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Research Article

Study on the Urban Air Quality Assessment and Pollution Characteristics in Daqing City

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Abstract: The aim of this study is to reveal the spatial and temporal variations of the main atmospheric pollutants in Daqing City by mathematical analysis of the monitoring data according to the atmospheric environmental monitoring data for nearly 15 years of Daqing City. The comprehensive pollution index method, the pollutant load factor method and the rank correlation coefficient method were used for the evaluation of atmospheric environmental quality. The results showed that the air quality of Daqing City was good as a whole in 15 years and it improved better step by step. Dusts and PM_{10} were the major air pollutants and the weight of NO_2 was increasing year by year. In addition, the air pollution type was developing from "coal smoke" to "oil smoke". Spearman rank correlation coefficient method was used to analyze the trend and significance of the main air pollutants in Daqing City. The results showed that PM_{10}, dusts and SO_2 presented downward trend and NO_2 Presented upward trend, but the trends were not significant and fluctuated on the same level. The task of energy-saving and emission-reduction will be still arduous for Daqing City.

Keywords: Characteristics of air pollution, Daqing ctiy, the air environmental quality assessment

INTRODUCTION

The atmospheric environment is a necessary condition for human survival and development and direct impacts the people's production, life and physical health (Tian *et al*., 2005; Helmm, 1999). With China's rapid social and economic development and the acceleration of industrialization and the urbanization process (Liu *et al*., 2004) our atmosphere shows the regional complex pollution characteristics (Wang *et al*., 2011) and air pollution has become a prominent urban environmental problem (Meng *et al*., 2012). Air pollution is harm to human health, affects the plant growth, damages to cultural relics, reduces the visibility and adversely affects to the life of city residents (Kuo *et al*., 2008; Qin *et al*., 2006). The main factors causing the deterioration of the environmental quality of urban air includes energy consumption, pollution sources, dusts, outside sources, vehicle exhaust (Streets and Waldhoff, 2000; Department of Environmental Protection, 2010). Improving urban air quality in the process of rapid urbanization becomes the main contents of urban ecological environmental protection.

Daqing City is a famous oil industrial and typical resource-based city and the economic and social development has great dependence on resources (Daqing Municipal People's Government, 2002, 2004). The main energy consumption categories are crude oil, coal, natural gas (Barletta *et al*., 2005). Accompanied by the rapid urbanization and energy increasing consumption, air quality of part region has deteriorated year by year. In addition, it is always temperature inversion weather in winter and long residence time of all kinds of exhaust gas in the low-altitude leads increased pollution. Although air quality is still relatively good, industries such as electricity, heat production and supply, chemical raw materials, chemical products manufacturing, petroleum processing and coking industry continue to affect air quality. The comprehensive pollution index method, the pollutant load factor method and the rank correlation coefficient method were used for the evaluation of atmospheric environmental quality and influencing factors during rapid urbanization process in this study. It can provide some scientific basis for the government and environmental protection departments to carry out environmental protection and governance.

The objective of the study is to explore the spatial and temporal variations of the main atmospheric pollutants in Daqing City by mathematical analysis of the monitoring data according to the atmospheric environmental monitoring data for nearly 15 years of Daqing City.

OVERVIEW OF THE STUDY AREA

Daqing City is located in the central Songnen Plain, west of Heilongjiang Province. The geographical

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Table 1: Environmental quality standard values

Items	Time	standard value First level	Second level	Third level	Unit
SO2	Annual mean	0.02	0.06	0.10	mg/m^3
NOX	Annual mean	0.05	0.05	0.10	mg/m^3
PM10	Annual mean	0.08	0.02	0.30	mg/m^3
dust	Monthly mean		10.0		$Ton/km^2/30$ d

Sources of data: ambient air quality standard (GB3095-1996), the dust standard value is provincial standard (10.0 Ton/ km^2.30 d).

position is 123°45′~125°47′E and 45°23′~47°28′N including Saertu District, Longfeng District, Ranghulu District, Honggang District, Datong District and Zhaoyuan Country, Zhaozhou Country, LinxunCountry and Duerbote Mongolia Autonomous Country. The total area is 21200 Km^2. Daqing City is an industrial city mainly in the petrochemical and oil extraction industry. The main air pollutants are sulfur dioxide, nitrogen oxides and PM_{10}. The hydrocarbons has been the characteristic pollutants in ambient air. Daqing City is the main research region in the study.

THE DATA SOURCE AND THE EVALUATION METHOD

The data source and the main monitoring items: Daqing City is famous for petrochemical industry. The main air pollutants are SO_2, NO_2, PM_{10} and dust. The data is provided by the environmental monitoring station. Based on the monitoring data of 1996-2010, the concentrations of different time and different monitoring points in the region are studied and the spatial and temporal distributions are analyzed of SO_2, NO_2, PM_{10} and dust. The seasonal and annual variation characteristics, variation characteristics of heating period and non-heating period and the distribution characteristics at the different monitoring points are analyzed in order to understand the air pollution characteristics and distribution of main pollutants providing the certain basis for the future trend of atmospheric environmental pollutions and environmental governance.

According to the population and area sampling method, five environmental air monitoring points are established by city environmental monitoring stations including Saertu District Environmental Monitoring Station, Longfeng District Environmental Monitoring Station, Ranghulu District Environmental Monitoring Station, Honggang district environmental monitoring station, Datong District Environmental Monitoring Station. Datong District Environmental Monitoring Station is the clean and control point. The main monitoring items include: SO_2, NO_2, PM_{10}, dust etc. which are 24 h automatic monitoring.

The environmental air quality assessment method:

- **The comprehensive pollution index method:** Combined with air quality evaluation criteria and environmental air pollution character, grade two (Table 1) of ambient air quality standard (GB3095-1996) is adopted for pollution evaluation standard and the environmental air quality assessment method is used to calculate. The computational formulae are:

$$Pi = \frac{Ci}{Si}$$

$$P = \sum_{i=1}^{n} \frac{Ci}{Si}$$

where,
P = Comprehensive pollution index
Pi = The single pollution index
C_i = Annual average pollutant
Si = Pollution assessment standard
n = Items number

- **The pollutant load factor method:** By calculating the pollution load proportion, the influences of different pollutants are reflected and the importance sequences of pollution factors are confirmed. The computational formula is:

$$f_i = P_i / P$$

- **The rank correlation coefficient method:** This is a commonly used at home and abroad pollution trends quantitative analysis method. By comparing the absolute value of rank correlation coefficient r_s with the critical value of Spearman rank correlation coefficient table, if $r_s > w_p$, it means the trends are remarkable. If r_s is negative, it means the downward trend.
The computational formulae are:

$$r_s' = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n\left(n^2-1\right)}, \quad d_i = x_i - y_i$$

n = Number of time period
d_i = Difference of x_i and y_i
x_i = The sorted No. concentration values from cycle i to cycle n
y_i = The sorted No. by time

RESULTS AND ANALYSIS

Seasonal variations of air pollutions: It can be seen from the monitoring data results (Fig. 1 and 2) that from 1996 to 2010 the sequence sorted by seasonal average concentrate of major pollutants is: the fourth quarter, the first quarter, the second quarter, the third quarter. It is significantly higher in winter than other seasons. Mainly due to the northern winter heating, boiler emissions increase the concentration of SO_2. At the same time, it is always temperature inversed weather which makes against the pollution diffusions and it increases the concentration of SO_2. The concentrations of PM_{10} and dust are high in spring and at the end of spring and the beginning of summer because it is drought, lack of rain, high wind and bare for land causing the serious dust pollutions.

Annual variations of the comprehensive pollution index: It can be seen from evaluation results of the air quality from 1996 to 2010 (Table 2) that annual variations of the comprehensive pollution index trends are downward in the whole (Fig. 3). It indicates that the air environmental quality is improving year by year mainly due to the creating of health city and environmental protection model city, the development of central heating and the ban on small boilers in recent years.

Comprehensive pollution index variations in the heating period and the non-heating period: From 1996 to 2010, the comprehensive pollution index variations in the heating period and the non-heating period can be seen that the most serious air pollution season is the heating period (Fig. 4). The highest comprehensive pollution index was 2.2 in 1997 and the lowest comprehensive pollution index was 1.4 in 2009. The highest comprehensive pollution index was 1.9 in 1997 and the lowest comprehensive pollution index was 1.3 in 2002 in the non-heating period. The heating period pollution index showed a downward trend from the annual changing trend which was relative to the central heating and close the small boilers and other measures.

From the single pollution index, we can see that except the dust other single pollution index were higher in the heating period than that in the non-heating period significantly (Fig. 5). The single pollution index of dust was higher in the non-heating period than that in the heating period

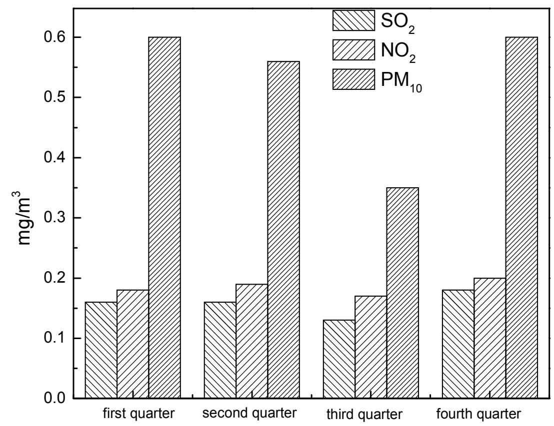

Fig. 1: Seasonal average changes of SO_2、NO_2、PM_{10}

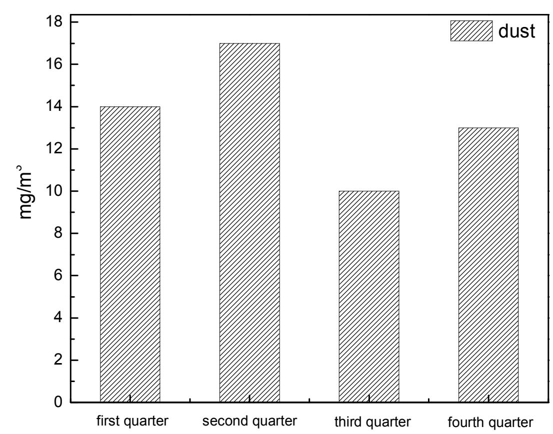

Fig. 2: Seasonal average changes of dust

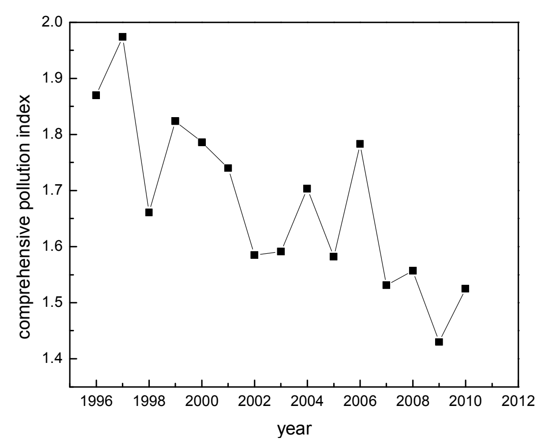

Fig. 3: Annual curves of the comprehensive pollution index

Pollutants spatial distribution characteristics in ambient air: From Fig. 6, 7 and Table 3, we can draw the conclusion that the annual average value of

Table 2: Evaluation results of the air quality from1996 to 2010

	P_i					
Year	SO_2	NO_2	PM_{10}	Dust	P	$\bar{P}$
1996	0.217	0.290	0.493	0.870	1.870	0.468
1997	0.283	0.250	0.447	0.994	1.974	0.494
1998	0.050	0.340	0.745	0.526	1.661	0.415
1999	0.083	0.480	0.615	0.646	1.824	0.456
2000	0.133	0.480	0.560	0.613	1.786	0.446
2001	0.183	0.212	0.600	0.745	1.740	0.435
2002	0.167	0.212	0.580	0.626	1.585	0.396
2003	0.167	0.238	0.660	0.526	1.591	0.398
2004	0.217	0.275	0.630	0.581	1.703	0.426
2005	0.217	0.212	0.570	0.583	1.582	0.400
2006	0.217	0.175	0.620	0.769	1.780	0.445
2007	0.217	0.188	0.510	0.617	1.532	0.383
2008	0.217	0.225	0.510	0.609	1.561	0.390
2009	0.183	0.175	0.490	0.588	1.436	0.359
2010	0.183	0.225	0.530	0.595	1.533	0.383
Average	0.177	0.264	0.570	0.66	1.672	0.418

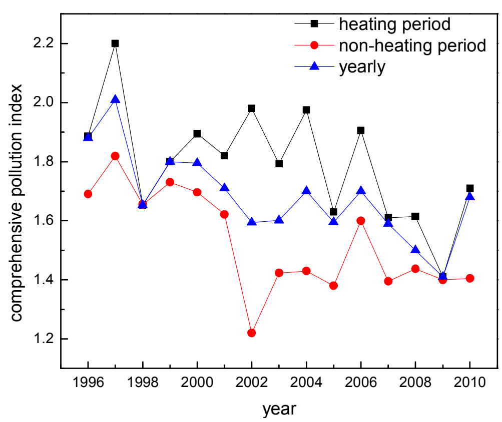

Fig. 4: Comprehensive pollution index variations in the heating period and the non-heating period

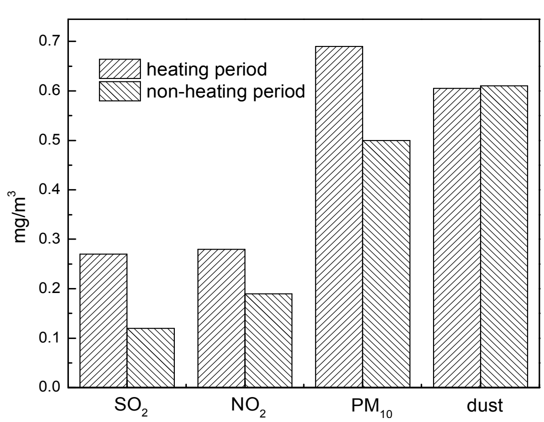

Fig. 5: Single pollution index variations in the heating period and the non-heating period

pollutants Saertu District and Ranghulu District was in a higher position and it was lower in Longfeng District, Honggang District and Datong District. From different

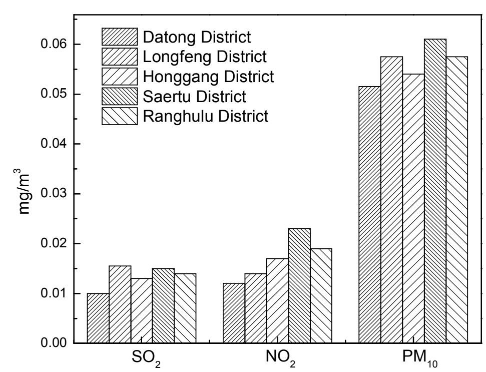

Fig. 6: Spatial distribution characteristics of annual average value of pollutants

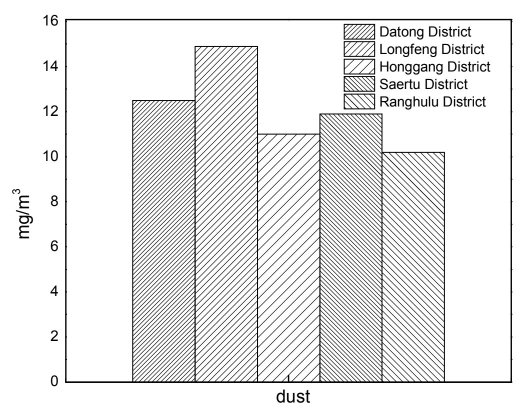

Fig. 7: Spatial distribution characteristics of annual average value of dust

district pollution load index, we can see that the pollution degree from heavy to light were as follows: Saertu District, Longfeng District, Honggang District, Ranghulu District, Datong District. Saertu District is

Table 3: Evaluation results of the different district air quality from1996 to 2010

		Pi						
Year	Items district	SO_2	NO_2	PM_{10}	Dust	P	$\bar{P}$	f_i (%)
1996-2000	Saertu	0.167	0.680	0.800	0.680	2.327	0.582	26.7
	Longfeng	0.200	0.520	0.725	0.729	2.174	0.544	25.1
	Hongyan	0.133	0.440	0.595	0.385	1.553	0.388	17.8
	Ranghulu	0.133	0.500	0.745	0.298	1.676	0.419	19.2
	Datong	0.100	0.200	0.430	0.254	0.730	0.243	11.2
2001-2005	Saertu	0.150	0.138	0.550	0.714	1.552	0.465	26.7
	Longfeng	0.267	0.175	0.630	0.650	1.722	0.430	19.8
	Hongyan	0.217	0.188	0.590	0.532	1.527	0.382	17.6
	Ranghulu	0.200	0.325	0.650	0.684	2.324	0.394	18.1
	Datong	0.150	0.325	0.620	0.480	1.575	0.388	17.8
2006-2010	Saertu	0.183	0.162	0.570	0.648	1.563	0.390	19.8
	Longfeng	0.250	0.175	0.530	0.797	1.752	0.438	22.3
	Hongyan	0.217	0.212	0.500	0.579	1.508	0.377	19.2
	Ranghulu	0.200	0.225	0.620	0.618	1.563	0.370	18.9
	Datong	0.183	0.212	0.540	0.548	1.483	0.390	19.8

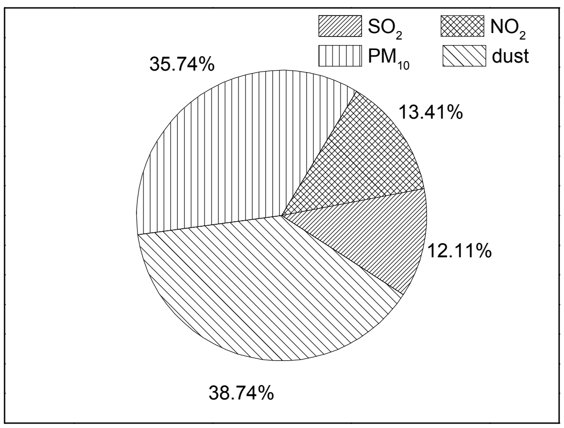

Fig. 8: The main pollutant load factors in 15 years

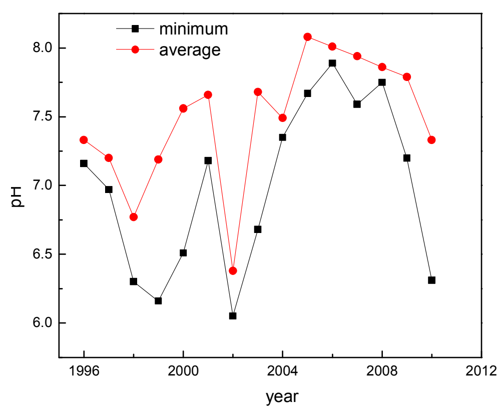

Fig. 9: The annual changes of precipitation pH values

located in the center of Daqing Ctiy and the main reasons led to pollute are too much motor vehicles, large industrial pollution sources and the living emissions. Datong District is located in the edge of Daqing City and the main agricultural area which are less industrial pollution source with flat terrain, easy to spread contaminant belonging to the lighter air pollution area.

Major pollutants evaluation in ambient air: Pollutant load factor method is used to evaluate the major pollutants in the air. We can draw the conclusions from the statistical analysis for air pollution loads that from 1996 to 2010 the pollutant load factor from large to small are as follows: dust, PM_{10}, NO_2, SO_2. So the main pollutions are dust and PM_{10} from 1996 to 2010 and the sum pollutant load factor is up to 74.4% (Fig. 8). The main reason is that Daqing city is located in the center of Songnen Plain and there are large area of saline-alkali soil and sandy loam soil. The vegetation coverage is low and it is easily destroyed and slow to be recovered which is easily to set off dust affected by the monsoon. Additionally, drought and little rain and high speed wind are also the main reason to form the dust. Moreover, with the increase of construction projects in recent years, the dust pollutions causing by the construction are followed. Especially in the spring, the climate is dry and the wind speed is great. The influence of dust to PM_{10} and dust fall is greater. From the changing trend, the pollution load factor of dust is downward and that of PM_{10} is upward.

The annual pH value changes of the precipitation: From 1996 to 2010, 914 samples of precipitation were collected. From the statistical results of precipitation monitoring (Table 4 and Fig. 9), it can be seen that the annual average of PH values changes from 6.77 to 8.08 which is not significant and in most years it is subalkalic. Although accompanied by the expansion of the oil industry as well as the increase of motor vehicles, the emissions of SO_2 and NO_2 are presenting the increasing trend. There is a large area of alkaline carbonate land which makes the total suspended particulate matters in the air alkaline and play a

Table 4: Statistics results of precipitation pH values from 1996 to 2010

Year	Samples	Max.	Min.	Average	Acid rain degree
1996	7	7.95	7.16	7.33	0.0
1997	21	7.62	6.97	7.20	0.0
1998	12	7.92	6.30	6.77	0.0
1999	10	8.34	6.16	7.19	0.0
2000	16	7.96	6.51	7.56	0.0
2001	28	7.96	7.18	7.66	0.0
2002	52	7.98	6.05	6.38	0.0
2003	48	8.35	6.68	7.68	0.0
2004	84	8.36	7.35	7.49	0.0
2005	168	8.35	7.67	8.08	0.0
2006	99	8.29	7.89	8.01	0.0
2007	132	8.16	7.59	7.94	0.0
2008	66	8.03	7.75	7.86	0.0
2009	108	8.40	7.20	7.79	0.0
2010	81	8.21	6.31	7.33	0.0

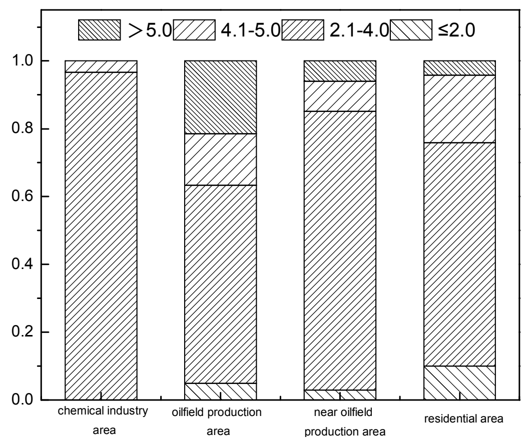

Fig. 10: Spatial distribution characteristics of total hydrocarbon concentration

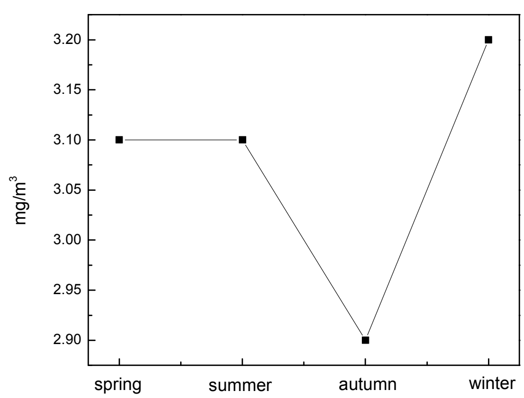

Fig. 11: Seasonal distribution characteristics of total hydrocarbon concentration in ambient air

cushioning effect to acidic precipitation so that the precipitation pH values are still neutral acidic alkaline.

Temporal and spatial distributions of total hydrocarbon in the air: Daqing City is an industrial city focusing on the petrochemical production. In the crude oil refining process, it is inevitably produce a range of toxic and harmful gases emitting into the atmosphere causing the air pollution which contain a large number of hydrocarbon pollutants. From the monitoring results from 1996 to 2010, total hydrocarbon data of different functional areas had spatial and temporal distribution characteristics.

- **Spatial distribution characteristics:** From the monitoring results (Fig. 10), we can see that the hour concentration in the chemical area of total hydrocarbon was not excessive the standard value which changed from 2.1 mg/m^3 to 4 mg/m^3 and accounting for 96.6% of the total numbers and distributing was concentrated. The hour concentration in the oilfield production area of total hydrocarbon was exceeded. The exceeded rate was 20.6%. The data mainly changed from 2.1 mg/m^3 to 4.0 mg/m^3 and accounting for 58.4% of the total numbers and distributing was relatively dispersed. The data changed from 4.1 mg/m^3 to 5.0 mg/m^3 and accounting for 15.2% of the total numbers. The data greater than 5 .0 mg/m^3 accounting for 21.5% of the total numbers and distributing was concentrated. The hour concentration near the oilfield production area of total hydrocarbon was exceeded. The exceeded rate was 5.95%. The data mainly changed from 2.1 mg/m^3 to 4.0 mg/m^3 and accounting for 82.15% of the total numbers and distributing was relatively dispersed. The data changed from 4.1 mg/m^3 to 5.0 mg/m^3 and accounting for 8.95% of the total numbers. The data greater than 5.0 mg/m^3 accounting for 9.95% of the total numbers and distributing was concentrated. The hour concentration in the residential area of total hydrocarbon was exceeded. The compliance rate was relatively high. It mainly distributed in the

Table 5: Statistics of annual changing trends and significances of the major air pollutants

Year	Items	SO_2	NO_2	PM_{10}	Dust	Comprehensive pollution index
"Ninth five"(1996-2000)	r_s value	-0.5	-0.35	-0.7	0.7	-0.56
	W_p	0.9	0.9	0.9	0.9	0.9
	Changing trend	↓	↓	↓	↑	↓
	Significance	Not significant	Not significant	Not significant	Not significant	Not significant
"Tenth five"(2001-2005)	r_s value	0.65	0.40	-0.20	-0.70	-0.60
	W_p	0.9	0.9	0.9	0.9	0.9
	Changing trend	↑	↑	↓	↓	↓
	Significance	Not significant	Not significant	Not significant	Not significant	Not significant
"Eleventh five"(2006-2010)	r_s value	-0.6	0.5	-0.3	-0.6	-0.5
	W_p	0.9	0.9	0.9	0.9	0.9
	Changing trend	↓	↑	↓	↓	↓
	Significance	Not significant	Not significant	Not significant	Not significant	Not significant

Table 6: Statistics of annual changing trends and significances of the major air pollutants in the heating and non-heating period

year	Seasons	Items	SO_2	NO_2	PM_{10}	Dust
"Ninth five"(1996-2000)	Heating period	r_s	-0.5	0.05	-0.7	0.7
		W_p	0.9	0.9	0.9	0.9
		Changing trend	↓	↑	↓	↑
		Significance	Not significant	Not significant	Not significant	Not significant
"Ninth five"(1996-2000)	Non-heating period	r_s	-0.5	-0.35	-0.7	0
		W_p	0.9	0.9	0.9	0.9
		changing trend	↓	↓	↓	
		significance	not significant	not significant	not significant	Not significant
"Tenth five"(2001-2005)	Heating period	r_s	-0.6	0.4	-0.4	-0.7
		W_p	0.9	0.9	0.9	0.9
		changing trend	↓	↑	↓	↑
		Significance	Not significant	Not significant	Not significant	Not significant
"Tenth five"(2001-2005)	Non-heating period	r_s	0.9	0.7	0.1	-0.9
		W_p	0.9	0.9	0.9	0.9
		Changing trend	↓	↓	↓	↓
		Significance	Significant	Not significant	Not significant	Significant
"Eleventh five"(2006-2010)	Heating period	r_s	-0.7	0.2	-0.3	-0.7
		W_p	0.9	0.9	0.9	0.9
		Changing trend	↓	↑	↓	↓
		Significance	Not significant	Not significant	Not significant	not significant
"Eleventh five"(2006-2010)	Non-heating period	r_s	0	0.8	-0.3	-0.8
		W_p	0.9	0.9	0.9	0.9
		Changing trend	Not relative	↑	↓	↓
		Significance	Not significant	Not significant	Not significant	Not significant

lower range. The data mainly changed from 2.1 mg/m^3 to 4.0 mg/m^3 and accounting for 65.2% of the total numbers and the data greater than 5.0 mg/m^3 was less.

- **Seasonal distribution characteristics:** From the seasonal distribution characteristics of total hydrocarbon in ambient air shown in Fig. 11, we can draw the conclusions that they were basically the same. It was lowest in autumn and highest in winter. It was mainly because that it was always temperature inversion weather in winter which was not conducive to the dispersal of pollutants. The seasonal distribution characteristics of total hydrocarbon in ambient air showed that the pollution was not apparently seasonal, but perennial, universal.

Changing trends in ambient air:

- **Annual changing trends:** The spearman rank correlation coefficient method was used. According to the annual average values of major air pollutants from 1996 to 2010, the changing trends and significances were counted (Table 5). As can be seen from the statistical results, the annual average values of PM_{10}, dust and SO_2 presented downward trend and that of NO_2 was upward trend, but the upward and downward trends were not significant and at the same level. From the comprehensive pollution index, they were downward trend and the air quality improved slightly, but not significantly. Energy saving task is still arduous.

- **The air pollution changing trends in the heating and non-heating period:** The spearman rank correlation coefficient method was used to analyze the air pollution changing trends in the heating and non-heating period during "ninth five" (1996-2000), "ninth five" (1996-2000) and "eleventh five" (2006-2010). As can be seen from the statistical results (Table 6), the annual average values of PM_{10}, dust and SO_2 presented downward trend and that of NO_2 was upward trend, but the upward and downward trends were not significant in the heating period. The annual average values were not significant and at the same level in the non-heating period.

CONCLUSION AND DISCUSSION

Based on the air monitoring data, pollutants characteristics in the air were analyzed. The results showed that the air quality was basically good from 1996 to 2010 and classified as moderately polluted. It was most polluted in 1997 and lowest in 2009. Dust, PM_{10}, NO_2 and SO_2 were the major pollutants in the air. The annual average values of SO_2 and NO_2 were lower than the national secondary standard. The sequences of the major four air pollutants load factors were dust, PM_{10}, NO_2 and SO_2. The factor of NO_2 presented upward trend indicting that the motor vehicle pollution was getting serious and should be taken seriously enough. From the changing situations of pollution load ratios from 1996 to 2010, the overall changing of dust fall pollution was flat to down and that of PM_{10} was upward. From the spatial distribution characteristics of pollution areas, Saertu District was heaviest polluted and Datong District was lightest polluted. Impacted of heating, special climate and urban landscapes, the pollution type were mainly coal-smoke pollution in spring and winter indicting that the air pollution was changing from coal-smoke pollution to the mixture of coal-smoke pollution and vehicle exhaust pollution. The air pollution characteristics and changing trends based on the historical monitoring data were analyzed in the study. Necessary measures should be taken to improve the air quality. Firstly, we should increase the environmental protection law enforcement and provide the implementation of unified supervisions and managements an strengthen the environmental protection capacity and team building and enhance the level of environmental regulation. Secondly, we should solve the pollution problem of coal smoke in winter and focus on improving the fuel structures and the development of heating. Thirdly, the public's environmental awareness should be continuously improved. Fourthly, we should strengthen the research efforts and actively carry out the governance research projects and provide the implementation of clean production processes. Fifthly, we should strengthen the management of motor vehicles and strictly carry out the national and local emission standards. Sixthly, we should strengthen the urban greening building and increase the urban the area of green space and improve the vegetation coverage to in some extent inhibited the ground secondary dust pollution. These measures will ensure that the ambient air quality in the future continue to show continuous turn for the better trend and the quality of the ecological environment will be continuously improved and ultimately an important guarantee for the healthy and stable transformation of resource based city will be provided.

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