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Study on the Temporal and Spatial Distribution of Air Pollutants in Typical Cities of China

He Tao† and Tihao Hou
College of Civil Engineering and Architecture, Zhengzhou University of Aeronautics, Zhengzhou 450046, Henan, China
†Corresponding author: Tao He: 54757050@qq.com

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ABSTRACT

The present study selects cities such as Zhengzhou, Kaifeng, Anyang, Hebi, Xinxiang, Jiaozuo, and Puyang along the Yellow River Basin in Henan Province. The data of six pollutants, such as PM2.5, PM10, SO_2, CO, NO_2, and O_3, in various cities from 2019 to 2021, and the monthly primary pollutant data of seven cities in the past five years were collected through various channels. The air quality of the above seven cities was analyzed with the spatial-temporal distribution of pollutants as the research objective and geographic information system as the research tool. The results show that affected by the distribution of key pollution sources and meteorological conditions in the urban area, the PM2.5 concentration generally shows a zonal feature of decreasing from northwest to Southeast. The high-value area is located in the north and west of the integrated area of the seven cities, and the low-value area is located in the Southeast of the seven cities.

INTRODUCTION

In recent years, the problem of air pollution in China has become more serious with the continuous improvement of social and economic levels, while accelerating the process of urbanization and industrialization. The form of air pollution has undergone significant changes, and pollutants will be transported and transformed between cities and regions, transforming from point source pollution and single pollution to non-point source pollution and composite pollution, seriously damaging the ecological environment.

China has proposed the concept of coordinated air pollution control, taking typical regions as pilot areas and adopting multiple measures to build a "regional" scale governance system. This is of great significance for controlling the scope of pollution, reducing the degree of air pollution, and building an environmentally friendly society. In this paper, the data of typical regions in recent years were compared to analyze the effectiveness of governance.

MATERIALS AND METHODS

Geographical Position

The Yellow River enters Henan Province from Tongguan City, Shanxi Province, and flows through 31 counties in 9 cities under the jurisdiction of Henan Province. The total length of rivers in Henan is 711km, and the drainage area is 36200 km^2, accounting for 21.7% of the total area of Henan Province. This paper takes seven cities of Zhengzhou, Xinxiang, Puyang, Kaifeng, Jiaozuo, Anyang, and Hebi as research areas, studies and evaluates the atmospheric environmental quality of the Yellow River Basin in the province, and analyzes the changes and reasons for the ecological environment in the seven cities in the past five years.

Climatic Conditions

The climate of the seven cities in Henan Province in the Yellow River Basin belongs to the temperate continental monsoon region. The annual average temperature is not lower than 0°C, and the annual accumulated temperature is between 3200°C and 4500°C. It is a transitional climate between subtropical and temperate regions with high temperatures and rain in summer, cold and dry in winter, and four distinct seasons. The terrain is mostly plain, and the population is relatively dense.

Social Development

In recent years, with the rapid economic development, the Yellow River Basin has become one of the areas where high energy consumption and high pollution enterprises are concentrated in Henan Province due to the continuous impact of human activities, industrial agglomeration, and other factors. At the same time, the rich water and soil resources brought by the Yellow River make agriculture more developed, the overall economic benefits are higher, and the population is relatively dense.

RESULTS AND DISCUSSION

Annual Variation of Air Pollutants in Typical Cities

CO Concentration in seven cities in 2019-2021: For excellent days, take Zhengzhou as an example, 203 days in 2019, 231 days in 2020, and 237 days in 2021. It can be seen that the number of excellent days has basically maintained a year-on-year growth trend in the past three years, and the air quality has gradually improved (Bai et al. 2020, 2021, Chen et al. 2019).

It can be seen from the above Fig. 1, 2, & 3 that the high value of the monthly average concentration of CO is in January, February, November, and December. The concentration in the other eight months is relatively stable at a low value, generally showing a U-shaped change trend (Cohen et al. 2017, Deng et al. 2020, Duan et al. 2020).

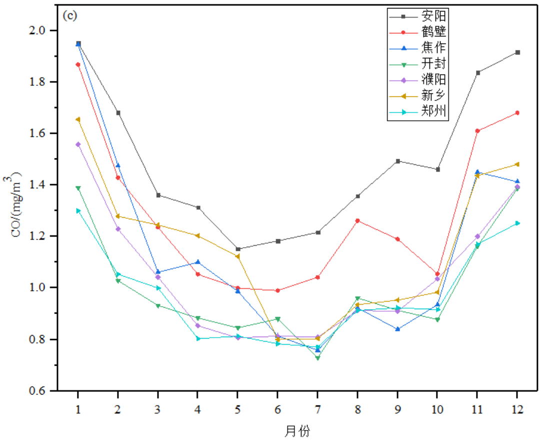

Fig. 1: CO concentration monthly changes in seven cities in 2019.

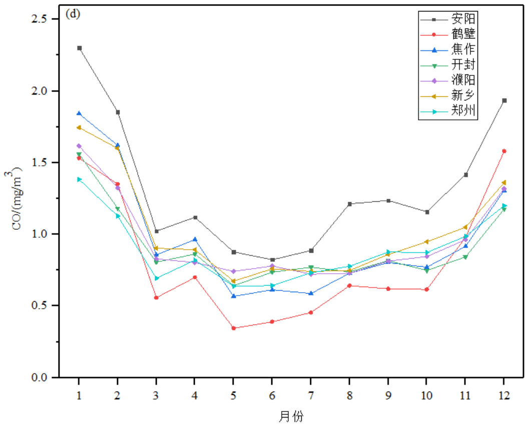

Fig. 2: CO concentration monthly changes in seven cities in 2020.

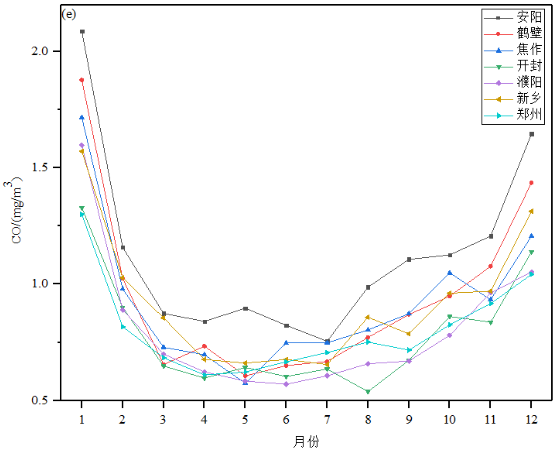

Fig. 3: CO concentration monthly changes in seven cities in 2021.

NO_2 concentration in seven cities in 2019-2021: It shows that the monthly concentration of NO_2 in January, November, and December is the highest, decreasing month by month from January to July and increasing month by month from July to December (Fig. 4 to Fig. 6). The overall trend of change is U-shaped, and the annual change is relatively smooth. The abnormal change curve of NO_2 in February and March 2020 is because of the pandemic. Travel was greatly reduced, and the concentration changes were in a low range (Fan et al. 2020a, 2020b).

SO_2 concentration in seven cities in 2019-2021: The monthly concentration of NO_2 in January, November, and December is the highest, decreasing month by month from January to July and increasing month by month from July to December (Fig. 7 to Fig. 9). The overall trend of change is U-shaped, and the annual change is relatively smooth.

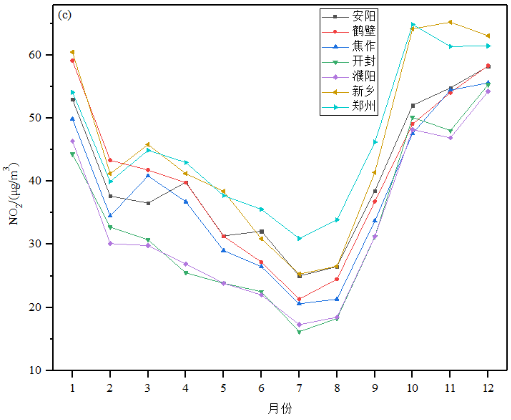

Fig. 4: NO_2 concentration monthly changes in seven cities in 2019.

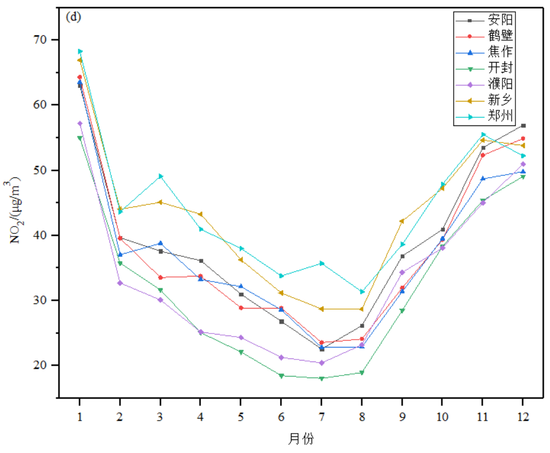

Fig. 5: NO_2 concentration monthly changes in seven cities in 2020.

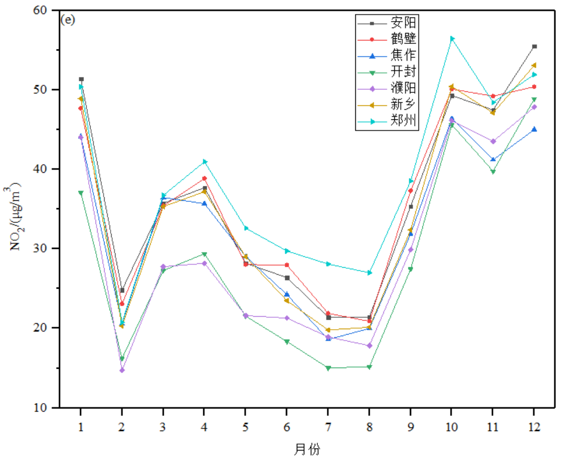

Fig. 6: NO_2 concentration monthly changes in seven cities in 2021.

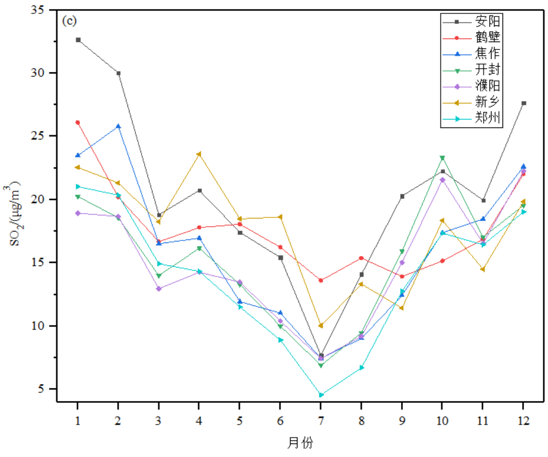

Fig. 7: SO_2 concentration monthly changes in seven cities in 2019.

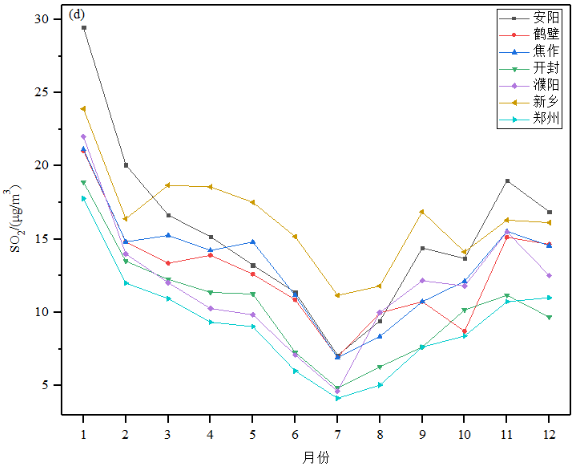

Fig. 8: SO_2 concentration monthly changes in seven cities in 2020.

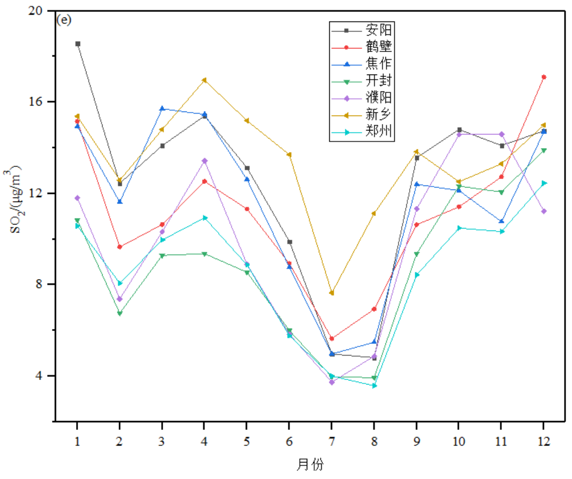

Fig. 9: SO_2 concentration monthly changes in seven cities in 2021.

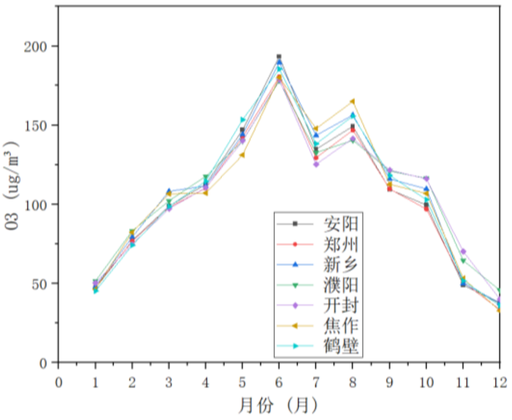

Fig. 10: O_3 concentration monthly changes in seven cities in 2019.

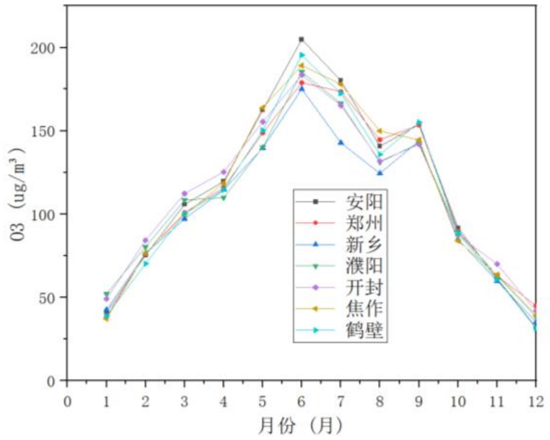

Fig. 11: O_3 concentration monthly changes in seven cities in 2020.

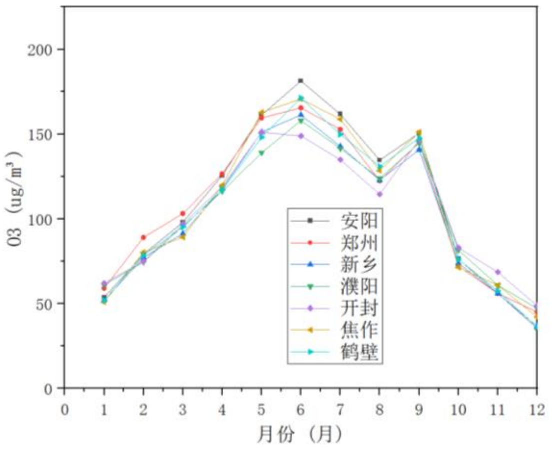

Fig. 12: O_3 concentration monthly changes in seven cities in 2021.

The abnormal change curve of NO_2 in February and March 2020 is due to the pandemic. Travel was greatly reduced, and the concentration changes were low. The monthly average concentration of SO_2 is not obvious. It is on the high side in January, February, and December, and the overall change also shows a U-shaped trend. It is worth mentioning that the change in SO_2 in 2020 was relatively disordered. Because of the pandemic, people living in isolation in winter used a large amount of coal for heating, resulting in an abnormal surge in February and March. The high concentration continued to decline slowly until June and July and then rose sharply due to the rebound of the pandemic.

O_3 concentration in seven cities in 2019-2021: The change curves of ozone in the past five years are the same, showing a convex change trend (Fig. 10 to Fig. 12). This is because the volatile organic compounds and nitrogen oxides mentioned above have a series of photochemical chain reactions under strong ultraviolet radiation in summer, which improves atmospheric oxidation and leads to a sharp increase in surface ozone concentration. In summer, the ozone concentration was at a high level in May, June, and August. In January, February, November, and December, when the concentration of other pollutants was higher, the ozone concentration remained at a low level.

Evaluation Method

Take the average concentration of PM2.5 in Zhengzhou in 2020 as an example. ArcGIS software was used to sort out the obtained GIS data through coordinate system transformation, distortion correction, screening, and other steps, and then obtain the parts related to Zhengzhou municipal area. All monitoring stations in the seven cities are marked in Fig. 12 to Fig. 14, with a total of more than ten points (Jiang et al. 2020, Kong et al. 2020, Kuerban et al. 2020).

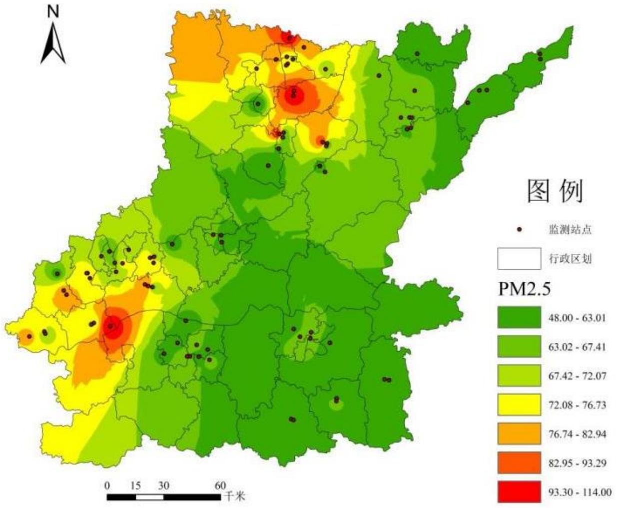

Fig. 12: Spatial distribution of PM2.5 in seven cities in 2019.

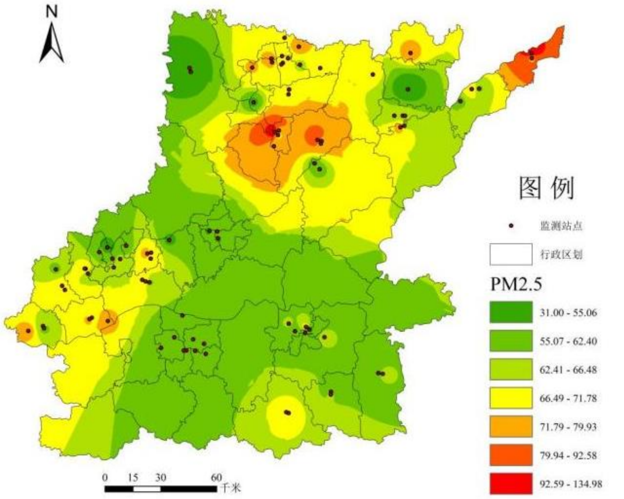

Fig. 13: Spatial distribution of PM2.5 in seven cities in 2020.

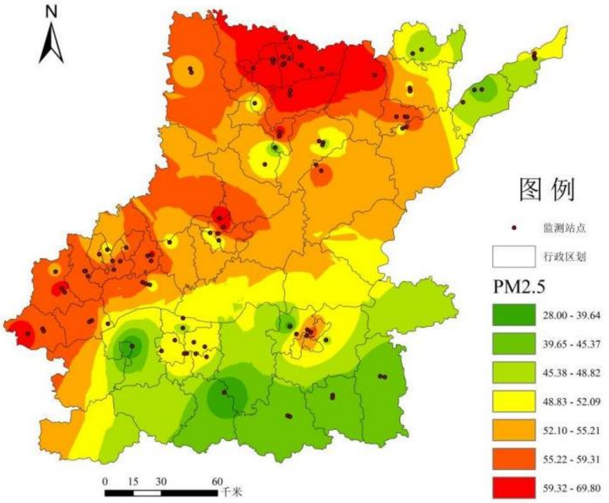

Fig. 14: Spatial distribution of PM2.5 in seven cities in 2021.

In the spatial scale analysis, after the annual average of pollutants at each monitoring station is linked to the location information of each monitoring point, Kriging interpolation analysis is carried out using the module in Arc GIS to present the spatial distribution of PM2.5 pollutants intuitively.

It can be seen from the data in Figs. 12, 13, & 14 that the regional atmospheric PM2.5 concentration data had a relatively downward trend in the past five years. Overall, the PM2.5 index of Jiaozuo, Xinxiang, and Anyang in the northwest is higher than that of Zhengzhou and Kaifeng in the Southeast. In the winter and spring seasons, with a high incidence of PM2.5 pollution in the seven cities, the wind direction is mainly northwest wind, and the pollutants mainly spread from northwest to Southeast.

It also can be seen, in the past three years, the months with a high monthly average concentration of PM2.5 in the seven cities are in January and February and November to December. The concentration is generally lower from March to September than 90 ug.m^{3-}. In the past five years, the average concentration of PM2.5 showed a downward trend year-on-year, but the downward trend was not obvious. Supervision and management should be strengthened during cold weather and less rainfall in winter.

CONCLUSION

This paper takes Zhengzhou, Kaifeng, Anyang, Hebi, Xinxiang, Jiaozuo, and Puyang in the Henan section of the Yellow River Basin as the research objects. It analyzes the data of six pollutants in the past three years. Various methods are used to determine the concentration of pollutants in various cities and analyze their spatial and temporal distribution. It provides a scientific reference and basis for the related research of air pollution prevention and control in cities in the future. The main conclusions of this paper are as follows:

(1) Each year's winter and spring seasons, i.e., January and February, November and December, are the peak periods of air pollution of PM2.5, PM10, and other pollutants except O_3. It is difficult for pollutants to be diffused or adsorbed for purification due to low temperatures, little winter rain, and low wind speed. In addition, coal resources are mainly used for heating and power generation in winter, and coal combustion emits more sulfur oxides, nitrogen oxides, and fine particles into the air.

(2) The seven cities in Henan in the statistics belong to the cities in northern China, which are vulnerable to sand and dust in spring. By analyzing the monthly variation curve of the ratio of PM2.5 to PM10, it can be seen that the impact of spring dust weather on PM10 is greater than that of PM2.5; The winter heating period has a greater impact on PM2.5 than on PM10.

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