Analysis on the Impact of Regional Air Quality in Industrial Cities: A Case Study of Huinong District of Shizuishan City

Wei Dong

1 Shanghai Baosteel Industry Technological Service Co., Ltd, Shanghai 201900, China

Abstract. In order to explore the influencing factors of regional air quality in industrial cities, this paper takes Huinong District of Shizuishan City as the object for analysis. The author sets up monitoring points in Huinong District of Shizuishan City to monitor the gas emission of polluting enterprises in various industries, and then analyzes the impact of the industrial park and surrounding environment of Huinong District on the air quality in the urban area. The analysis results show that the hourly contribution values of SO₂ and PM₁₀ emitted by Hebin Industrial Park were 0.756 mg/m³ and 0.444 mg/m³, respectively, while that of sulfur dioxide and PM₁₀ emitted by heating companies were 0.865 mg/m³ and 7.629 mg/m³. These are the main causes of serious air pollution in the District.

1 Introduction

Shizuishan City, Ningxia Hui Autonomous Region is a city focusing on industrialization with an industrial structure based on the coal industry. Its climate is featured with low precipitation and extremely uneven seasonal distribution. Under the influence of meteorology and topography, the atmospheric inversion phenomenon in Shizuishan City in winter is obvious, leading to the gradual accumulation of air pollutants near the surface, which are difficult to diffuse and dilute [1]. The rapid industrial development has aggravated environmental pollution. The atmospheric environmental problems in the region are monitored, but not further researched or analyzed (such as traceability analysis) [2, 3]. Serious air quality problems will affect the city's economic development, people's health, and lead to corresponding social problems [4-6]. This paper studies and analyzes the air quality in the industrial park and surrounding area of Huinong District, Shizuishan City, with the purpose of revealing the influencing factors of air quality in industrial cities.

2 Research methods and treatment

Huinong District is located at the northern end of Shizuishan City, and its landform consists of the Yellow River alluvial plain, proluvial slope plain, and Helan hilly land. Its climate is characterized by sufficient light and large temperature differences between day and night. According to the Technical Guide for Analyzing the Source of Atmospheric Particulate Matter (trial), the author sets up monitoring points at appropriate locations in Huinong District to monitor the gas emissions of polluting enterprises in various industries. Then, the author uses SPSS 16.0 statistical software and EIAProA 2008, a professional auxiliary system for atmospheric environmental assessment, to process the data, and analyzes the impact of the industrial park and surrounding environment in Huinong District on the air quality in the urban area.

3 Impact of Hebin Industrial Park on air quality in Huinong Urban District

Hebin Industrial Park is the major industrial park around Huinong District. It is located in the 2.5km due north away from the air automatic monitoring station in Huinong District. The author sets up monitoring points at appropriate locations in Huinong District to monitor the gas emissions of polluting enterprises in various industries. Then, the author uses SPSS 16.0 statistical software and EIAProA 2008, a professional auxiliary system for atmospheric environmental assessment, to process the data, and analyzes the impact of the industrial park and surrounding environment in Huinong District on the air quality in the urban area.
In the most unfavourable situation, the predicted one-hour average concentration of SO$_2$ diffused from the Hebin Industrial Park to the automatic station in Huinong urban area is 0.756 mg/m$^3$, which contributes 283% to the maximum background concentration value. After superimposing with the maximum background value, the predicted concentration can reach 1.023 mg/m$^3$, the twice the secondary standard of the one-hour average concentration limit listed in the Air Quality Standard. The AQI score is 228, which can cause severe air pollution at this station. When the weather condition in our city is better (SO$_2$ concentration = 0.037 mg/m$^3$), SO$_2$ in Taisha Industrial Park can cause the concentration in the monitoring station to be 0.793 mg/m$^3$, which is 1.5 times the one-hour average concentration limit of the Air Quality Standard. The AQI score is 150, which can cause moderate air pollution at this station. Therefore, in some cases, the Hebin Industrial Park can cause severe air pollution in Huinong urban area.

4 Impact of mining at Zhengyiguan Mine on air quality in Huinong District

Zhengnongguan Mine is located in the northwest of Huinong District, 12 kilometers away from the environmental monitoring station in this District. The author calculates the amount of dust produced during mining and uses the value to predict the impact of PM$_{10}$ on Huinong District. The analysis results are shown in Table 2. The distribution of the 1-hour mean concentration contour of the mine non-point source to PM$_{10}$ in Huinong urban area is shown in Fig. 1.
urban area is shown in Figure 3; the distribution of the 24-hour mean concentration contour of the mine non-point source to PM$_{10}$ in Huinong city is shown in Figure 4.

Table 2. Prediction results of PM$_{10}$ diffusion value in Zhengyiguan Mine

| SO$_2$ | 1 hour average | 24 hour average |
|--------|----------------|-----------------|
|        | Predictive value (mg/m$^3$) | Maximum background overlay value | Minimum background overlay value | Predictive value mg/m$^3$ | Background overlay | Background values mg/m$^3$ |
| Spread to monitoring site | 0.003 | 0.289 | 0.045 | 0.0002 | 0.1442 |
| Predicted maximum contribution rate | | | 7% | | |
| Predicted minimum contribution rate | | | 1% | | 0.0002 | 0.1462 |
| Spread throughout the area | 0.017 | 0.303 | 0.059 | 0.002 | 0.146 |
| Predicted maximum contribution rate | | | 40% | | 0.0002 | 0.146 |
| Predicted minimum contribution rate | | | 6% | | | |

In the most unfavourable situation, the predicted one-hour average concentration of PM$_{10}$ emitted by the mine to the Dawukou Automatic Air Station is 0.003 mg/m$^3$. After the superposition with the maximum background value, the concentration reaches 0.289 mg/m$^3$, which can cause moderate air pollution at this station. When the air quality in the city is good (PM$_{10}$ concentration value = 0.042 mg/m$^3$), the superimposed value of the minimum contribution concentration of PM$_{10}$ to Huinong urban area is 0.045 mg/m$^3$, which does not affect the air quality of Huinong District.

5 Prediction and analysis of the influence of Hongguozi central heating boiler on air quality in Hongguozi urban area

5.1 Impact of SO$_2$ emitted by heating boilers in Hongguozi Town on the air quality in Hongguozi urban area

The main pollution sources affecting the air quality of Hongguozi Town in Huinong District include Hongguo Central Heating Company and some residents who perform heating by themselves. Hongguozi central heating boiler is 1 km west-northwest from the air monitoring station. It is mainly used for central heating in the Town. The self-heating area of some residents of Hongguozi Town is 0.5 km due east away from the monitoring station.
Table 3. SO2 diffusion prediction of Hongguozi central heating boiler

| SO2 | 1 hour average | 24 hour average |
|-----|----------------|-----------------|
|     | Predictive value (mg/m³) | Maximum background overlay value | Minimum background overlay value | Background values mg/m³ | Background overlay | Background values mg/m³ |
|     | 0.865 | 1.132 | 0.902 | 0.079 | 0.216 |
| Spread to monitoring site | | | | | | |
| Predicted maximum contribution rate | | | | | | 2338% |
| Predicted minimum contribution rate | | | | | | 324% |
|     | 0.638 | 0.905 | 0.675 | 0.057 | 0.194 |
| Spread throughout the area | | | | | | |
| Predicted maximum contribution rate | | | | | | 1724% |
| Predicted minimum contribution rate | | | | | | 239% |

This paper uses prediction software to predict and analyze the SO2 emitted by the heating boiler in Hongguozi Town, as shown in Table 3.

In the most unfavourable situation, the predicted one-hour average concentration of SO2 diffused from the central heating boiler to the automatic station in Huinong urban area is 0.756 mg/m³, which contributes 324% to the maximum background concentration. After superimposing with the maximum background value, the predicted concentration can reach 1.132 mg/m³, 1.3 times higher than the secondary standard of the one-hour average concentration limit listed in the Air Quality Standard. The AQI score is 228, which can cause severe air pollution at this station. When the weather condition in our city is better (SO2 concentration = 0.037 mg/m³), SO2 in central boiler can cause the concentration in the monitoring station to reach 0.902 mg/m³, 1.8 times the limit of the Air Quality Standard. The AQI score is 213, which can cause severe air pollution at this station. Therefore, the sulphur dioxide hour value of Hongguozi central heating boiler is one of the main reasons leading to the serious air pollution in winter in Hongguozi Town.

In the worst case, the 24-hour average concentration of SO2 diffused by the central heating boiler to the Hongguozi automatic air station is 0.079 mg/m³, which contributes 57% to the daily average concentration of this Town. The superimposed concentration value is 0.216 mg/m³, and AQI score is 110. The SO2 contributed by the central heating boiler can cause slight air pollution. That may also be the reason for slight air pollution in Hongguozi Town in certain meteorological conditions, even when all polluting enterprises meet emission standards.

5.2 Prediction and analysis of PM10 emitted by heating boilers in Hongguozi Town

This paper uses prediction software to predict and analyze the PM10 emitted by the heating boiler in Hongguozi Town, as shown in Table 4.

Table 4. PM10 diffusion prediction of Hongguozi central heating boiler

| SO2 | 1 hour average | 24 hour average |
|-----|----------------|-----------------|
|     | Predictive value (mg/m³) | Maximum background overlay value | Minimum background overlay value | Background values mg/m³ | Background overlay | Background values mg/m³ |
|     | 7.629 | 7.915 | 7.671 | 0.693 | 0.837 |
| Spread to monitoring site | | | | | | |
| Predicted maximum contribution rate | | | | | | 18164% |
| Predicted minimum contribution rate | | | | | | 2667% |
|     | 5.624 | 5.91 | 5.91 | 0.504 | 0.648 |
In the most unfavourable situation, the predicted one-hour average concentration of PM$_{10}$ emitted by the boiler to the Hongguozi Automatic Air Station is 7.629 mg/m$^3$. After superposition, the concentration reaches 7.915 mg/m$^3$, which can cause serious air pollution at this station. When the air quality in the city is good (PM$_{10}$ concentration value = 0.042 mg/m$^3$), the PM$_{10}$ emitted by the central heating boiler contributes 2667% to the minimum background concentration in the urban area. The superposed concentration reaches 7.671 mg/m$^3$ and the AQI index is 3861, which can cause serious air pollution at this station.

In the most unfavourable situation, the predicted one-hour average concentration of PM$_{10}$ diffused from the central heating boiler to the Dawukou automatic station is 0.693 mg/m$^3$, which contributes 481% to the background concentration value. After superimposing with the maximum background value, the predicted concentration can reach 0.837 mg/m$^3$, 4.6 times higher than the secondary standard of the one-hour average concentration limit of the Air Quality Standard. The AQI score is 444, which can cause severe air pollution at this station.

6 Conclusion

According to the forecast analysis, the one-hour contribution values of SO$_2$ and PM$_{10}$ of the Hebin Industrial Park are 0.756 mg/m$^3$ and 0.444 mg/m$^3$, respectively. After superposition, the concentration values reach 1.023 mg/m$^3$ and 0.730 mg/m$^3$, exceeding the limits listed in Air Quality Standard, causing serious air pollution in Huinong District. That is the main reason for the serious air pollution in Huinong District in some time periods. Zhengyiguan has a little impact on the air quality in Huinong District, while Wusutai Industrial Park and Lazeng Temple Industrial Park in Wuhai City have a certain impact on the air quality in this District. The municipal heating company of Hongguozi Town, Hu’nan City is equipped with no desulfurization facilities for centralized heating boilers, therefore producing out-of-limit sulfur dioxide and smoke and dust, exerting a significant impact on the air quality of Hongguozi Town in Huinong District. According to the prediction analysis, the one-hour contribution values of sulfur dioxide and PM$_{10}$ emitted by heating companies are 0.865 mg/m$^3$ and 7.629 mg/m$^3$, respectively. After superimposition, the values reach 1.132 mg/m$^3$ and 7.915 mg/m$^3$, respectively, exceeding the limit of Air Quality Standard, leading to severe air pollution at this station. That is the main cause of serious air pollution in Hongguozi Town during a certain period, especially during the heating nights. The 24-hour contribution values of sulfur dioxide and PM$_{10}$ emitted by heating companies are 0.865 mg/m$^3$ and 0.693 mg/m$^3$. After superimposition, the values reach 0.216 mg/m$^3$ and 0.837 mg/m$^3$, respectively, exceeding the limits listed in Air Quality Standard, leading to severe air pollution at this station. That is the main reason for the severe air pollution in Hongguozi Town in winter.

Acknowledgement

The authors gratefully acknowledge the support provided by the Shanghai Science and Technology Support Program (09231202702) in China.

References

1. Q. H. Kou, R. Yang, J. Arid. Land. Resour. Environ. 24, 82 (2010)
2. X. R. Ren, Y. Jin, C. M. Ma, Y. Q. Suo, N. B. Zhang, Ningxia. Eng. Technol. 11, 40 (2012)
3. C. J. Zhou, B. Li, Resour. Surv. Environ. 29, 233 (2008)
4. Q. Zhang, J. N. Quan, X. X. Tie, X. Li, Q. Liu, Y. Gao, D. L. Zhao, Sci. Total. Environ. 502, 578 (2015)
5. J. H. Gao, A. Woodward, S. Vardoulakis, S. Kovats, P. Wilkinson, L. P. Li, L. Xu, J. Li, J. Yang, J. Li, L. Cao, X. B. Liu, H. X. Wu, Q. Y. Liu. Sci. Total. Environ. 578, (2017)
6. T. Liu, Y. H. Zhang, Y. J. Xu, H. L. Lin, X. J. Xu, Y. Luo, J. P. Xiao, W. L. Zeng, W. F. Zhang, C. Chu, K. Keogh, S. Rutherford, Z. M. Qian, Y. D. Du, M. J. Hu, W. J. Ma, Environ. Pollut. 187, 116 (2014)