in the middle is relatively low and flat. As a result, the pollutants in the area are not easy to diffuse, and the self-purification capacity of the atmosphere is relatively low.

4.2 Meteorological factors The dilution, diffusion and self-removal ability of pollutants are the result of a variety of meteorological factors, in which wind field, turbulence, precipitation and temperature play a decisive role.

4.2.1 The average wind speed is the lowest and the quiet wind frequency is the highest. Wind system includes wind direction and speed, and the change of wind direction determines the transmission direction of pollutants, while the size of wind speed determines the transport distance of pollutants.

The annual average wind speed in Luojiang District of Deyang City is 1.4 − 1.6 m/s, and the frequency of ground static wind is the highest in winter. Such meteorological conditions are extremely unfavorable to the diffusion of pollutants, resulting in the accumulation of pollutants and the sharp deterioration of air quality, which is an important factor aggravating air pollution.

4.2.2 The atmospheric stratification is relatively stable, and the thickness of the mixing layer is small, while the temperature inversion frequency is high in winter. The temperature inversion and low wind speed seriously hinder the convective movement of air, inhibit the development of turbulence, result in relatively stable atmospheric stratification, and limit the development of the mixing layer. The thickness of the mixing layer determines the range of vertical diffusion of pollutants.

The frequency of temperature inversion in winter is high in Luojiang District of Deyang City. The physical mechanism of temperature inversion is mainly the result of the joint action of geographical location, topographic conditions, weather and climate characteristics.

4.2.3 Precipitation varies greatly with the seasons, and is less

in winter. Precipitation plays an important role in reducing dust, increasing vegetation cover, and removing suspended particles and gaseous pollutants (wet deposition) from the atmosphere. The precipitation in Luojiang District of Deyang City is more in summer and less in winter and spring, which is not conducive to the removal of air pollutants.

4.3 Human factors

4.3.1 Industrial pollution. The economic growth of Luojiang District in Deyang City is mainly driven by industry, and the industrial development is inseparable from the burning of fossil fuels, while the burning of fossil fuels leads to the accumulation of air pollutants. In Luojiang District of Deyang City, the wind near the ground is mostly northeast wind, and there is an industrial park in the north of Luojiang District, where a large number of enterprises are located in the uptake, which has a certain impact on air pollution.

4.3.2 Automobile exhaust pollution. With the continuous increase of per capita income, the number of urban motor vehicles is increasing, and the exhaust pollution is becoming more and more serious. However, the public transportation system of Luojiang is not perfect, and the traffic structure is not reasonable enough, so that urban traffic jams are easy to occur, which further deepens the pollution degree of the atmospheric environment. The discharge of motor vehicle exhaust is a major source of air pollution in Luojiang District of Deyang City.

4.3.3 Heat island effect. With the acceleration of urbanization, the acceleration of economic development and the destruction of ecological environment, the annual temperature difference between the urban and suburb areas of Luojiang District of Deyang City has gradually increased, and the temperature in the urban area is obviously higher than that in the suburbs, indicating that the urban heat island effect is obvious. Urban heat island circulation causes pollutants discharged by surrounding factories to enter the city, aggravating urban air pollution.

5 Conclusions

(1) In terms of primary pollutants, the air pollutants affecting the air quality of Luojiang District in Deyang City from 2018 to 2022 was mainly $PM_{2.5}$, and the secondary pollutant was PM_{10}.

(2) From the perspective of seasonal variation, $PM_{2.5}$ and PM_{10} in Luojiang District of Deyang City showed obvious seasonal changes from 2018 to 2022. $PM_{2.5}$ and PM_{10} concentration exceeded the limits mainly in autumn, winter and early spring (from September to next March). The pollution was more serious from December to February in winter, and both $PM_{2.5}$ and PM_{10} concentration often exceeded the limits simultaneously.

(3) From the perspective of annual variation, due to the implementation of special actions such as "Blue Sky Defense War", "Air Pollution Battle" and "Eight Projects dedicated to Blue Sky Defense War", the overall air condition of Luojiang District in Deyang City from 2018 to 2022 was mainly good, and the pollution is mainly light. The air pollution situation continued to get lighter, and the number of pollution days decreased significantly.

(4) $PM_{2.5}$ concentration was positively correlated with daily average temperature, daily maximum temperature, daily average relative humidity and pressure, and negatively correlated with daily minimum temperature, 2-min average wind speed and daily precipitation. PM_{10} concentration was negatively correlated with daily average temperature, daily maximum temperature, daily minimum temperature, 2-min average wind speed and daily precipitation, and negatively correlated with pressure, while it had no obvious correlation with daily relative humidity in the absence of precipitation. $PM_{2.5}$ and PM_{10} were most affected by rainfall, and rainfall has a good effect on the elimination of major and minor air pollutants in Luojiang.

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