The Analysis of Atmospheric Environment Capacity in the Winter of 2016 in Liaoning

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Abstract. The variations of atmospheric environmental capacity and its relationship to AQI and the height of the atmospheric mixing layer have been studied by using meteorological and environmental monitoring data from Shenyang, Dalian, Dandong and Jinzhou in the winter of 2016. The results show that the atmospheric environmental capacity is obviously different in four cities, but the daily variation trend of atmospheric environmental capacity for PM$_{2.5}$, PM$_{10}$, SO$_2$, NO$_2$ and CO is basically the same. The atmospheric environmental capacity and AQI show negative correlation and the correlation coefficients ($R^2$) of the atmospheric environmental capacity to AQI in four cities are respectively 0.1016, 0.1109, 0.3014 and 0.1723. The correlation between the atmospheric environmental capacity of PM$_{10}$ and the height of the atmospheric mixing layer show positive correlation and the average correlation coefficients($R^2$) in four cities.

1. Introduction

With the rapid development of economy and the rapid growth of the auto industry, air pollution in Liaoning province has intensified, which leads to ozone pollution on the ground, sandstorms, low visibility and more haze days [1-2]. In order to improve the quality of air environment in Liaoning area, it is necessary to control the total amount of air pollutant emission [3]. A-P method is one of the important methods to estimate atmospheric environmental capacity. This method takes the air environment quality control standard as the control target. On the basis of considering the law of atmospheric pollutant diffusion and dilution, the total allowable value of the control area and the allowable value of point source emission are used to calculate the air environment capacity [4]. Some research on atmospheric environmental capacity had been done in recent years in China [5-8]. For example, CMAQ air quality model was used to establish a calculated methodology of atmospheric environmental capacity by Li Li et al [9] based on different air quality guideline-satisfaction ratio under the real conditions, which would be helpful to the air quality management. Taking the single-box model method as the basis model and using the meteorological data of Shanxi Province from 1961 to 2008, the amending A-value method for the control estimation of atmospheric environment have been deduced by Wenhui Li et al [10]. There have been some related reports about the research on atmospheric environmental capacity in Liaoning province [11], but very few systematic studies have been done, in Liaoning, on the variation and its relationship to AQI and the height of the atmospheric mixing layer.
The changes of the atmospheric environmental capacity and its relationship to AQI and the height of the atmospheric mixing layer have been analysed in this paper by using environmental monitoring data from Shenyang, Dalian, Dandong and Jinzhou in the winter of 2016.

2. Data and method

Environmental monitoring data is obtained from Liaoning Provincial Environmental Monitoring Center Station, and the meteorological data from Liaoning Meteorological Bureau. The observation data of different frequency has been processed by deleting useless and wrong data due to instrument malfunction, blackout and so on. After sorting out and analyzing the data, we get the hourly mean data. Then the daily and monthly mean data are respectively calculated based on the hourly mean data.

Atmospheric environmental capacity is calculated based on the A value method. A is the regional total control coefficient that reflects the bearing capacity of the atmospheric environment\cite{12}. Its unit is $10^4$ tkm$^2$/a and the design formulas is as follow:

$$A=3.1536 \times 10^{-3} \sqrt[4]{Ve}/2$$

$Ve$ for ventilation rate.

3. Results and discussion

3.1. The atmospheric environmental capacity in Shenyang, Dalian, Dandong Jinzhou

Table 1 shows the total discharge source and areal source in the winter of 2016 in Shenyang, Dalian, Dandong Jinzhou. Here the total discharge source is the atmospheric environmental capacity. In terms of total discharge sources, the total discharge sources of PM$_{2.5}$ in Shenyang and Dalian are relatively high in the winter of 2016, which are $1.36 \times 10^4$ t and $0.78 \times 10^4$ t respectively. The total discharge sources of PM$_{10}$ in Shenyang and Dalian are relatively high, which are respectively $1.95 \times 10^4$ t and $1.17 \times 10^4$ t. The total discharge source of SO$_2$ in Shenyang is higher, which is $2.4 \times 10^4$ t. The total discharge sources of CO in Shenyang and Dalian are relatively high, which are respectively $0.03 \times 10^4$ t and $0.03 \times 10^4$ t. The total discharge sources of NO$_2$ in Shenyang and Dalian are relatively high, respectively $1.45 \times 10^4$ t and $0.95 \times 10^4$ t.

In terms of areal sources, the emission of PM$_{2.5}$ areal sources in Shenyang is $0.26 \times 10^4$ t in the winter of 2016, which is higher than other three regions. There have high values of PM$_{2.5}$ in Shenyang and Dalian, which are respectively $0.37 \times 10^4$ t and $0.22 \times 10^4$ t. Areal source emissions of SO$_2$ in Shenyang is high, which is $0.46 \times 10^4$ t. The areal source emissions of CO in the four regions is relatively close, about 80-100t. There have high values of NO$_2$ in Shenyang and Dalian, which are $0.28 \times 10^4$ t and $0.18 \times 10^4$ t respectively.

|       | PM$_{2.5}$ | PM$_{10}$ | SO$_2$ | CO | NO$_2$ |
|-------|------------|-----------|--------|----|--------|
| Shenyang | TDS | AS | TDS | AS | TDS | AS | TDS | AS | TDS | AS |
| Dalian | 1.36 | 0.26 | 1.95 | 0.37 | 2.40 | 0.46 | 0.03 | 0.01 | 1.45 | 0.28 |
| Dandong | 0.78 | 0.15 | 1.17 | 0.22 | 0.87 | 0.17 | 0.03 | 0.01 | 0.95 | 0.18 |
| Jinzhou | 0.35 | 0.07 | 0.54 | 0.10 | 0.55 | 0.11 | 0.02 | 0.00 | 0.39 | 0.07 |
Figure 1 shows the daily variation of atmospheric environmental capacity in Shenyang, Dalian, Dandong and Jinzhou. The variation trend of atmospheric environmental capacity for PM$_{2.5}$, PM$_{10}$, SO$_2$, NO$_2$ and CO in Shenyang, Dalian, Dandong Jinzhou is basically the same. The atmospheric environmental capacity in Dandong is significantly lower than that of the other three regions, followed by Dalian and Jinzhou. In general, the atmospheric environmental capacity of Shenyang is highest in four cities.

3.2. Mean concentration characteristic in Shenyang, Dalian, Dandong Jinzhou
Table 2 shows Average pollutant concentrations in the winter of 2016 in Shenyang, Dalian, Dandong Jinzhou. In the winter of 2016, the PM$_{2.5}$ concentrations in Jinzhou and Shenyang are high, which are 86.7 μg/m$^3$ and 86.0 μg/m$^3$ respectively. The PM$_{10}$ mass concentrations in Shenyang and Jinzhou are high, which are 123.6 μg/m$^3$ and 109.8 μg/m$^3$ respectively. The concentration of SO$_2$ in Jinzhou and Shenyang is relatively high, which are 92.3 μg/m$^3$ and 88.6 μg/m$^3$. Dandong and Jinzhou have high concentration of CO, which are 1.6 mg/m$^3$ and 1.5 mg/m$^3$ respectively. The NO$_2$ concentration of Shenyang and Jinzhou are high, which are 53.5 μg/m$^3$ and 47.9 μg/m$^3$ respectively. The O$_3$ mass concentration in Dalian is higher than the other three regions, and the average value is 78.1 μg/m$^3$. 

| Jinzhou | 0.56 | 0.11 | 0.70 | 0.13 | 1.02 | 0.19 | 0.02 | 0.00 | 0.53 | 0.10 |

Figure 1 Daily variation of atmospheric environmental capacity in Shenyang, Dalian, Dandong and Jinzhou
Table 2 Average pollutant concentrations in the winter of 2016 in Shenyang, Dalian, Dandong and Jinzhou

|            | PM$_{2.5}$/($\mu$g/m$^3$) | PM$_{10}$/($\mu$g/m$^3$) | SO$_2$/($\mu$g/m$^3$) | CO/(mg/m$^3$) | NO$_2$/($\mu$g/m$^3$) | O$_3$/($\mu$g/m$^3$) |
|------------|-----------------------------|--------------------------|----------------------|--------------|----------------------|----------------------|
| Shenyang   | 86.0                        | 123.6                    | 88.6                 | 1.3          | 53.5                 | 55.6                 |
| Dalian     | 53.7                        | 80.7                     | 34.9                 | 1.1          | 37.8                 | 78.1                 |
| Dandong    | 54.7                        | 83.4                     | 50.0                 | 1.5          | 35.0                 | 59.3                 |
| Jinzhou    | 86.7                        | 109.8                    | 92.3                 | 1.6          | 47.9                 | 66.1                 |

3.3. The correlation between the atmospheric environmental capacity and AQI

Figure 2 shows the correlation between the atmospheric environmental capacity of PM$_{10}$ and AQI. According to Figure 2, the atmospheric environmental capacity and AQI show negative correlation and the correlation coefficients (R$^2$) of the atmospheric environmental capacity to AQI in Shenyang, Dalian, Dandong and Jinzhou are respectively 0.1016, 0.1109, 0.3014 and 0.1723, which shows that the higher the AQI is, the less the atmospheric environmental capacity is. The correlation coefficients (R$^2$) of the atmospheric environmental capacity to AQI in Dandong is the highest in four cities, which is up to 0.3014. The correlation coefficients (R$^2$) of the atmospheric environmental capacity to AQI in Shenyang is the Minimum in four cities, which is 0.1016. So it is also known that when the environmental capacity is small, the pollutants cannot spread and transport in time, which leads to poor air quality.

3.4. The correlation between the atmospheric environmental capacity and the height of the atmospheric mixing layer

Figure 3 shows the correlation between the atmospheric environmental capacity of PM$_{10}$ and the height of the atmospheric mixing layer. The correlation between the atmospheric environmental capacity of PM$_{10}$ and the height of the atmospheric mixing layer show positive correlation and the average correlation coefficients (R$^2$) in Shenyang, Dalian, Dandong and Jinzhou are respectively 0.79, 0.86, 0.87 and 0.88. So it is also known that the higher the atmospheric mixing layer, the more the atmospheric environmental capacity.
4. Conclusions and discussions.

(1) In terms of total discharge sources, the total discharge sources of PM$_{2.5}$ in Shenyang and Dalian are relatively high in the winter of 2016. The total discharge source of SO$_2$ in Shenyang is higher, which is $2.4 \times 10^4$ t. The total discharge sources of CO in Shenyang and Dalian are relatively high, which are respectively $0.03 \times 10^4$ t and $0.03 \times 10^4$ t. The daily variation trend of atmospheric environmental capacity for PM$_{2.5}$, PM$_{10}$, SO$_2$, NO$_2$, and CO in Shenyang, Dalian, Dandong and Jinzhou is basically the same.

(2) The PM$_{2.5}$ concentrations in Jinzhou and Shenyang are high, which are 86.7 μg/m$^3$ and 86.0 μg/m$^3$ respectively. The PM$_{10}$ mass concentrations in Shenyang and Jinzhou are high. The O$_3$ mass concentration in Dalian is higher than the other three regions, and the average value is 78.1 μg/m$^3$.

(3) The atmospheric environmental capacity and AQI show negative correlation and the correlation coefficients ($R^2$) of the atmospheric environmental capacity to AQI in Shenyang, Dalian, Dandong and Jinzhou are respectively 0.1016, 0.1109, 0.3014 and 0.1723. The higher the AQI is, the less the atmospheric environmental capacity is.

(4) The correlation between the atmospheric environmental capacity of PM$_{10}$ and the height of the atmospheric mixing layer show positive correlation and the average correlation coefficients ($R^2$) in Shenyang, Dalian, Dandong and Jinzhou are respectively 0.79, 0.86, 0.87 and 0.88.

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