Research on two methods of atmospheric environmental impact assessment a case study of lead zinc smelter

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Abstract. Two methods of atmospheric environmental impact assessment for enterprises were discussed in this paper. One was the pollutant contribution rate assessment based on regional maximum value point and sensitive sites, the other was the global pollutant contribution rate assessment method based on all grids in the region. The emission contributions to the atmospheric SO₂ concentrations from the lead zinc smelting enterprise were simulated by AERMOD using 100m scale grids within 25 square kilometres in 2018. The results showed that the change of environmental benefits caused by the increase of chimney height presented different trends by using the two assessment method, and the regional assessment method was disturbed by the terrain factor. The further research should be doing in order to reflect the pollution diffusion of emission contributions better.

1. Introduction

In recent years the emphasis on controlling pollutants had shifted towards the atmospheric environmental impact assessment. The method for atmospheric environmental impact assessment become one of hot topic among people, such as the model simulation assessment with AERMOD, CAMx [1-2], CALPUFF, the statistical methods using the principal component analysis (PCA) and canonical correlation analysis (CCA). In China, atmospheric pollution was a serious environmental problem faced by many industrial cities. It not only poses threats to human health, but directly affects local economic development. The China’s pollution prevention and control plan was put by Ministry of Environmental Protection of the People’s Republic of China to solve the atmospheric pollution problems. However, assessment of the pollution emission [3] is still an uncertain factor for many smelting sites, including the lead zinc smelter [4]. This paper would research two methods of atmospheric environmental impact assessment for enterprises. Generally speaking, the increase of the emission height of pollution emission would be more conducive to the diffusion of pollutants. However, economic factor was also an important factor. When the height of the chimney exceeds 80 meters, it would lead to a sharp rise in the cost to increase more and some problems in the usual environmental supervision and maintenance. Therefore, it was necessary to evaluate the relationship between chimney height and environmental benefits. In order to solve this problem, two kinds of environmental assessment methods were used to evaluate the relationship between the increase of height and the environmental benefits. One was the pollutant contribution rate assessment based on regional maximum value point and sensitive sites, the other was the global pollutant contribution rate assessment method based on all grids in the region [5]. The emission contributions to the atmospheric SO₂ concentrations from the lead zinc smelting enterprise were simulated by AERMOD.
2. Methodology

2.1. Atmospheric environmental impact prediction

2.1.1. AERMOD introduction. The atmospheric dispersion model AERMOD [6], which also named AERMIC Model, has replaced the ISC (Industrial Source Complex) model and been widely used by EPA present regulatory platform. The AERMOD modeling system consists of two pre-processors and dispersion models. The AERMIC meteorological preprocessor (AERMET) uses meteorological data and surface characteristics to calculate boundary layer parameters needed by AERMOD. The AERMIC terrain pre-processor (AERMAP) uses gridded terrain data for the modeling area to calculate a representative terrain-influence height associated with each receptor location. The terrain preprocessor AERMAP can also be used to calculate elevations for both discrete receptors and receptor grids. AERMOD should provide reasonable concentration estimates under a wide variety of conditions with minimal discontinuities and is used perfectly and could capture the essential physical processes while remaining fundamental simple.

2.1.2. Model setup. The AERMOD was used to simulate SO\(_2\) concentrations contribution of the lead zinc smelting enterprise in 2018. Three scenarios were selected. (1) Scenario 1: According to the actual emissions of the enterprise in 2018, the AERMOD was used to predict the spatial-temporal distribution of SO\(_2\) concentration. The chimney height of the pollution source that emit the most SO\(_2\) is 100 meters. (2) Scenario 2: The AERMOD simulated again with only the emission’s height increased to 110 meters. (3) Scenario 3: The AERMOD simulated again with only the emission’s height increased another 10 meters. The air pollutant emission inventories were provided by the lead zinc smelter (SO\(_2\) emission is 51.12kg/h, the gas flow rate is 761238m\(^3\)/h). Referring to the chimney height of acid making tail gas and the largest smoke emission in most non-ferrous metal smelting enterprises (usually 80 ~ 120 m), the above three scenarios were determined. Then the 1-hour, 24-hour and annual average SO\(_2\) concentrations within two receptors (Receptor 1 and Receptor 2) were calculated, respectively.

The AERMOD was configured using one-level nested modeling domain (25km\(^2\)), which was established with a dimension of 100 × 100 grid cells with the cell size of had a spatial resolution of 100m by 100m. The hourly meteorological observations data of full-year in 2018 was from surface and upper air monitoring stations of the Chinese Meteorological Information Comprehensive Analysis and Process System (MICAPS). The Wind roses of 2018 at MICAPS was shown in Figure 1. The terrain and land-use data were obtained from USGS with 30s resolution (shown in Figure 2).

2.2. Assessment method

2.2.1. Assessment method based on Receptor 1. The pollutant contribution rate assessment based on receptor 1 was commonly used in atmospheric environmental impact assessment. Receptor 1 was the sensitive sits and the maximum pollution concentration point. Residential areas, nature reserves, scenic spots and other areas which need special protection were all sensitive points. There are thirty-eight sensitive sites (shown in Figure 3) around the lead zinc smelting project. The data of 1-hour, 24-hour and annual average SO\(_2\) concentrations from the model prediction to thirty-eight sensitive sites were averaged calculated and the maximum point calculated separately.

2.2.2. Assessment method based on Receptor 2. The pollutant contribution rate assessment based on receptor 2 was a regional pollution contribution assessment method. Receptor 2 was the whole nest grids. This method was usually used to evaluate the annual average concentration contribution. However there was little analysis of hourly and daily average maximum concentration values, which would be calculated in this paper. The data of 1-hour, 24-hour and annual average SO\(_2\) concentrations from the model prediction to Receptor 2 were averaged calculated.
3. Results and discussions

3.1. Analysis of the SO$_2$ concentration spatial distribution

The SO$_2$ concentration contribution values of the full-year (2018) were calculated using AERMOD. The hourly-average, daily-average and year-average SO$_2$ concentrations of the three discharge schemes were shown in Table 1. It showed that all concentration data of the scenario 3 were smaller than the two other scenarios. Change rates of the 1 hour average, 24 hour average and year-average contribution for the thirty-eight sensitive sites of the next scenario were 2.63~3.70% greater than above, which indicate a well SO$_2$ dispersion of the higher chimney. The SO$_2$ concentrations for the maximum point and all grids gave the consistent results.

The year-average concentration contribution of Scenario 1 was shown in Figure 4 in order to analysis the region SO$_2$ pollution by the lead zinc emissions. The meteorological observation data in 2018 demonstrated that south winds were the main wind direction in these areas, so the concentration contributions of the smelter to South sites are weaker than North. However, the concentrations of pollutants in high altitude receptors were significantly higher than others. Results indicated that the SO$_2$ contribution values of high altitude areas in the north of the plant were generally above 0.002mg/m$^3$, while that in other areas were below 0.001mg/m$^3$. The result is consistent with Liu’s research [7], which showed that, for the elevated chimneys release in the complex terrain, the maximum hourly concentration calculated by AERMOD always occurred near high altitude receptor.

3.2. Analysis of the two assessment methods

The change rates of concentration contribution value by three scenarios were listed in the Table 1. It showed that, for the year-average concentration of the thirty-eight sensitive sites, the height of pollution source was increased by 10 meters for the first time, which brought 2.68% (C5) environmental benefits, while the height increased for the second time which brought 2.63% (C6) environmental benefits. However, the environmental benefit of the second change was less than and
not as cost-effective as the first one. The maximum value point of the regional grid showed the same
law as the sensitive sites, which also proved the consistency of this evaluation method.

**Figure 4.** The SO$_2$ concentration contour map.  
**Figure 5.** Difference between C6 and C5($\triangle$3).

**Table 1.** The results of SO$_2$ concentration simulation.

| Concentration type | Scenario          | Sensitive sit | Maximum value point | All grids  |
|--------------------|-------------------|---------------|---------------------|------------|
| 1-hour             | Scenario 1 (mg/m$^3$) | 1.52E-02      | 5.24E-01            | 5.32E-02   |
| average            | Scenario 2 (mg/m$^3$) | 1.46E-02      | 5.00E-01            | 4.96E-02   |
| 24-hour            | Scenario 3 (mg/m$^3$) | 1.41E-02      | 4.38E-01            | 4.58E-02   |
| average            | Scenario 1 (mg/m$^3$) | 1.74E-03      | 1.07E-01            | 6.26E-03   |
| 24-hour            | Scenario 2 (mg/m$^3$) | 1.67E-03      | 9.44E-02            | 5.81E-03   |
| average            | Scenario 3 (mg/m$^3$) | 1.62E-03      | 8.31E-02            | 5.23E-03   |
| Annual             | Scenario 2 (mg/m$^3$) | 2.67E-04      | 6.65E-03            | 5.89E-04   |
| average            | Scenario 3 (mg/m$^3$) | 2.60E-04      | 5.87E-03            | 5.65E-04   |
| Change rate of C1  | = (Scenario 1 - Scenario 2)/ Scenario 1 | 3.46% | 4.58% | 6.72% |
| 1-hour             | C2=(Scenario 2 - Scenario 3)/ Scenario 2 | 3.68% | 12.40% | 7.72% |
| Change rate of C3  | = (Scenario 1 - Scenario 2)/ Scenario 1 | 3.70% | 11.78% | 7.08% |
| 24-hour            | C4=(Scenario 2 - Scenario 3)/ Scenario 2 | 3.53% | 11.97% | 10.10% |
| Change rate of C5  | = (Scenario 1 - Scenario 2)/ Scenario 1 | 2.68% | 11.73% | 4.07% |
| annual             | C6=(Scenario 2 - Scenario 3)/ Scenario 2 | 2.63% | 9.03%  | 6.75% |
| $\triangle$1=C2-C1|                   | 0.23% | 7.82%  | 1.00% |
| $\triangle$2=C4-C3|                   | -0.16% | 0.19% | 3.02% |
| Difference         | $\triangle$3=C6-C5 | -0.05% | -2.70% | 2.68% |

Nevertheless, the year-average concentration of the receptor 2 showed the opposite situation. When
the chimney changed for the second time, the change rate of SO$_2$ concentration to the region still
showed an upward trend. There might be several reasons for this result. (1) Affected by the terrain
(shown in Figure 2) and the annual main wind direction [8] (shown in Figure 1), the SO$_2$
concentration gathered in the northern mountainous area (shown in Figure 4). When the values of the
whole grids were averaged, the high concentration areas were likely to cover the environmental effects
in low one. (2) The difference between C5 and C6 was shown in Figure 5. It indicated that the change
rate to the northern mountainous area decreases more as the height of the pollution source increased. While most of the sensitive sites were located in the south of the lead zinc smelter, which the terrain was relatively flat, within the difference of the change rate less than 3%. Therefore, when increased the height of pollution emissions once again, the environmental benefits of sensitive points were covered by the northern mountainous areas.

3.3. Application suggestions
There was still a lot of research space for the assessment of atmospheric environment quality. The author analyzed the two assessment methods and put forward the following suggestions. (1) This study concluded that the process of assessing environment impact of pollution emissions was necessary to fully consider the terrain, wind direction and other factors. Fu’s research [9] showed that the model correlation was the best in complex terrain conditions between predicted results and the monitoring value, which also proved the important effect of the topographical factor in assessment. We could not only rely on a single assessment method for analysis, nor just looking at the assessment data of regional environmental quality without considering the terrain and other factors. (2) The relationship between the influencing factors should be analyzed by statistical methods, such as principal component analysis (PCA), canonical correlation analysis (CCA) and other statistical methods, to analyze the impacts of meteorological factors and terrain data on emission contribution variations. (3) The further study was to establish an optimal model, and scientifically and reasonably assign weights to each grid, in order to obtain the optimal atmospheric environment control scheme.

4. Summary
Two methods of atmospheric environmental impact assessment for enterprises were discussed in this paper. One was the pollutant contribution rate assessment based on regional maximum value point and sensitive sites, the other was the global pollutant contribution rate assessment method based on all grids in the region. The comparative study took a lead zinc smelter as an example. The results showed the opposite results by using the two assessment method, when the chimney changed for the second time, the change rate of SO\(_2\) concentration to the region still showed an upward trend. Several reasons were analysed, while the most important affect factors were the terrain and the annual main wind direction. The regional assessment method was disturbed by the terrain factor. The further research should be doing in order to reflect the pollution diffusion of emission contributions better. The relationship between the influencing factors should be analyzed by statistical methods. One of the development directions of this study was to establish an optimal model, and scientifically and reasonably assign weights to each grid, in order to obtain the optimal atmospheric environment control scheme.

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