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Analysis of SO_2 Pollution in Baoding Based on MATLAB Grey Model

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The purpose of this paper is to analyze the SO_2 Pollution in Baoding based on the MATLAB grey model. The monitoring results of sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and respirable particulate matter (PM10) were obtained at 5 monitoring sites in Baoding in 2011~2016. According to the national ambient air standard, a reasonable comprehensive evaluation of air quality in Baoding was made by using the weighted grey relational analysis model based on MATLAB. Judging from the weight of pollution factors in the model, sulfur dioxide (SO_2) is the controlling factor of air quality in Baoding, and the weight of nitrogen dioxide (NO_2) is gradually increasing. Based on the analysis data, the main sources of the three pollutants were analyzed. Then, the grey model is established according to the mass concentration of the main air pollutants, and the grey forecasting model is tested. The test results show that the model can be effectively applied to the prediction of ambient air quality. Based on the above finding, it is concluded that the environment quality in Baoding can be improved by effective governance.

1. Introduction

The pollutants in the atmosphere are mainly composed of particles, chemical pollutants and so on. In order to protect and improve the human living environment, many domestic scholars have investigated the pollution status of urban air. According to the analysis of the atmospheric conditions in various cities, the main pollutants in the atmosphere are atmospheric particulates, sulfur dioxide and nitrogen oxides. For the urban atmospheric pollution situation, many experts consider it from these three aspects and give evaluation. At present, grey system theory has become an important forecasting method, which includes decision-making, evaluation, planning control, system analysis and modeling (Gu et al., 2014; Ding, 2016; Wang, 2016). In particular, it has a unique way of analysis and model building, short time series of statistical data and incomplete information systems. Many colleges and universities have built grey systems in China and studied with hundreds of doctors and graduate students using the grey system (Moazami et al., 2016). Grey systematic papers were published in 200 international and domestic academic journals. Many topics of grey system discussion, such as SCI, EI and so on, have a great influence on the international system of grey system theory in China (Li et al., 2015). At present, there are many scholars engaged in the research and application of grey system. There scholar mostly come from the United States, Germany, Russia, Japan, Britain, Austria, Australia, Canada and other countries, regions and international organizations (Kadiyala and Kumar, 2012).

2. Weighted grey incidence analysis model of urban air environmental impact index

Taking Baoding city as an example, monitoring results of sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and respirable particulate matter (PM10) were obtained at 5 monitoring sites in Baoding in 2011~2016. According to the national ambient air standard, a reasonable comprehensive evaluation of air quality in Baoding was made by using the weighted grey relational analysis model (Cheng, et al., 2015).

2.1 Arrangement of climatic condition and monitoring points in Baoding

Baoding is located in the middle of Hebei province, the east of northern Taihang Mountain and the west of Jizhong plain. It is located in the hinterland of Beijing, Tianjin and Shek triangle. Baoding is known as "kyocera

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area" and "South Gate of the capital". It is a temperate continental monsoon climate with semi humid and semi arid state and has distinct four seasons. In Baoding, the annual average temperature of 12.2 °C and annual sunshine is 2563 h. The frost free period is about 210 D and the average annual precipitation is 570 mm. The annual average evaporation is 1758.3 mm. There are 5 air conventional monitoring points in Baoding, which are located in Baoding shopping malls, Lucky Film Factory, Baoding surface water plant, Baoding City reception station and Baoding monitoring station. It is mainly used for monitoring of SO_2, NO_2 and PM_{10}.

2.2 Sources and analytical methods of major air pollutants

The air quality in Baoding in the past two years was analyzed from three factors, such as civil heating factor, fugitive dust factor and industrial pollution factor.

Analysis of civil heating factors: Civil heating season leads to lower air quality and higher mass concentration of sulfur dioxide. Burning coal results in an increase in the concentration of pollutants. Civil heating is an important factor affecting air quality (Shi et al., 2016; Labed et al., 2015; Balocco et al., 2015; Gattuso et al., 2016; Mo et al., 2016; Liu et al., 2016).

Analysis of fugitive dust factors: Baoding belongs to the north and is a city with less rainfall. The concentration of inhalable particles in the air is larger than that of the coastal city, thus affecting the overall air quality in Baoding.

Analysis of industrial pollution factors: The rapid development of urban industry and frequent production activities have aggravated the pollution of cities. At the same time, serious industrial pollution leads to poorer air quality. The mass concentration of nitrogen dioxide and sulfur dioxide will increase accordingly (Gupta et al., 2016).

Sulfur dioxide, SO_2, nitrogen dioxide, NO_2 and respirable particulate matter PM_{10} in the atmosphere are studied. The methods and sources of various pollutants are described in Table 1.

Table 1: Analysis methods and sources of various pollutants

Pollutant name	Analysis method	Source
Sulfur dioxide (SO_2)	Formaldehyde absorption-pararosaniline spectrophotometric method; Four mercury chloride salt-pararosaniline spectrophotometric method; UV fluorescence method	GB/T 15262-94 GB 8970-88
Inhalable particles	gravimetric method	GB6921-86
Nitrogen dioxide (NO_2)	Saltzman method Chemiluminescence method	GB/T 15436-95

2.3 Monitoring results of major air pollutant concentrations

Dongyu 1000 series of air quality automatic monitoring system is used for continuous monitoring of Baoding city monitoring of air pollutants (the data come from the Baoding municipal environmental protection monitoring station). The annual average value of air pollutants SO_2, NO_2 and PM_{10} (as shown in Table 2) in 2011-2016 was selected as the evaluation target (Ogunkunle et al., 2015).

Table 2: Monitoring results of air pollutants in Baoding

Years	SO2 (mg/m^3)	NO2 (mg/m^3)	PM10 (mg/m^3)
2011	0.134	0.033	0.109
2012	0.137	0.039	0.107
2013	0.084	0.036	0.098
2014	0.079	0.025	0.109
2015	0.077	0.022	0.097
2016	0.063	0.032	0.087

2.4 Comprehensive evaluation of atmospheric environmental quality

The evaluation standards are listed in the national air quality standard of People's Republic of China (GB3095 - 1996) and revised in 2000 (as shown in Table 3).

Table 3: Grading standards for atmospheric environmental quality

Contaminants	Sample time	Concentration limit (mg/m^3)		
		I- level standard	II- level standard	III- level standard
SO_2	Annual mean	0.04	0.10	0.15
NO_2	Annual mean	0.04	0.08	0.08
PM_{10}	Annual mean	0.02	0.06	0.10

Weighting is obtained by taking into account the position of the factors in the population and assigning weights. According to the contribution rate of the evaluation factors in each evaluation unit, the weight coefficients of each evaluation factor in the pending evaluation unit can be determined. The formula is as follows:

$$\alpha_i = \frac{x_i / s_i}{\sum x_i / s_i} \tag{1}$$

α_i -Weight value of pollutant i;
s_i -The standard arithmetic mean of each level of the i pollutant;
x_i -Actual concentration value of pollutant i.
According to the formula, the weights of Baoding city in 2011 -2016 are calculated (shown in Table 4).

Table 4: Weight calculation result

Years	Weight coefficient			
	SO_2	NO_2	PM_{10}	Primary pollutant
2011	0.489	0.133	0.378	SO_2
2012	0.520	0.133	0.347	PM_{10}
2013	0.400	0.191	0.409	PM_{10}
2014	0.452	0.167	0.381	SO_2
2015	0.449	0.131	0.420	SO_2
2016	0.427	0.185	0.387	SO_2

Table 3 gives the values of the pollutant weighting factor AI for each year. Through the weight calculation results, it shows that SO2 and PM10 are the main pollutants affecting the air quality in Baoding. The major pollutants in each year are: SO_2 (2011), PM_{10} (2012), PM_{10} (2013), SO_2 (2014-2016). From the main pollutants every year, it shows that the air pollution in Baoding is gradually changing from PM_{10} to SO_2, but there is still a long way to go to mitigate the impact of PM_{10} on the environment.

2.5 Evaluation results of weighted grey relation

According to the above calculation method, the air quality calculation results in each year are shown in Table 5.

Table 5: Comprehensive evaluation results by years

Years	Relational grade			
	r1	r2	r3	Quality level
2011	0.528	0.650	0.815	III level
2012	0.433	0.502	0.347	III level
2013	0.529	0.810	0.538	II level
2014	0.137	0.623	0.090	II level
2015	0.422	0.846	0.457	II level
2016	0.467	0.816	0.439	II level

Through the comprehensive analysis of Table 3 and Table 4, it is concluded that the air quality of Baoding city in 2011 - 2012 belongs to the three grade, which is light pollution. In 2013 -2016, the air quality in urban environment was two, and the air was clean. It showed that the environmental air quality in Baoding was gradually improving. This kind of good air quality benefits from the positive measures taken by Baoding Environmental Protection Bureau in recent years. An advantage of the gay relational analysis is that the

quality of the analysis environment can be sorted. In accordance with the order from high to low, it shows that the air environment quality was best in 2014 and the worse was in 2011 from 2011 to 2016.

2.6 Evaluation results divided by season and heating period

Each year is divided into heating period and non heating period. The non-heating period is from March 15th to November 15th every year. And the heating period is from November 15th to March 15th in next year. The evaluation results are shown in Table 6.

Table 6: Comprehensive evaluation results by year

Years	Time limit	Concentration limit (mg/m3)			Quality level	Primary pollutant
		I level standard	II level standard	III level standard		
2011	heating period	0.373	0.515	0.584	III level	SO_2
2012	non-heating period	0.642	0.801	0.701	II level	PM_{10}
	heating period	0.519	0.610	0.675	III level	SO_2
2013	non-heating period	0.607	0.776	0.416	II level	PM_{10}
	heating period	0.466	0.557	0.766	II level	SO_2
2014	non-heating period	0.679	0.645	0.392	I level	PM_{10}
	heating period	0.552	0.775	0.834	III level	SO_2
2015	non-heating period	0.483	0.801	0.416	II level	PM_{10}
	heating period	0.452	0.543	0.792	III level	SO_2
2016	non-heating period	0.694	0.820	0.453	II level	PM_{10}

Table 5 shows that the environmental quality of Baoding city is relatively good in the non heating period, and the primary pollutant is PM_{10}. The environmental quality of the heating period is relatively poor, and the primary pollutant is SO_2. It can be seen that Baoding is a coal polluted city, and further control and control of coal burning pollution need to be further strengthened.

3. Prediction of air pollution in Baoding based on grey model

3.1 Model assumptions

Other pollutants in the atmosphere within the target control range are ignored;
The error of data in the process of testing pollutants is ignored;
It is assumed that the urban natural environment will be stable without major natural disasters such as earthquakes, sandstorms, floods and so on;
It is assumed that major industrial accidents will not occur in the past two years.

3.2 Establishment of grey prediction model

Grey forecast system theory is applied to forIn order to guarantee the consistency of the parameter rate for the model, the time of data selection is from August 2016 to March 2017. The mass concentrations of PM_{10}, NO_2 and SO_2 are selected within 6 months. According to the analysis results of the previous chapter, three grey forecasting models are established respectively for PM_{10}, NO_2 and SO_2 in Baoding. The grey prediction model is as follows:

$$\begin{aligned}\hat{\chi}^1_{(k+1)} &= \text{-}5822.23\exp\left(\text{-}0.0376k\right)+6277.38\\ \hat{\chi}^1_{(k+1)} &= \text{-}2823.35\exp\left(\text{-}0.0177k\right)+4545.56\\ \hat{\chi}^1_{(k+1)} &= \text{-}822.67\exp\left(\text{-}0.0736k\right)+678.34\end{aligned} \tag{2}$$

3.3 Prediction result test

According to the formula of grey prediction model, the mass concentration of SO_2 was calculated in Baoding from August 2016 to March 2017 (Figure 1). The predictive value of the grey model is used as the input value, and the actual value is the output value. The input and output values are iterated. The maximum number of cycles is set to 5000 times, and the initial step size is 0.0001 m.
According to the formula of grey prediction model, the pollution situation of PM10, NO2 and SO2 in Baoding (Figure 2) will be obtained in the next six months, and the prediction results of grey forecasting model are

tested. The residual test and the posterior difference test are used to test the accuracy of the model. The results obtained by residual test are shown in Table 7.

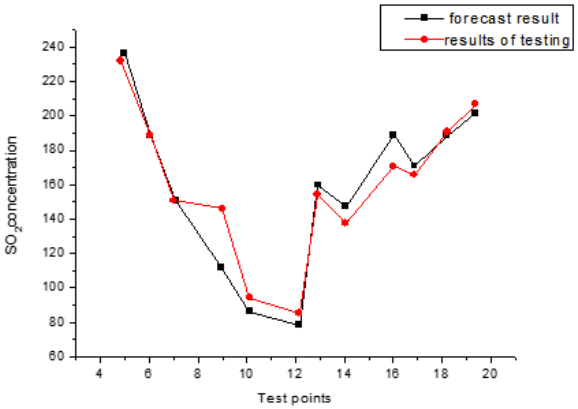

Figure 1: Prediction of SO_2 mass concentration in Baoding from August 2016 to March 2017

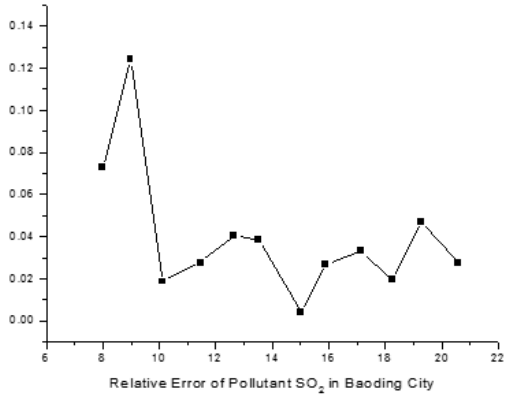

Figure 2: Prediction of mass concentration of SO_2 in Baoding

Table 7: SO_2 residual test table in Baoding

Years	SO_2			
	Monitoring value	Predicted value	Residual error	Relative error (%)
August 2016	86.53	61.0388	-18.88676	18.43
October 2016	100.61	121.1906	14.10033	17.24
December 2016	189.53	139.7011	17.14607	7.79
February 2017	237.36	185.6357	10.16509	21.79

4. Conclusion

Through the study of atmospheric environmental quality from 2011 to 2016 in Baoding, the following conclusions are obtained. First, in the past six years, the quality of the air environment in Baoding has improved a lot. The quality of atmospheric environment is three-level in 2011 and 2012. However, the quality of the environment has been maintained at two level since 2013, which meets the requirements of the state. However, the quality of the environment is still in a state of repetition, and it is necessary to continue efforts. Second, by applying grey correlation method to comprehensive analysis of air environmental quality in Baoding, the result accords with the reality and achieves the expected evaluation result. This shows that the grey correlation method is suitable for the comprehensive evaluation of atmospheric environment in Baoding.

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