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Analysis of Air Pollutants in Xiong'an New Area Based on MATLAB Grey Model

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Abstract

The purpose of this paper is to study the air pollutants in Xiong'an New Area based on MATLAB grey model [1]. From 2011 to 2016, the results of sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and inhalable particulate matter (PM_{10}) detected at monitoring points in the three counties of Xiong'an were analyzed. According to the national environmental air quality standard [2], the air quality in Xiong'an New Area was reasonably evaluated based on grey model in MATLAB. Judging from the weight of pollution factors in the model, sulfur dioxide (SO_2) is the controlling factor of air quality in Xiong'an New Area, and the weight of nitrogen dioxide (NO_2) gradually increases. The main sources of the three pollutants were obtained by comprehensive data analysis, and a grey model was established according to the mass concentration of the main air pollutants, and the grey forecasting model was tested. The experimental results show that the model can be effectively applied to the forecasting of ambient air quality. On this basis, the present situation of atmospheric environmental quality in Xiong'an New Area and suggestions for improvement are obtained.

Keywords

Xiong'an New Area, Air Pollution, Grey Model, Forecasting, Suggestion

1. Introduction

On April 1, 2017, the Central Committee of the Communist Party of China (CPC) and the State Council announced their decision to establish Xiong'an New Area in Hebei Province. Xiong'an New Area is located in the hinterland of Beijing, Tianjin and Hebei, with obvious geographical advantages. It is another New Area of national significance after Shenzhen Special Economic Zone and Pudong New Area in Shanghai. The key task of planning and building Xiong'an New Area is to relax the non-capital functions of Beijing, build a green and intel-

ligent new city and create a beautiful ecological environment. Like other regions in Beijing, Tianjin and Hebei, the three counties in Xiong'an New Area have long been plagued by environmental pollution, especially atmospheric pollutants [3] [4] [5] [6].

The pollutants in the atmosphere are mainly composed of chemical pollutants and particulates, etc. In order to protect and improve the living environment of human beings, many domestic scholars have investigated the air pollution in cities. The main pollutants in the atmosphere are atmospheric particulates, sulfur dioxide and nitrogen oxides [7] [8] [9] [10] [11]. According to the situation of urban air pollution, many experts consider and evaluate it from these three aspects. At present, grey system theory has become an important forecasting method, including decision-making, evaluation, planning and control, system analysis and modeling. (Grey system theory is based on the concept of associative space, smooth discrete function and other concepts to define gray derivatives and gray differential equations, and then use discrete data columns to build dynamic models in the form of differential equations, since this is the basic model of the intrinsic gray system, and the model is approximate Non-unique, so this model is a gray model, which is denoted as GM (Grey Model), that is, the gray model is generated by using discrete random numbers to become random, which is significantly weakened and more regular. A model of the equation form facilitates the study and description of its changing process.) In particular, it has a unique analysis and model building method, short time series of statistical data and incomplete information systems [12] [13] [14]. Many researchers in China have established a grey system, and many doctors and researchers have applied the grey system to research [15] [16] [17] [18] [19].

There are few applications of the grey theoretical model in atmospheric environment prediction. Using the powerful matrix function of MATLAB, there are not many gray GM (1,1) model algorithms. (The gray model is generally expressed as GM(n,x) model, which means that the x variables are modeled by n-order differential equations.) Based on the MATLAB grey GM (1,1) model, this paper theoretically predicts the concentration of atmospheric pollutants in Xiong'an New District.

2. Weighted Grey Relational Analysis Model of Urban Air Pollution Index

Taking Xiong'an New Area as an example, the monitoring data of sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and inhalable particulate matter (PM_{10}) were monitored at monitoring points in the three counties of Xiong'an from 2011 to 2016 [20] [21] [22]. According to the national environmental air quality standard, a weighted grey correlation analysis model is used to make a reasonable comprehensive evaluation of the air quality in Xiong'an New Area.

2.1. Climatic Characteristics of Xiong'an New Area

Xiong'an New Area includes Xiongxian, Rongcheng and Anxin counties in He-

bei Province and some surrounding areas. Located in the hinterland of Beijing, Tianjin and Baoding, it has a temperate continental monsoon climate with distinct seasons, drought and windy spring, hot and rainy summer, cool autumn, cold and less-snow winter. The average annual temperature is 11.7˚C, the highest monthly (July) average temperature is 26˚C, and the lowest monthly (January) average temperature is −4.9˚C with the annual sunlight of 2685 hours and an average annual rainfall of 551.5 mm, accounting for 80% from June to September, and a frost-free period of 191 days a year.

2.2. Sources and Analysis Methods of Major Air Pollutants

This paper analyzes the air pollution from the three factors of civil heating, dust raising and industrial pollution in Xiong'an New Area [23] [24].

Analysis of civil heating factors: the civil heating season leads to a decrease in air quality and a higher concentration of sulfur dioxide. Coal burning directly leads to an increase in pollutant concentration. Civil heating is an important factor affecting air quality. The level of economic development in Xiong'an County is relatively low, with coal-fired heating in rural areas and coal-fired heating in some county residents [25].

Analysis of the factors of floating dust: Xiong'an New Area is a city with little rain in the north, and the concentration of inhalable particulate matters in the air is higher than that in coastal cities, thus affecting the air quality in Xiong'an New Area.

Analysis of industrial pollution factors: The three counties of Xiong'an take plastic packaging, latex products, leather shoes and non-ferrous metal processing industries as the main pillar enterprises, and the development of the enterprises has also brought serious air pollution to the local area [26] [27].

Refer to **Table 1** for the sources and analysis methods of the major atmospheric pollutants sulfur dioxide, nitrogen dioxide and inhalable particulate matters PM_{10}.

2.3. Monitoring Results of Concentration of Mainair Pollutants

The continuous monitoring data of air pollution monitoring in Xiong'an New Area (from the real-time air quality publishing platform of Hebei Environmental Monitoring Center Stationadopts the Dongyu 1000 series air quality automatic

Table 1. Sources and Analysis methods of various pollutants.

Name of pollutant	Analytical method	source
Sulfur dioxide (SO_2)	Sulfur dioxide (SO_2) formaldehyde absorption para rosaniline spectrophotometry; Mercury tetrachloride parafuchsin spectrophotometry; UV fluorescence method;	GB/T 15262-94 GB 8970-88
Inhalable particulate matter	Gravimetric analysis	GB6921-86
Nitrogen dioxide (NO_2)	Saltzman analysis method Chemiluminescence method	GB/T 15436-95

monitoring system. The main air pollutants are O_3, PM2.5, PM10, SO_2, NO_2, CO, etc., and the main pollutants which have serious impact on air quality are selected for analysis and research. The data in this paper are based on the annual average of air pollutants SO_2, NO_2 and PM_{10} (as shown in Table 2) from 2011 to 2016.

2.4. Comprehensive Evaluation of Atmospheric Environmental Quality

The evaluation criteria are listed in the *National Air Quality Standard of the People's Republic of China* (GB 3095-1996) and revised in 2000 (refer to Table 3).

Weighting is determined by considering population factors and weight distribution position. According to the contribution rate of evaluation factors of each evaluation unit, the weight coefficient of each evaluation factor of the unit to be evaluated can be determined.

The formula is as follows:

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

α_i —The weight coefficient of pollutant I;

s_i —Standard arithmetic mean of i pollutant concentration;

x_i —The actual concentration value of pollutant i.

According to the formula, the weight of Xiong'an New Area in 2011-2016 is calculated (refer to Table 4).

Table 4 gives the values of the annual pollution weight factor a_i. The weight calculation results show that SO_2 and PM_{10} are the main pollutants affecting the air quality in Xiong'an New Area. The main pollutants each year are SO_2 (2011), PM_{10} (2012), PM_{10} (2013) and SO_2 (2014-2016). In recent years, air pollution in Xiong'an New Area has gradually changed from PM_{10} to SO_2, but there is still a long way to go to reduce the impact of PM_{10} on the environment.

2.5. Evaluation Results of Weighted Grey Correlation

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \cdot \sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{2}$$

x_i, y_i represent the actual value, the sequence of the fitted value,

$\bar{x}$, $\bar{y}$ represent the actual value and the average of the fitted values.

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

The r1, r2 and r3 in Table 5 are the correlation coefficients of the theoretical data of SO_2, NO_2 and PM10 and the measured data.

Through the comprehensive analysis of Table 4 and Table 5, it is concluded that the air quality in Xiong'an New Area from 2011 to 2012 belongs to the III

Table 2. Monitoring results of air pollutants in Xiong'an New Area.

Year	SO_2 (mg/m^3)	NO_2 (mg/m^3)	PM_{10} (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

Table 3. Grading standards for atmospheric environmental quality.

Pollutant	Sample time	Limit concentration (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

Table 4. Weight calculation results.

Year	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 5. Results of comprehensive evaluation in recent years.

Year	Correlation degree			
	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

level, that is, light pollution. From 2013 to 2016, the urban ambient air quality was 2 and the air was good. This indicates that the ambient air quality in the New Area is gradually improving. This good air quality benefits from the posi-

tive measures taken by the State Environmental Protection Administration in recent years. The advantage of grey correlation analysis is that it can sort the quality of analysis environment. According to the order from high to low, the air quality is the best in 2014, and the situation is worse from 2011 to 2016.

2.6. Evaluate According to the Season and Heating Cycle

Each year is divided into heating period and non-heating period. The non-heating period is from March 15 to November 15 of each year, and the heating period is from November 15 to March 15. The evaluation results are shown in Table 6.

Table 6 shows that the air quality in Xiong'an New Area is good during non-heating period, with PM_{10} as the main pollutant. The air quality is relatively poor during the heating period, and the main pollutant is sulfur dioxide. It can be seen that Xiong'an New Area is a coal-polluted city and needs to further control coal pollution.

3. Forecast of Air Pollution in Xiong'an New Area Based on Grey Model

3.1. Assumptions of Model

Other pollutants in the atmosphere within a reasonable range are ignored;

Ignoring the error of data in the process of detecting pollutants;

Assuming no major natural disasters such as earthquakes, sandstorms and floods, the city's natural environment will remain stable.

Assuming that no major industrial accident will occur in the past two years.

3.2. Establishment of Grey Forecasting Model

In order to ensure the consistency of the model parameter rate, the grey forecasting system theory was used to select data from August 2016 to March 2017, and the mass concentrations of PM_{10}, NO_2 and SO_2 were selected within 6 months. According to the previous analysis results, three grey forecasting models of PM_{10}, NO_2 and SO_2 in Xiong'an New Area are established respectively. The grey forecasting model is as follows:

$$\hat{\chi}^1_{(k+1)} = -5822.23\exp(-0.0376k) + 6277.38 \quad (1)$$

$$\hat{\chi}^1_{(k+1)} = -2823.35\exp(-0.0177k) + 4545.56 \quad (2)$$

$$\hat{\chi}^1_{(k+1)} = -822.67\exp(-0.0736k) + 678.34 \quad (3)$$

(1) grey forecasting models of PM10.

(2) grey forecasting models of NO_2.

(3) grey forecasting models of SO_2.

3.3. Test of Forecast Results

According to the formula of grey forecasting model, the mass concentration of SO_2 in the atmosphere in Xiong'an New Area from August 2016 to March 2017

Table 6. Comprehensive evaluation results for the whole year.

Year	Term	Pollutant concentration (mg/m^3)			Quality level	Primary pollutant
		Ⅰ level	Ⅱ level	Ⅲ level		
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}

is calculated. (See Figure 1) The forecasted value of the grey model is taken as the input value, and the actual value is the output value. Iterate input and output values. The maximum number of cycles is set to 5000 and the initial step size is 0.0001 m.

The data processing shows that the experimental data and the theoretical data are basically fitted.

According to the formula of the grey forecasting model, PM_{10}, NO_2 and SO_2 pollution in Xiong'an New Area (See Figure 2) will be obtained in the next 6 months, and the forecasting results of the grey forecasting model will be tested. The accuracy of the model was verified by residual error test and posterior error test. The results of the remaining tests are shown in Table 7.

4. Conclusion

Through the study of the air environmental quality in Xiong'an New Area from 2011 to 2016, it is found that the air environmental quality in the New District has greatly improved in the past six years, and the air environmental quality reached the III level in 2011 and 2012. Since 2013, the environmental quality has been maintained at II level, meeting the national requirements. However, the environmental quality is still in a state of constant repetition and it is necessary to continue efforts. Secondly, the grey correlation method is used to comprehensively analyze the air environmental quality in Xiong'an New Area. The results are in line with the actual situation and reach the expected evaluation results [28] [29] [30]. The grey correlation method is applicable to the comprehensive evaluation of Xiong'an New Area's air environment.

5. Suggests

"Green environmental protection, standards first" If Xiong'an New Area wants to realize the development vision of green ecology and livability, it must

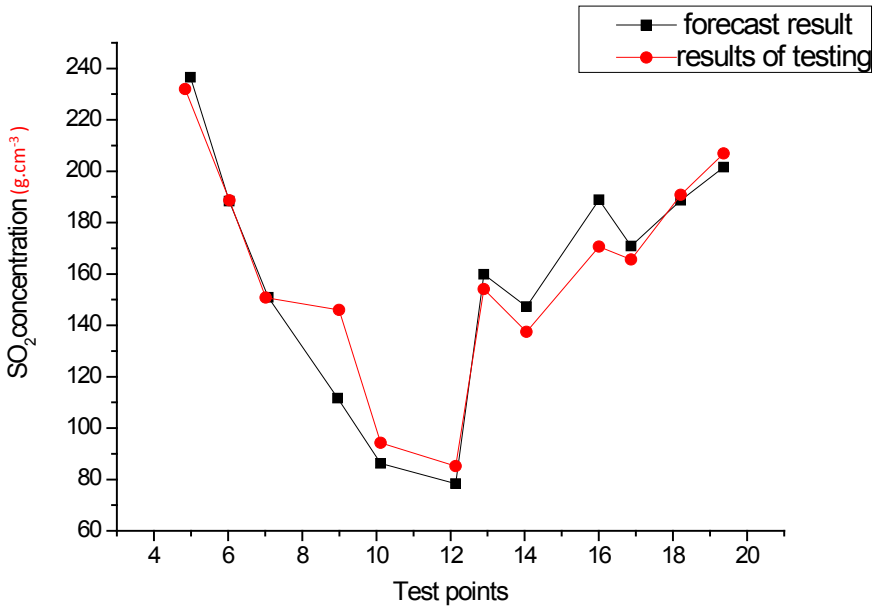

Figure 1. Forecasting of SO_2 Concentration in Xiong'an New Area from August 2016 to March 2017.

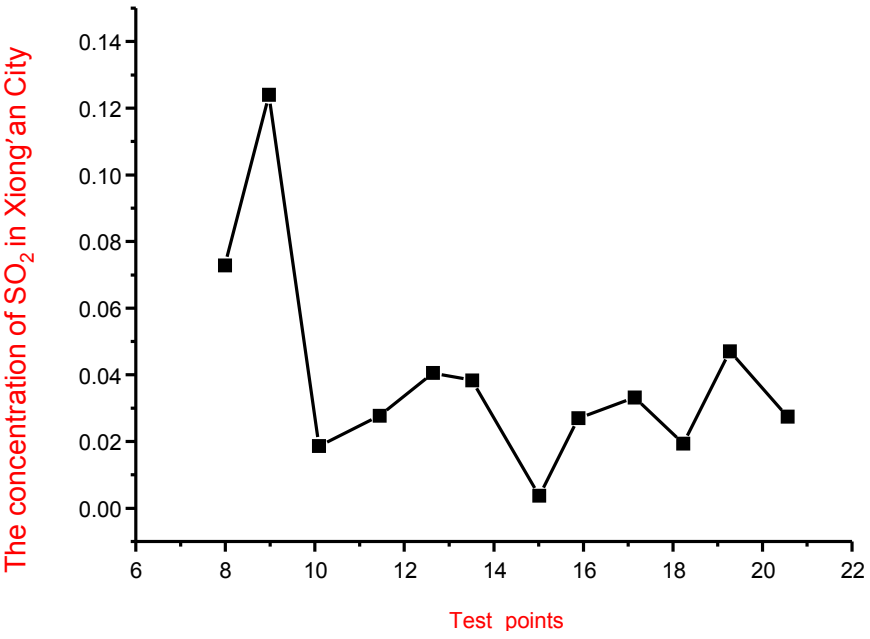

Figure 2. Forecasting of SO_2 mass concentration in Xiong'an New Area.

Table 7. The results of residual error test and posterior error test.

Time	SO_2			
	Monitoring value	Forecasted value	Residual error	Relative error (%)
2016.08	86.53	61.0388	−18.88676	18.43
2016.10	100.61	121.1906	14.10033	17.24
2016.12	189.53	139.7011	17.14607	7.79
2017.02	237.36	185.6357	10.16509	21.79

effectively crack the restrictive factors affecting environmental pollution, which requires that the industrial emission standards of enterprises settled in Xiong'an New Area should reach the international level, while the existing industrial standards in China are low and slow to update, and new standards are urgently needed. Based on the understanding of the surrounding environment of the New District, it is suggested that some teachers and scientific research departments in colleges and universities in the province may participate in the drafting of the standards.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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