Research on the Treatment of Regional Air Pollution

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Abstract. According to the change of air quality in the Beijing-Tianjin-Hebei region, this paper analyzes the pollution characteristics of the air environment in this region, constructs the air quality evaluation model, and finds that the main pollution sources affecting the air quality in Beijing-Tianjin-Hebei region are coal combustion and automobile exhaust. By using the flow-diffusion equation, the air pollution concentration gradients of the Second Ring Road, the Fourth Ring Road, and the Sixth Ring Road in Beijing are given. Finally, this paper also puts forward specific countermeasures for the prevention and control of air pollution.

1. Introduction

With the rapid development of the social economy, air pollutant emission has become one of the important pollution problems in China. The content of air pollutants exceeds the environmental bearing capacity, which worsens the air quality and causes adverse effects on people's life, work, health, and ecological environment. Especially for a period of time, the increasing haze weather has disturbed people's travel order and quality of life. Through the investigation of air pollution caused by regional transmission, it can be found that air pollution between cities is common in China [1]. Air pollution through regional transmission, also known as cross-border air pollution, refers to the air pollution caused by other regions. In recent years, the problem of air pollution in the Beijing-Tianjin-Hebei region has become more and more serious, so it is necessary to study the transboundary pollution of air pollutants in the Beijing-Tianjin-Hebei region [2]. It is generally believed that the main pollutants affecting air quality are *PM*2.5, *PM*10, nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone, hydrogen sulfide, hydrocarbon, smoke, and so on. The co-existence of bituminous coal pollution and oxidation pollution, the superposition of local pollution and regional pollution, and the coupling of pollutants are the complex characteristics of air pollution. The impact of new compound pollution represented by haze weather on people's health is more and more serious, and the air pollution caused by photochemical smog has attracted more and more attention [3].

Therefore, the study of cross-border air pollution in the Beijing-Tianjin-Hebei region and the effective suggestions through numerical calculation will help to improve the environment and promote sustainable development. This paper takes the Beijing-Tianjin-Hebei region as the research object, referring to the existing national standards, through the establishment of a mathematical model to measure the air quality, the purpose is to make the evaluation results closer to the people's personal feelings as far as possible, and make the urban air quality standard rate rise significantly.

2. Evaluation of air quality

Because the background concentration limits of air pollutants are different in different regions, different air quality sub-indexes and corresponding pollutant concentration limits should be determined for different regions. When the concentration of pollutants changes in an equal proportion, the subjective difference perception of the concentration of pollutants also changes in an equal proportion. [4] In this paper, the index scaling method of "equal difference classification, equal ratio assignment" is used to calculate the limit of six-level standard concentrations of each air pollutant in the Beijing-Tianjin-Hebei region. According to the air quality sub-indexes and the corresponding pollutant concentration limits, the corresponding results are shown in Table 1.

Table 1. The air quality sub-indexes and the corresponding pollutant concentration limits

$IAQI$	24-hour average of pollutant concentration (mg/m^3)					
	SO_2	NO_2	$PM10$	CO	O_3	$PM2.5$
0	0.00	0.00	0.00	0.00	0.00	0.00
50	75.23	58.11	103.07	2000.00	95.34	24.65

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100	146.22	100.46	148.72	3940.70	166.29	44.28
150	300.27	182.34	222.18	7777.38	277.32	81.11
200	611.39	302.29	302.79	15390.65	471.88	151.15
300	1280.77	543.23	420.39	30389.70	789.22	270.66
500	2620.00	940.00	600.00	60000.00	800.00	500.00

The air quality index (AQI) is used to measure the level of air quality, and the air quality sub-index of an air pollutant is an important standard to judge the level of air quality [5]. The calculation method is as follows:

$$IAQI_i = \frac{IAQI_{HI} - IAQI_{LO}}{BP_{HI} - BP_{LO}}(C_i - BP_{LO}) + IAQI_{LO} \quad (1)$$

Here, $IAQI_i$ represents the air quality sub index of the $i-$th pollutant; C_i represents the mass concentration of the $i-$th pollutant; BP_{HI} represents the upper limit of pollutant concentration close to C_i; BP_{LO} represents the lower limit of pollutant concentration close to C_i; $IAQI_{HI}$ represents the air quality sub index corresponding to BP_{HI}; $IAQI_{LO}$ represents the air quality sub index corresponding to BP_{LO}. Corresponding to the concentration of the $i-$th pollutant, BP_{HI}, BP_{LO}, $IAQI_{HI}$ and $IAQI_{LO}$ can be found in Table 1. Then the air quality index can be calculated:

$$AQI = \max\{IAQI_1, IAQI_2, IAQI_3, \cdots, IAQI_n\} \quad (2)$$

Here, there are n kinds of pollutants in the air [5].

The monthly average concentrations of air pollutants in Beijing-Tianjin-Hebei region in March 2015 were found on the China air quality online monitoring and analysis platform. According to equation (1), the air quality sub-index of each pollutant can be calculated, as shown in Table 2.

Table 2. Air quality sub-index of pollutants

Pollutant	SO_2	NO_2	$PM10$	CO	O_3	$PM2.5$
Beijing	14.99	45.99	95.54	56.03	63.86	153.82
Tianjin	25.90	44.31	111.25	56.03	40.81	136.60
Shijiazhuang	40.89	47.66	123.08	56.03	62.39	158.21

According to equation (2), the air quality indexes of Beijing, Tianjin and Shijiazhuang can be calculated and the corresponding primary pollutants can be found, as shown in Table 3.

Table 3. The calculation results

Cities	Beijing	Tianjin	Shijiazhuang
AQI	153.82	136.60	158.21
Primary pollutant	$PM2.5$	$PM2.5$	$PM2.5$

The main pollutant in the Beijing-Tianjin-Hebei region is PM2.5, followed by PM10. The pollution sources include coal-fired, motor vehicle exhaust and industrial emissions. Beijing-Tianjin-Hebei region is a major high-tech and heavy industrial region in China, and coal power generation occupies a very important position. Sulfur is the most harmful component in coal, when coal is burned, most of the sulfur is oxidized into sulfur dioxide, which pollutes the atmosphere and causes haze with the emission of flue gas [6]. Of course, Beijing, Tianjin and Hebei have different reasons for affecting air quality because of their different economic development.

3. Diffusion of pollutants

The smog emitted in the production process is composed of gas and micro pollutant particles. Because the pollutants usually contain sulfide, it will cause great harm to the farmland around the factory. How to determine the degree of pollution on the surface according to the law of airflow and smoke diffusion is a key problem.[7]

Here, we first assume that the distribution of pollutants is in a stable state, that is, the wind speed, wind direction and smoke volume do not change with time. Secondly, the diameter of the chimney mouth is very small relative to the height of the chimney, so the chimney outfall can be regarded as a point. Finally, the effect of gravity on pollutant is ignored, and only the effect of pollutant flow and pollutant diffusion is considered.

Taking the intersection of the symmetry axis of the chimney and the ground as the origin, the axis consistent with the wind direction as the x axis, and the symmetry axis of the chimney as the z axis, then a right-handed coordinate system is formed.

Let $c(x, y, z)$ denote the concentration of pollutants at (x, y, z), U be the wind speed, h be the height, and D be the diffusion coefficient [8].

At this time, the flow-diffusion equation of pollutant is as follows:

$$U\frac{\partial c}{\partial x} = D\left(\frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2} + \frac{\partial^2 c}{\partial z^2}\right) \quad (3)$$

Here, a new variable is introduced, that is,

$$\bar{c}(x,z) = \int_{-\infty}^{+\infty} c(x,y,z)\,dy$$

The above flow-diffusion equation can be simplified as follows:

$$U\frac{\partial \bar{c}}{\partial x} = D(\frac{\partial^2 \bar{c}}{\partial x^2} + \frac{\partial^2 \bar{c}}{\partial z^2}) \quad (4)$$

After using the above equation to obtain $\bar{c}(x, z)$, and then the following function

$$c(x, y, z) = \frac{\bar{c}(x,z)}{\sigma\sqrt{2\pi}} e^{-\frac{y^2}{\sigma^2}} \quad (5)$$

can be used to approximate the distribution function of pollutant concentration [9].

The distance between Beijing's outer ring road and the city center is shown in Table 4.

Table 4. Distance between Beijing outer ring road and downtown (*km*)

Position	The Second Ring	The Fourth Ring	The Sixth Ring
East	3.3	7.8	26.7
West	3.4	10.5	21
South	3.5	8.4	20.5
North	3.6	8.8	28
Average distance	3.45	8.88	24.05

According to equation (3), the gradient diagram of the total concentration of automobile exhaust in each loop road can be calculated, as shown in Figure 1.

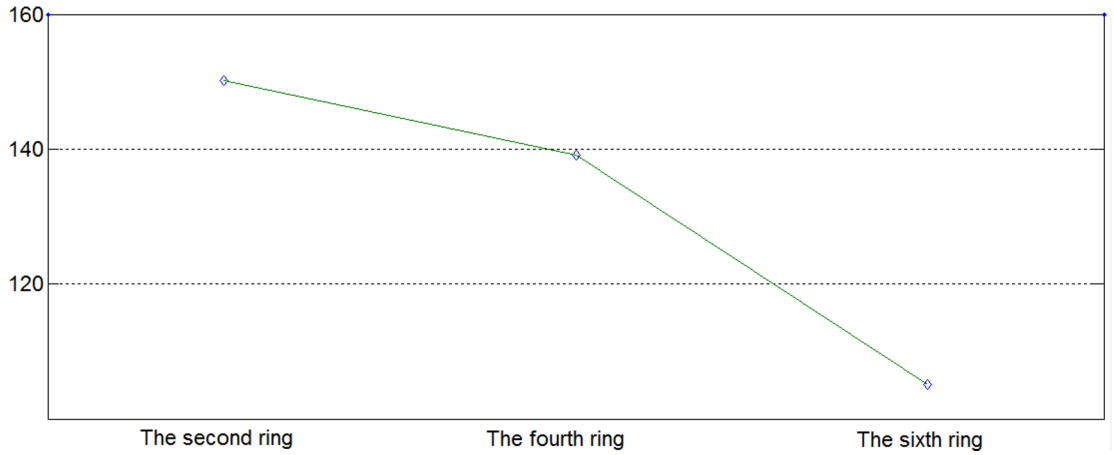

Figure 1. The gradient of air pollution concentration

It can be seen from Figure 1 that the gradient of air pollution concentration from the Second Ring Road to the Sixth Ring Road shows a downward trend, and the downward trend increases from the Fourth Ring Road to the Sixth Ring Road. The main reason is that the distance from the Second Ring Road, the Fourth Ring Road and the Sixth Ring Road to the city center gradually increases, so the traffic flow gradually decreases, and the air pollution concentration gradient shows a downward trend.

4. Measures for pollution control

In the aspect of air pollution prevention and control, how to improve the adverse effects of air pollution caused by regional transmission is particularly important. As for air pollution caused by regional transmission, we can't determine which factory, which enterprise, or what other reasons are responsible for the pollution. Within the scope of existing scientific identification technology, we can clearly identify the pollution area and its contribution. Therefore, the responsibility subject of air pollution can only be the local government as the administrative subject. Local people's governments at all levels shall be responsible for the quality of the atmospheric environment in their respective administrative areas, formulate plans and take measures to control or gradually reduce the discharge of atmospheric pollutants, so that the quality of the atmospheric environment can meet the prescribed standards and be gradually improved [10]. Of course, the local government for pollution prevention, pollution reduction, supervision and management is mainly the control of pollution emissions. [11]. Therefore, the local government of pollution sources should also bear the corresponding responsibility for regional air pollution.

At the present stage, the following three aspects should be strengthened in particular:

(1) We should find the source of pollution and control the number of waste gas emissions, scientifically and reasonably arrange the key projects of emission reduction, promote the desulfurization project of thermal power plants with large amounts of sulfur dioxide emissions, and the reduction tasks will be implemented layer by layer.

(2) We should strengthen the control of motor vehicle exhaust pollution, and establish a compulsory scrapping system for old vehicles, meanwhile, we should encourage motor vehicles to use clean fuels, install effective exhaust purification devices, and strengthen the supervision and management of motor vehicle exhaust emissions.

(3) We should strengthen the control of urban dust pollution, implement closed management of building construction and road construction, actively use modern greening technology, improve the urban greening rate, reduce the area of bare sites, and promote the development of urban environmental protection.

5. Conclusion

Taking the Beijing-Tianjin-Hebei region as an example, this paper studies the air quality status and air pollution diffusion, obtains the main pollution sources and pollution parameters that affect the air quality status in Beijing-Tianjin-Hebei region, and gives the method of calculating the air quality status, which is conducive to the local environmental governance. Moreover, the model can be used as a reference for the study of air pollution and environmental control in other areas. Air pollution caused by regional transmission is an important environmental pollution problem. The establishment of administrative subject responsibility mechanism based on administrative compensation and civil compensation can not only show the determination of national pollution control, but also enhance the attention of local governments and ordinary citizens to air pollution control, and promote the scientific treatment of air pollution.

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