Variation Characteristics of PM2.5 Concentration and Analysis of Meteorological Factors in Shanghai (Postprint)

Authors: Wang Yidi, Wang Zhenxiang

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Abstract

Data on PM2.5 mass concentration and meteorological factors in Shanghai from 2012 to 2016 were compiled and statistically analyzed. By combining qualitative analysis with quantitative calculations, the variation characteristics of PM2.5 concentration and its pollution status in Shanghai in recent years were revealed; furthermore, using correlation analysis, the relationship between PM2.5 concentration and meteorological factors including temperature, atmospheric pressure, relative humidity, wind direction, wind speed, and precipitation was investigated. The results show that air quality in Shanghai over the past five years has been primarily excellent and good, with the proportion of polluted days throughout the year decreasing. PM2.5 concentration exhibits seasonal characteristics of low levels in summer and high levels in winter, with August having the lowest PM2.5 concentration, ranging from 16 to 36 g m^{-3}; the diurnal variation of PM2.5 shows a double-peak and double-valley structure, with concentration peaks occurring at 8:00-9:00 and 19:00-20:00, with the latter having higher concentrations. Threshold values for temperature, atmospheric pressure, and relative humidity appear at 9.8 °C, 766.3 mm Hg, and 83%, respectively, with maximum PM2.5 showing significant changes at these thresholds; maximum PM2.5 concentration shows a logarithmic relationship with cumulative wind speed and precipitation, and when the cumulative wind speed of northeasterly and southeasterly winds exceeds 350 m s^{-1}, PM2.5 concentration generally decreases to 35 g m^{-3}; the greater the precipitation, the lower the PM2.5 concentration.

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Full Text

Characteristics of PM2.5 Concentration Variability and Its Meteorological Factors in Shanghai

WANG Yidi[1,2], **WANG Zhenxiang**[3]

[1] School of Geographic Sciences, East China Normal University, Shanghai 200241, China
[2] Dept. of Ecosystem Science and Sustainability, Colorado State University, CO 80521, United States
[3] Yangtze Estuary Hydrology and Water Resources Survey Bureau, Shanghai 200136, China

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Abstract

This paper systematically analyzes the temporal variability of the mass concentration of PM2.5 in Shanghai, and discusses the effects of meteorological factors on the concentration of PM2.5. It reveals the temporal variability of the PM2.5 concentration and the status of atmospheric pollution in recent years in Shanghai through multi-scale statistics, qualitative analysis and quantitative computation on meteorological data provided by China Air Quality Online Monitoring and Analysis Platform, as well as China Meteorological Administration. The correlation analysis is applied in understanding the relationship between the PM2.5 concentration and meteorological factors (the temperature, air pressure, the relative humidity, wind direction, wind speed and precipitation) in Shanghai from 2012 to 2016.

The results showed that most of the time the air quality in Shanghai has been good or excellent in recent 5 years and the number of days when it was suffered from the pollution has been decreasing. The PM2.5 concentration displayed a seasonal feature which indicated a lower value in the summer and a higher value in the winter with the lowest value in August of 16–36 $g \cdot m^{-3}$. The daily variation shows a structure of two peaks and two valleys, with the concentration peaks occurred during 8:00 AM to 9:00 AM and 7:00 PM to 8:00 PM higher during the latter period. The thresholds of the temperature, the air pressure and the relative humidity were 9.8℃, 1021.6 hPa and 83% respectively which were normally the inflection points of the PM2.5 concentration. There was a logarithmic relationship between the maximum PM2.5 concentration and the accumulated wind speed and precipitation. When the accumulated wind speed of northeasterly and southeasterly reached 350 $m \cdot s^{-1}$, the PM2.5 concentration was decreased to 35 $g \cdot m^{-3}$. The bigger the precipitation was, the lower the concentration of PM2.5 became. This paper showed a good correlation between meteorological factors and the concentration of PM2.5, and its numerical model

had a positive effect on the prediction of the concentration of PM2.5 and the treatment for atmospheric environment.

Keywords: PM2.5 concentration; pollution characteristics; meteorological factors; correlation

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2. Data and Methods

2.1 Data Sources

2.1.1 PM2.5 Data PM2.5 concentration data for Shanghai from 2012 to 2016 were obtained from the China Air Quality Online Monitoring and Analysis Platform. According to the Chinese National Ambient Air Quality Standard (GB3095-2012) and the U.S. National Ambient Air Quality Standards (NAAQS), PM2.5 concentrations are classified into three categories: excellent ($12\mu g \cdot m^{-3}$), good (12–$35\mu g \cdot m^{-3}$), and polluted ($> 35\mu g \cdot m^{-3}$).

Seasonal analysis indicates that summer months (June–August) had the lowest PM2.5 concentrations, with averages of 16–36 $g \cdot m^{-3}$, while winter months (December–February) exhibited the highest concentrations, reaching 64–122 $g \cdot m^{-3}$. The five-year average PM2.5 concentration was 25.51 $g \cdot m^{-3}$ in summer and 74.22 $g \cdot m^{-3}$ in winter.

Daily variation analysis reveals a characteristic two-peak pattern (Fig. 7). The first peak occurs in the morning (8:00–9:00 AM), while the second, more pronounced peak occurs in the evening (7:00–8:00 PM). The proportion of hours with good air quality varies seasonally, with summer showing the highest percentage (36%) and winter the lowest (6%).

2.1.2 Meteorological Data Meteorological data, including temperature, air pressure, relative humidity, wind direction, wind speed, and precipitation, were collected from the China Meteorological Administration for the same period. Daily and seasonal averages were calculated for correlation analysis with PM2.5 concentrations.

2.2 Analysis Methods

Correlation analysis was employed to investigate relationships between PM2.5 concentration and meteorological factors. The analysis focused on identifying critical thresholds and quantitative relationships.

Temperature: The temperature range during the study period was -8°C to 40°C, with a mean of 9.8°C. Statistical analysis reveals a significant negative correlation between temperature and PM2.5 concentration (correlation coefficient = -0.761, $p < 0.01$). When temperature falls below 9.8°C, PM2.5 concentration increases substantially (Fig. 8). The relationship between maximum PM2.5 concentration and temperature shows an inflection point at 9.8°C (Fig. 9).

Air Pressure: The air pressure range was 985.39–1041.2 hPa, with a mean of 1021.6 hPa. Air pressure demonstrates a positive correlation with PM2.5 concentration, with 1021.6 hPa serving as a critical inflection point. When air pressure exceeds 1021.6 hPa, PM2.5 concentration increases significantly. For each 1 hPa increase above this threshold, PM2.5 concentration rises by approximately 1 $\text{g} \cdot \text{m}^{-3}$.

Relative Humidity: The threshold value for relative humidity is 83%. Higher humidity levels correlate with increased PM2.5 concentration due to enhanced particle hygroscopic growth and secondary aerosol formation.

Wind Speed and Precipitation: A logarithmic relationship exists between maximum PM2.5 concentration and accumulated wind speed. When accumulated wind speed from northeasterly and southeasterly directions reaches 350 $\text{m} \cdot \text{s}^{-1}$, PM2.5 concentration decreases to 35 $\text{g} \cdot \text{m}^{-3}$. Precipitation exhibits an inverse relationship with PM2.5 concentration, with larger precipitation amounts leading to lower PM2.5 concentrations through wet deposition processes.

Figure Captions

Fig. 1. Proportions of days with excellent, good, and polluted air quality status in Shanghai during 2012–2016 (based on Chinese standard)

Fig. 3. Proportions of hours with excellent, good, and polluted status in Shanghai during 2012–2016 (seasonal distribution)

Fig. 4. Proportions of hours with excellent, good, and polluted status in Shanghai during 2012–2016 (monthly distribution)

Fig. 5. Distribution of seasonal average concentration of PM2.5 in Shanghai during 2012–2016

Fig. 6. Distribution of monthly average concentration of PM2.5 in Shanghai during 2012–2016

Fig. 7. Daily variation of the concentration of PM2.5 in Shanghai during 2012–2016

Fig. 8. Relationship between the concentration of PM2.5 and air temperature in Shanghai during 2012–2016

Fig. 9. Relationship between the maximum concentration of PM2.5 and air temperature in Shanghai during 2012–2016

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Note: Figure translations are in progress. See original paper for figures.