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Improving urban air quality in China: investigation and control measures of PM_{2.5}, PM₁₀, NO₂ and SO₂ in air

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ABSTRACT

In recent years, the quality of urban atmospheric environment in China has caused widespread concern in the whole society. Improving air quality has become a major content of air pollution prevention and control in China. To do a good job in atmospheric prevention and control, we must investigate and analyze the sources of major atmospheric pollutants and their pollution characteristics firstly. With the acceleration of urbanization, the air pollution situation in Jinan city has become an environmental problem that people are particularly worried about. Based on the monitoring data of Jinan atmospheric environment, this paper analyzed the monthly average concentration values of PM_{2.5}, PM₁₀, NO₂ and SO₂ in Jinan City from 2015 to 2017. Meanwhile, the main reasons for the air pollution in Jinan City were clarified in detail. Finally, air pollution control strategies were proposed corresponding the aspects of pollution sources, topography and meteorological conditions, rational planning, environmental supervision capabilities, environmental awareness, and practical treatment technologies in Jinan City. These measures can provide a theoretical basis for relevant leading departments to build a beautiful city.

Keywords: Air quality; Environmental protection; Prevention suggestions.

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1. Introduction

1.1 The Overview of Jinan City Air Quality

With the development of society and economic development, the national economy has improved and life has improved.^[1] While enjoying the convenience brought by the new era, people gradually began to pay attention to ecological problems and put forward higher and higher requirements for the ecological environment. Nowadays, environmental problems are becoming more and more prominent, so it is especially important for us to study environmental issues. The normal survival of mankind cannot be separated from the air. Jinan City is one of the most polluted cities in China. The air quality is poor. The concentrations of typical atmospheric pollutants (SO₂, NO₂, O₃, CO, etc.) and particulate matter (PM₁₀, PM_{2.5}) are different to the national air quality standards. At present, Jinan City is in a period of rapid economic development, urban population is expanding, and the development of large-scale industrial and agricultural development zones and university parks makes Jinan's environmental problems more prominent. In particular, air pollution is one of the most important environmental problems in the city, directly affecting the improve-

ment of people's quality of life and people's health. The population of Jinan has increased rapidly and the population distribution is uneven. In recent years, the environmental quality of Jinan City has improved, and the number of days of "star-studded blue sky and white clouds" has increased significantly, and the number of severely polluted days has decreased. By studying the state of air quality, understanding the causes of poor air quality, finding ways and means to remedy and improve, so that our air quality will be better, the ecology of our country will be better, and sustainable development will continue.

2. Jinan City air quality status and analysis

2.1 Status of air quality in Jinan City

We collected the concentration data of atmospheric pollutants PM_{2.5}, PM₁₀, NO₂ and SO₂ in Jinan City from 2015 to 2017 (**Table 1**). The main data comes from the external network data center ^[2] (<http://datacenter.mep.gov.cn>). Trends of monthly average concentrations were shown in **Fig. 1**. The monthly average concentration values of PM_{2.5}, PM₁₀, NO₂ and SO₂ in five cities from 2015 to 2017 were analyzed using statistical calculation methods.

Table 1 Monthly average concentrations of PM_{2.5}, PM₁₀, NO₂ and SO₂ in air in Jinan City from 2015 to 2017.

Time	PM _{2.5} /μg·m ⁻³	PM ₁₀ /μg·m ⁻³	NO ₂ /μg·m ⁻³	SO ₂ /μg·m ⁻³	Composite index	Maximum index
2015.01	112	209	95	80	10.97	3.20
2015.02	97	174	80	55	9.05	2.77
2015.03	82	197	62	56	8.82	2.81
2015.04	77	157	43	39	7.61	2.24
2015.05	75	156	42	36	7.69	2.23
2015.06	73	139	35	27	7.22	2.09
2015.07	75	132	39	28	7.10	2.14
2015.08	60	97	38	23	5.90	1.71
2015.09	69	128	52	27	6.94	1.97
2015.10	91	175	60	34	8.73	2.60
2015.11	114	155	59	43	8.95	3.26
2015.12	160	231	71	71	12.03	4.57
2016.01	127	193	68	79	10.55	3.63
2016.02	82	140	45	57	7.55	2.34
2016.03	80	186	48	51	8.29	2.66
2016.04	82	202	46	40	8.51	2.89

2016.05	58	129	38	28	6.54	1.84
2016.06	53	104	33	24	5.95	1.51
2016.07	61	108	35	20	6.15	1.74
2016.08	43	88	35	22	5.16	1.26
2016.09	60	133	56	27	7.17	1.90
2016.10	58	118	53	22	6.27	1.69
2016.11	102	154	58	36	9.52	2.58
2016.12	120	162	65	45	10.18	3.62
2017.01	130	209	61	49	10.56	3.71
2017.02	83	148	50	44	7.53	2.37
2017.03	68	141	54	31	6.91	2.01
2017.04	62	141	47	22	6.59	2.01
2017.05	57	144	35	21	6.48	2.06
2017.06	54	108	37	21	6.11	1.54
2017.07	51	98	35	13	5.78	1.46
2017.08	37	75	39	12	4.82	1.21
2017.09	39	93	46	14	5.29	1.33
2017.10	56	111	54	16	6.08	1.60
2017.11	55	133	54	23	6.14	1.90
2017.12	88	163	63	35	8.06	2.51

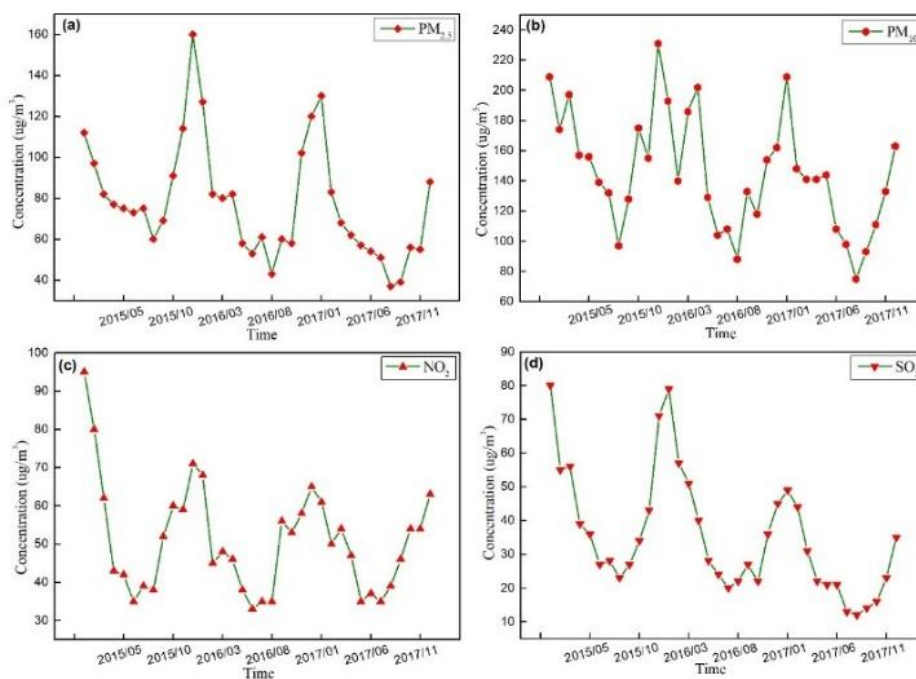


Fig. 1: Trends of Monthly average concentrations of PM_{2.5}, PM₁₀, NO₂ and SO₂ in the air of Jinan City from 2015 to 2017.

2.2 Analysis of air pollutants in Jinan City

Using the atmospheric monitoring data of Jinan City from 2015 to 2017, the current and air distribution characteristics of the city's air quality were analyzed.^[3] The results showed that the

mass concentration of air pollutants in Jinan City exceeded the secondary standard limit of the Ambient Air Quality Standards (GB3095-2012) for 9 months in 2015. In 2016, it has exceeded the "Ambient Air Quality Standards (GB3095-2012) secondary standard limit for 6 months, and exceeded the Ambient Air Quality Standards (GB3095-2012) second-

ary standard limit for 3 months in 2017.^[4] The severe air pollution period is winter heating period and particulate pollution. The serious area is the western and northwestern part of the city. The SO₂ and NO₂ pollution serious areas are the central urban areas, and corresponding pollution prevention and control measures are proposed from three aspects: point source, surface source and mobile source. **Table 1** showed that the annual average concentration values of PM_{2.5}, PM₁₀, NO₂ and SO₂ in 2015 were 90.42μg·m⁻³, 162.5μg·m⁻³, 43.25μg·m⁻³ and 56.33μg·m⁻³. In 2016, the average annual concentration values of PM_{2.5}, PM₁₀, NO₂ and SO₂ were 77.17μg·m⁻³, 143.08μg·m⁻³, 37.58μg·m⁻³, 48.33μg·m⁻³. In 2017, the average annual concentration of PM_{2.5}, PM₁₀, NO₂ and SO₂ is 65.00μg·m⁻³, 130.33μg·m⁻³, 25.08μg·m⁻³, 47.92μg·m⁻³. From 2015 to 2017, the concentration of PM_{2.5} exceeded the Ambient Air Quality Standards (GB3095-2012) secondary standard limit 2.5 times, 2.2 times, 1.86 times, respectively, PM₁₀ exceeding 2.3 times, 2.04 times, 1.86 times, NO₂ concentration value exceeding 1.08 times, 0.94 times, and 0.63 times, SO₂ concentration exceeding 0.93 times, 0.81 times, and 0.80. Times. **Fig. 1** objectively show the changes in the concentration values of PM_{2.5}, PM₁₀, SO₂ and NO₂ in the air from 2015 to 2017, and the air quality is significantly improved.

The average mass concentration distribution of PM_{2.5}, PM₁₀, SO₂ and NO₂ in the heating period and non-heating period of major pollutants in Jinan City has obvious seasonal variation characteristics (**Fig. 1**). The winter has (January, February and December) the highest average concentration, followed by spring (March, April, May) and autumn (September, October, November), and summer has (June, July, August) the lowest average quality concentration. The seasonal variation characteristics in 2015-2017 are similar, but the four concentration values are reduced in the same season. Winter should be an important period for air pollution prevention and control in Jinan City.

3. Analysis of the reasons of pollution status

The urban air quality status is related to many factors. The main influencing factors are: pollution source, topography and meteorological conditions, rational planning, environmental supervision ability, environmental awareness, practical treatment technology, etc. Changes in air pollution are the result of a combination of various factors

3.1 Air pollution sources

Industrial exhaust emissions. Jinan City is a typical northern inland city with an energy structure dominated by coal. The industrial structure is dominated by the ferrous metal smelting and rolling processing industry, the production and supply of electricity, steam, hot water, chemical raw materials and chemical products manufacturing, non-metallic mineral manufacturing industries, etc.^[5] The formation of smoke has increased the degree of air pollution in Jinan. Green energy applications are still not popular. Heavy industry consumes a lot of energy, industrial waste gas discharges are large, and pollution is heavy.

The impact of transportation. At present, the pollution of automobile exhaust gas is quite serious, accounting for 40% to 60% of the total pollutants. Many diesel vehicles, motor vehicles, and motorcycles also contain large amounts of particulate matter in their emissions. The smaller the particle size, the closer the motor vehicle exhaust pollution is to the driving situation. When the motor vehicle runs fast and accelerates, the exhaust gas emissions are the largest, and the green energy vehicles are still not popular. The motor vehicle inspection and maintenance system in Jinan is still not perfect, and there is still a complete set of legal norms and technical requirements.

3.2 Topographical topography and meteorological conditions

Jinan is located in the south of Shandong Province. It is high in the south and low in the north, which is conducive to the accumulation of surface water and groundwater. There are

many mountains and mountains, including the Happy Valley and the Great Wall Ridge. It can be roughly divided into three zones: the northern part of the Yellow Belt, the central mountain front plain belt, and the southern hilly mountainous area. There are many rivers in Jinan, mainly including the Yellow River and Xiaoqing River. There are many mountains in the south, relying on Mount Tai and relying on the Yellow River in the north. The terrain is complex and there are small basins, and many springs have emerged. It is located in the mid-latitude zone, at the junction of the southwest and Liaocheng city. It is located in the Hebei Plain, the seismic belt of the Lubei Plain. The underground is soluble limestone.^[6]

Jinan is located in the mid-latitude, and is temperate monsoon climate. Spring is dry and rainless, summer is warm and rainy, autumn is cool and dry, winter is cold and less snow, it can be described as four seasons, and the climate is pleasant. The winter is long, and the spring and autumn are short. Because of the topography of the mountains on three sides, the condensation of water vapor and hot air should not spread, more than the summer precipitation in the northern cities.

3.3 Lack of rational planning for coordination between economic development and ecological protection

Jinan's economy is developing rapidly, and there are many factories, but the reasonable plan corresponding to it is like the morning star. On the one hand, people lack the awareness of the coordination between economic development and ecological protection. On the other hand, although some of the ideas are advanced, and keen people have put forward some constructive opinions, it is impossible to turn ideas into ideas in view of various practical reasons such as technology.^[8] Planning in this area is still particularly lacking. Therefore, we must realistically propose a reasonable plan for the coordination of economic development and ecological protection based on the local humanities and other conditions in Jinan, and

once we propose it, we must unswervingly go on, and we must follow the path of sustainable development. While the Jinan economy is developed, the ecological environment can also be protected. After all, lucid waters and lush mountains are invaluable assets.

3.4 Insufficient atmospheric environmental supervision

On the whole, the current direction of Jinan's atmospheric governance is correct and these measures are effective. However, the relevant departments have insufficient capacity for monitoring the atmospheric environment. In many areas, especially at the district and county levels, the environmental supervision is seriously inadequate. The aging of equipment is also very prominent, and it is difficult to adapt to heavy regulatory tasks. Once the supervision is not strict, some unscrupulous manufacturers will be intensified, and even less in accordance with emission standards. Therefore, the supervision must be large, and all relevant laws and regulations must be detailed. The various measures must be clear. The key is to implement the work, and to implement the work already done, to grasp the details, and to do a good job.

3.5 Weak awareness of environmental protection

The atmospheric environment is the environment on which human beings depend. The polluted atmosphere is difficult to return to its original state. Atmospheric pollution will bring disaster to people. People have insufficient awareness of protection and lack of knowledge to protect the atmosphere. They have never considered the harm caused by environmental pollution and have turned a blind eye to environmental issues. Everyone only considers the immediate interests and local economic development needs, and does not think about the disaster we will bear in the future. In the face of economic development and industrial construction, people often trade for economic development at the expense of the environment to meet people's money demand, causing pol-

lution and damage to the atmospheric environment.^[9] These are all related to weak awareness of environmental protection, and people are not aware of the serious consequences of environmental pollution. Numerous urban rubbishes are discarded on the road, and the polluted atmosphere is diffused in the air. People are facing serious environmental problems, and we are responsible for their actions, greenhouse effects, smog events, various air pollution incidents occur frequently, affecting people's normal life and travel.

3.6 Lack of practical governance techniques

Although a large amount of manpower and material resources have been invested in the research, development, promotion and use of air pollution control technologies and equipment, the control effect on air pollution is not satisfactory. The weak areas are still clean energy technology metallurgy, chemicals, building materials and other industries, and the pollution control effects of industrial furnaces and production facilities in these industries are still not satisfactory. In addition, the purification technology of motor vehicle waste cannot achieve good results, and the lack of practical technology directly affects the progress and effect of air pollution control.

4. harm to human health caused by air pollutants

4.1 Atmospheric particulate matter

Atmospheric particulate matter is a great hazard to human health. PM_{2.5} is the main carrier of pollutants released by human activities, carrying a large amount of heavy metals and organic pollutants. The size of the particles has an important impact on human health hazards. The smaller the particles, the easier it is to be absorbed by the body, and the greater the harm to human health. Small particles easily enter the respiratory system of the human body, causing respiratory diseases in people, which can lead to the failure of cardiopulmonary function and endanger people's health. Exposure to high pM_{2.5} environment tends to increase the incidence of lung cancer, acute respiratory

diseases and cardiovascular and cerebrovascular diseases. Affects the human immune system and nervous system. PM₁₀ is a particulate matter having an aerodynamic diameter of less than or equal to 10 microns. Due to its small particle size, it is easily inhaled to damage the human respiratory system and endanger human health.

4.2 Nitrogen dioxide (NO₂)

NO₂ mainly comes from the process of high temperature combustion. NO₂ has a toxic effect on the human body, mainly affecting the human respiratory system. Exposure to the low atmospheric environment of NO₂ can cause symptoms such as pharyngeal discomfort and cough, which have a certain impact on the normal life of the human body. Exposure to the environment where the concentration of NO₂ is too high may cause serious harm to human health, cause pneumonia, and even cause lung damage. It causes serious harm to the human respiratory system and causes serious death.

4.3 Sulfur dioxide (SO₂)

Sulfur dioxide is a toxic gas, mainly from the combustion of sulfur-containing fuels, and the sulfur in the fuel can be almost completely converted into SO₂. SO₂ in the atmosphere affects the human respiratory system. It stimulates the respiratory tract and increases respiratory resistance, causing difficulty in breathing. In severe cases, it has a serious impact on life and health. SO₂ is strongly irritating to the respiratory mucosa and can cause symptoms such as inflammation and dizziness. It has certain damage to the liver and adversely affects the immune function of the body.

5. Suggestions on prevention and control of PM_{2.5}, PM₁₀, NO₂ and SO₂ pollutants

5.1 Prevention purposes

At present, particulate matter has become the most important pollutant in China's air pollution, and has become a key indicator of urban environmental quality standards. At present, atmospheric environmental quality management systems and policies cannot effectively solve the problem of particulate matter pollution.

Therefore, we must take the protection of the health of the people as the starting point, improve the quality of urban and regional atmospheric environment, focus on controlling PM_{2.5} and other pollutants, optimize economic development with scientific environmental policies and industrial and energy strategies, and comprehensively apply Comprehensive measures such as law, economy, information, administration, and technology to build a national air pollution control policy system.

5.2 Prevention and control recommendations and emission reduction measures

5.2.1 Suggestions and measures at the level of policies and regulations

Improving environmental quality standards and the monitoring system for particulate matter. The pollution of atmospheric particulate pollutants in Jinan City has been very serious, and the high level of pollution of PM_{2.5} is also surprising. However, there is no reference limit indicator for PM_{2.5}. During the "Twelfth Five-Year Plan" period, the detection of O₃, CO and PM_{2.5} was gradually increased. It is recommended to develop a corresponding inspection plan, improve the particulate matter monitoring system, and gradually establish a fine particle detection network.^[10]

Strengthen law enforcement and increase illegal costs. Despite significant progress in the construction of air pollution control standards and air pollution control in Jinan, the environmental management efforts need to strengthen the corresponding air pollution prevention and control policies are not matched, and the phenomenon of non-compliance, law enforcement, and illegality is still very serious. It is recommended to strengthen the enforcement of air pollution and increase the illegal cost of enterprises.

Construct a green transportation model and give priority to the development of public transportation. Establish a good public transport service system, facilitate the operation of buses, facilitate bus travel, and strive to transform the travel modes of people in most

areas of Jinan from individual traffic to public transportation; guide the public to green travel, vigorously promote bicycles, reduce Emissions. Promoting public choice of public transportation is an important measure to reduce urban daily motor vehicle flow and reduce vehicle exhaust emissions.

5.2.2 Technical level recommendations and measures

Strengthen the monitoring of particulate pollutants and gradually improve the monitoring system. Since secondary particulate matter is produced by oxidation of gaseous precursors in the atmosphere, control measures for pollutants should also be carried out in two ways. On the one hand, the number of gaseous precursors of the secondary particulate component is controlled, and on the other hand the conversion of gaseous precursors is controlled. Reduce vehicle emissions. With the gradual increase in people's income, the number of motor vehicles owned by residents will increase greatly. In this regard, the number of traffic exhaust pollutants caused by the growth of motor vehicles should be controlled in a timely manner. At the same time, the acceleration of coal-to-oil hybrid development of soot-type air pollution has also increased the difficulty of pollution control. To reduce traffic pollution, on the one hand, we must start with fuel, improve fuel utilization, and promote clean fuels. On the other hand, the number of motor vehicles is strictly controlled. To reduce atmospheric pollutants, it is necessary to control the amount of pollutant emissions from both the enhancement of fuel quality and the number of vehicles.

Adjust the industrial structure and reduce particulate matter emissions. Jinan's economy is experiencing rapid growth and rapid changes in industrial structure. Due to the unreasonable industrial structure of Jinan, the contribution of industrial dust to atmospheric particulate matter has intensified. Adjusting the industrial structure has become the most effective measure and means to solve the air pollution in Jinan city from the source. Therefore, reducing at-

atmospheric pollutants through optimization and adjustment of industrial structure is an urgent task at present. Only develop high-tech industries, limit high-energy-consuming industries, upgrade traditional industries with advanced technologies and clean production technologies, promote the development of emerging leading industries, and further promote the green economy as the main way of economic growth and reduce atmospheric pollutants. This is the root of reducing atmospheric pollutants.

5.2.3 Popularize environmental protection knowledge and create a “two-type” city

For the pollution of the atmosphere, compared with the industry, the exhaust gas emitted by residents is also an important aspect. We should carry out extensive publicity to carry out environmental knowledge education among the citizens, improve the public's environmental protection concept, and make the public aware. The protection to the atmospheric environment is not only the responsibility of an individual or a certain department, but the responsibility that every citizen has to perform. Starting from the side, starting with small things, encouraging and advocating people to drive less and ride more public transportation; burning coal and using clean fuel such as natural gas, truly build Jinan into a resource-saving and environment-friendly city.

6. Conclusion

According to the investigation and analysis, it is known that the trend of environmental air pollution in Jinan City has been initially controlled, and the concentration of pollutants has gradually declined. The air quality in winter and spring is worse than in summer and autumn. The least polluting month is August, and the most polluting month is December or January. For the fast-growing Jinan city, the problem of atmospheric particulate pollution has seriously restricted the development of Jinan city and the health of the people. To strengthen the management and construction of roads, it is recommended that vehicles exceeding the standard are strictly prohibited, vehicles with higher

pollution should be phased out, and vehicles such as zero-polluted solar energy should be actively promoted. The people's awareness of environmental protection should be improved. We should adhere to the basic national policy of saving resources and protecting the environment, treating the ecological environment like life, and build a beautiful China.

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