

URBAN SMOG IN THE PROCESS OF INDUSTRIALIZATION - TAKE XI'AN, CHINA, FOR EXAMPLE

Esmog urbano en el proceso de industrialización. El caso de Xi'an, China, como ejemplo

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ABSTRACT

This paper takes “industry development - urban smog” as the line to discuss the interaction between them, it tells us that the industry of Xi'an city has developed rapidly since the founding of the People's Republic of China. However, the industrialization process in Xi'an is also accompanied by the appearance of smog. We found that the appearance of urban smog in Xi'an shows a certain regularity in the process of industrialization. Through analyzing the spatial distribution, historical characteristics and seasonal changes of urban smog, it reveals that the industrial production based on coal burning is an important inducement for smog in Xi'an. It calls for exploring an environmental protection road suitable for China. For example, energy structure transformation, laws improvement, promoting people's awareness of environmental protection and industrial upgrading are all feasible ways to control urban smog. It is of practical significance to correctly handle the coordination between industrial economic development and environmental protection.

Palabras clave: desarrollo industrial, contaminación del aire, medidas de control.

RESUMEN

Este documento toma el “desarrollo de la industria - esmog urbano” como la línea para discutir la interacción entre ellos, nos dice que la industria de la ciudad de Xi'an se ha desarrollado rápidamente desde la fundación de la República Popular de China. Sin embargo, el proceso de industrialización en Xi'an también está acompañado por la aparición de esmog. Encontramos que la aparición de esmog urbano en Xi'an muestra una cierta regularidad en el proceso de industrialización. Al analizar la distribución espacial, las características históricas y los cambios estacionales del esmog urbano, se revela que la producción industrial basada en la quema de carbón es un inductor importante del esmog en Xi'an. Lo anterior exige explorar un camino de protección ambiental adecuado para China. Por ejemplo, la transformación de la estructura energética, la mejora de las leyes, la promoción de la conciencia de la población sobre la protección del ambiente y el mejoramiento industrial son formas viables de controlar la contaminación urbana. En la práctica, es importante gestionar correctamente la coordinación entre el desarrollo económico industrial y la protección del ambiente.

INTRODUCTION

Since the founding of People's Republic of China, in Xi'an city the urban smog has emerged within the process of industrialization. "Industrial development - Urban smog" seems to be an interrelated chain, appearing at different times in different parts of the world. As early as the 18th century, UK suffered severe smog disaster after industrial revolution. Since the founding of People's Republic of China, with the increase of factories and the expansion of production scale, the air quality of Xi'an city has declined. In the 21st century, air pollution has become more and more serious. In 2004, Xi'an industrial emissions reached 42 831.05 million m^3 , in 2005, the industrial emissions were up to 47 058.41 million m^3 , in 2006, the number has increased to 64 250.76 million m^3 . In 2013, the sulfur dioxide emission in Xi'an city reached 64 664.15 tons, the nitrogen oxide emission reached 34 921.76 tons, and the dust emission was 13 658.34 tons. In this year, the $PM_{2.5}$ in Xi'an city was $121.6 \mu g/m^3$, and the PM_{10} was as high as $202.3 \mu g/m^3$, which has become the disaster area of smog in China (Xi'an Bureau of Statistics 2014).

Historical process of industrial development in Xi'an

In the early years after the founding of People's Republic of China, Xi'an responded to the call of "learning from the industrial development experience of the Soviet Union", establishing an industrial development route dominated by the development of heavy industry. Since the reform and opening, under the environment of China's opening and economic development, the industrial economy of Xi'an city has shown a good trend of continuous growth. The industrial added value increased from 1.38 billion yuan in 1979 to 2.253 billion yuan in 1984, 1.6 times that of that in 1979, with an average annual growth of 9%. In the 1990s, the proportion of heavy industry in Xi'an increased from 50% to 61%, among which the total output value of heavy industry such as machinery industry, electrical industry, building materials and chemical industry was large (Xi'an Bureau of Statistics 2000). In 2008, the proportion of heavy industry in Xi'an increased to 80.3%, with an average annual growth rate of 23.3% (Xi'an Bureau of Statistics 2009). In the past 2000 to 2013, the total industrial output value of Xi'an city has increased from 21 844 billion yuan to 148 463 billion yuan, an increase of about seven times. The industry of Xi'an started from the early stage of the founding of

People's Republic of China, and gradually developed into a modern industrial system with considerable scale benefits.

DATA ANALYSIS

The appearance of air pollution in Xi'an

Economy and environment are a pair of contradictory relations that interact and restrict each other. Economic growth and environmental quality often change in reverse, that is, the larger the economic scale is, the more serious the environmental pollution is. People obtain resources and energy from the environment and convert them into the material and energy they need. Then they return them to the environment in the form of wastes through consumption activities.

Spatial distribution characteristics of smog in Xi'an city

Industrial production is the main cause of air pollution, and industrial layout of Xi'an causes regional differences in air pollution. From the perspective of different spatial locations of Xi'an, the southern area mainly focuses on culture and education, which is the university town and cultural district of Xi'an with relatively low air pollution. The eastern area is dominated by power generation and textile industry, while the western area is dominated by electric machinery, chemical metallurgy and steel smelting (Zuo et al. 2020). The heavy industry has become the key development industry in the eastern and western areas, and the air pollution in these regions is relatively heavy. In January 2022, Xi' had 20 days of pollution, including ten days of heavy pollution. The 5-day air quality index is shown in **Table I**.

TABLE I. THE AIR QUALITY INDEX (AQI) OF XI'AN FROM JANUARY 11TH TO 15TH (2022).

Date	AQI
11 th	169
12 th	169
13 th	175
14 th	140
15 th	183

AQI describes the degree of cleanliness or pollution in the Air. Above 150 is considered an Intermediate level pollution, which may affect the heart and respiratory system of healthy people. Adapted from: <http://www.86pm25.com/city/xian.html> (2022)

The period and seasonal variation characteristics of Xi'an smog

From the time period, the air quality of Xi'an also presents a certain change trend and characteristics. Through the monitoring of the worst smog episode in Xi'an in 2013, it was found that December and January were the high incidence months of smog (Duan 2014). Take 2019 as another example, when the smog was more serious, the monitoring results of 13 air monitoring stations distributed in different spatial areas in Xi'an city, showed that at least 75% of the pollution related to weather appeared in the winter. In 2020, smog appeared in Xi'an again, with 170 days, with the most from November to December, reaching 28 to 38 days (Xi'an Bureau of Statistics 2020). From the perspective of the seasonal changes of different pollutant concentrations, the concentrations of sulfur dioxide, nitrogen dioxide, PM_{2.5} and PM₁₀ all show seasonal high and low changes, which are generally characterized by low in summer and high in winter. In particular, the concentrations of PM_{2.5} and PM₁₀ decreased significantly in summer, with substantial increases in winter, with partial increases reaching or even exceeding 100%.

From the perspective of the seasons, the lowest number of smog days occurs in June, in summer, and gradually rises since October. December is the peak month of the smog phenomenon. This is closely related to the increase of emissions caused by coal-fired heating in winter. At the same time, the increase of temperature inversion days in winter obstructs the convective movement of the atmosphere, forming a stable and long smog weather.

The effect of climate and terrain factors on smog

A large amount of industrial production leads to an increase in coal consumption, and climate and terrain factors further aggravate the smog in Xi'an. The diffusion ability of air determines the degree of pollution. The diffusion ability of air is mainly affected by wind direction, wind speed and air stability. The calm wind is most prone to the smog phenomenon. From the perspective of climatic characteristics, Xi'an has abundant summer rain, high temperature, high atmospheric mixing layer and vigorous convection activities, which are conducive to the settlement and diffusion of pollutants. In winter, the weather is cold, the static wind frequency is large, the air mixing layer height is low, easy to form the inversion phenomenon, the vertical diffusion of pollutants is restrained. In adverse weather situations, urban production and living emissions of particulate matter and other pollutants near the ground cannot diffuse or settle, forming smog.

From the perspective of geography and landform, Xi'an is in Guanzhong plain, the Loess plateau in the north and the Qinling mountains in the south. The pollutants in the atmosphere are mainly cleaned by advection transport turbulence diffusion and dry and wet settlement. In winter, the height of atmospheric mixing layer decreases. Due to the obstruction of the Qinling mountains in the south and the Loess plateau in the north, it is difficult for the pollutants in Guanzhong region to be transported and diffused in the north-south direction. The unique trumpet mouth topography makes the east wind an unfavorable wind direction, and the basin effect greatly restricts the horizontal flow of pollutants in Guanzhong area. Therefore, with the increase of coal burning in winter, special climatic conditions and topographic factors further boost the intensity of smog, resulting in the seasonal variation of air pollution in Xi'an.

The control methods of urban smog in Xi'an

As for the air pollution caused by industrial coal burning, Xi'an is just a typical representative of many smoggy cities in China. Faced with the "black crisis" brought by "smog", we should explore a sustainable development path that is suitable for economic development and resources and environment. The smog weather in recent years not only affects a wide range, but also lasts for a long time, which requires Chinese cities to carry out profound reflection from the aspects of environmental governance and air quality improvement. China can not only learn from the experience of early developing countries, draw lessons from them and avoid detours, but also explore new ideas and methods in the path of development in the face of its own national conditions. The development of the later-developing countries is not only in the economic level, it also includes the living standard of the people, living conditions and other factors. Within the developed countries in the world, UK was the first country to experience smog episodes (John 1883). Then the United States, Japan and other countries, have experienced air pollution during their industrialization because of extensive development and energy consumption, which has seriously affected people's living environment and quality of life. As a late-development country, China is in the early stage of industrialization, faces demographic pressures, economic increase and various kinds of practical problems such as environmental burdens on previous experience in the developed countries, and summarized the successful management with less cost and greater achievements. The implementation

of the strategy of sustainable development promotes the coordinated development of the economy and environment, and plays an important practical significance in China today.

Rational utilization of energy

After the industrial revolution, UK suffered from coal-smoke pollution for hundreds of years. The British government has moved its factories out of downtown areas and has promoted the use of new energy. After the “photochemical pollution incident” broke out in Los Angeles in the USA, the government forced the conversion of new energy sources, and the air quality of the city was significantly improved. The transformation of the energy structure adopted by developed countries in their industrial growth path has played an important role in the improvement of urban environment. The promotion of green energy and the development of a low-carbon economy provide a powerful reference for China’s air pollution control today. Nowadays, the traditional extensive industrial development road with high energy consumption, high pollution and high emission, leads to the increasingly frequent smog caused by smoke pollution in China. It can be concluded from the governance experience of capitalist countries that the adjustment of energy structure plays a crucial role in the process of smog control (Francis 1997, Cao 2020). Nowadays, promoting green economy and low-carbon development are clearly pointed out in the report of China. “Low-carbon economy” is also an important transformation goal of China’s economy, and rational transformation of energy is an important move to promote China’s sustainable development.

Xi’an city has made great efforts in energy transformation and upgrading and taken corresponding measures. Since 1996, Xi’an has also implemented the coal-free zone project, in which stoves are switched to burning natural gas, liquefied natural gas and other clean fuels. New coal-fired boilers are no longer approved in the city’s natural gas supply area, and the smoke-control area covers more than 95%. In 2002, the municipal party committee and government optimized the urban energy structure and vigorously implemented the demolition and renovation project of coal-fired boilers (Crafts 2004). By 2006, more than 5200 coal-fired boilers had been dismantled and renovated. In terms of improving the urban gas rate, the city completed the first stage of Xi’an urban gasification project with a total investment of 828 million yuan and a daily gas supply of 1 million m³ in 2001. The second stage of the project will provide an additional 880 000 cubic meters of gas per day,

with 95% of urban residents using gas. By the end of June 2017, all designated coal marketing outlets were banned, and the burning of bulk coal replaced by clean energy. The reduction of coal utilization rate has curbed the occurrence of smog at the source. It can be said that the transformation of energy utilization contributes the most in air pollution control. The promotion and use of new energy vehicles are the latest air pollution control measures. By 2021, the production of new energy vehicles reached 600 000 in Xi’an, by 2025, the production of new energy vehicles will reach more than 1.5 million. New energy vehicles will be exempted from a license fee of 125 yuan per vehicle in Xi’an. The Xi’an municipal government subsidizes 10 000 yuan for each family buying new energy vehicles to encourage them to save energy and protect the environment. New energy vehicles are allowed to drive in the city’s bus lanes.

Enactment and improvement of laws

It is not uncommon for air pollution incidents to occur in the industrial development process of developed countries, and law is the most authoritative supervision method in its management process. After the air pollution event in Japan, the “smog restriction law” has been issued to effectively control the combustion of coal in industrial enterprises (Duan 2012). As the birthplace of the industrial revolution, Britain is the first country in the world to experience large-scale air pollution (Eric 1981). The comprehensiveness and refinement of its laws are worthy of emulation and reference by late-developing industrial countries (Goklany 2019).

These years, some progress has been made in air pollution controls from a legal perspective in Xi’an. Interim provisions on the prevention of environmental pollution by construction projects were issued by the former revolutionary committee of Shaanxi province in February in 1978. In order to control air pollution, the Shaanxi provincial people’s government approved the report of Shaanxi provincial environmental protection committee on the opinions on the prevention and control of urban air pollution in 1988 (Li 2005). It stipulated that the total suspended air particles in Xi’an should be reduced by 25%, and it also stipulated that the reform rate of industrial boilers and furnaces in the city should be increased, and the utilization rate of natural gas and central heating in the city should be developed. In 2006, Shaanxi Provincial Government issued relevant regulations on smog control by science and technology in view of the air pollution problem in Xi’an. In 2012, the “2012-2014 Shaanxi environmental protection” regulatory program was compiled.

According to the regulations, industrial enterprises have not only installed various kinds of monitoring instruments for air pollutants, but also regularly release emission information on the Internet, strengthening the supervision of relevant departments on emissions. In view of the characteristics of frequent air pollution in 2020, the Municipal Environmental Protection Bureau of Xi'an, relevant departments and enterprises have formulated emergency plans for heavy pollution episodes, and will start in the case of continuous heavy pollution. Emergency plans for heavy pollution, mainly include road cleaning and sprinkling, emission reduction, and emergency measures, among others.

Strengthening the public education, enhancing the public awareness

In addition to strengthening the control of the authority at the central level, the promotion of the public's environmental awareness also plays a certain supervision and promotion role in the treatment of air pollution. Many years ago, when London and Manchester were hit by smog, a series of social groups organized by local people made positive contributions to the improvement of air pollution in Britain. By holding large-scale environmental protection exhibitions in local areas and popularizing fuel knowledge, they propagate the impact of air pollution on human life to the general public, which not only improves people's environmental protection concept, but also plays a positive role in promoting the government to formulate powerful measures. In the early days, foreign publicity and education only focused on the field exhibition. However, with the progress of science and technology for hundreds of years, we can carry out propaganda and education through various emerging media such as Internet and new media, to expand people's knowledge of smog in a more comprehensive and in-depth way and enhance the environmental protection concept of "everyone is responsible" (Luan 2016).

Promoting and upgrading industrial transformation

After decades of development since the reform and opening-up, China has entered the middle industrialization period and realized the transformation from an agricultural country to an industrial one. The traditional industrial development mode mainly adopts large-scale extensive operation method, with large resource consumption, large pollutant emission and serious environmental damage (Lin 2015). With the emergence of the world technological revolution, the service industry will become one of the major industries in the future. At present, China's service industry is relatively backward, and accelerating the

development of service industry should become an important part of economic transformation, which is also an important measure to reduce the carbon dioxide emission intensity in industrial production. Faced with the environmental problems brought by China's economic development, the occurrence of smog has brought us a severe test. The goal of China's future development is to strengthen the transformation and upgrading of traditional industries, walk the path of harmonious development with the environment, and promote the construction of a "resource-saving and environment-friendly" society. As developing country, it is the most fundamental way to summarize experience in the process of economic development and explore the development mode in line with its own national conditions. Strengthening the service and information industries is an important step in the process of building the low-carbon society (Tao et al. 2016).

RESULTS

Through comprehensive prevention and control measures, the air quality of Xi'an city has been improved year by year. In 2015, there were 251 days with ambient air quality above grade II; of these, 15 days had excellent air quality and 236 days had good air quality (Zhang 2016). The number of days reaching the standard accounted for 69.1% of the total number of days, and the number of days with excellent air quality accounted for 70% of the total number of monitoring days. In 2016, 192 days in Xi'an reached grade II of air quality or above in the Ambient Air Quality Standard, accounting for 52.5% of the total number of days reaching the standard, and 53% of the total number of days were with good ambient air quality in the whole year. From January to October 2018, the number of good days in Xi'an was 166, an increase of 3 days compared with the same period of the previous year. From January to November 2019, the number of good days in Xi'an has been increasing, which is 211 days. As recently as January 19, 2020, the air quality index of Xi'an city was 67, indicating a significant improvement in air quality.

CONCLUSION

Many countries have encountered air pollution problems in the process of industrialization. As the largest developing country in the world, China is also

faced with the environmental pollution problems like developed countries in the process of industrialization. Large cities with factories gathering use coal as the industrial fuel, which inevitably leads to the decline of urban air quality. China's overall energy consumption is overly dependent on coal, which is the main source of PM_{2.5} emissions. With the further advancement of urbanization, changes have taken place in national economic structure, social structure and spatial structure, which not only cause a series of economic and social changes, but also lead to the sharp increase of population, excessive traffic pressure and serious excess of automobile exhaust emissions in big cities. Industrial production is the main culprit of smog. "Industrial development - air pollution" is like a chain of interactive constraints, industrial production not only drives economic development, but also brings environmental damage. Air quality problems in major cities in China have become increasingly serious. This period is also an important stage for China's industrialization and urbanization rate.

Through the above analysis it is clear that, especially after the reform and opening in 1978, along with the development of regional economy and the speeding up of city industrialization, urban smog arised. The smog in Xi'an shows regional, periodic and seasonal characteristics. Faced with the complex fuel structure and high-density industrial agglomeration, how to effectively control urban smog presents us with great challenges. Xi'an is just one of the representatives of many smoggy cities in China. By learning from the air pollution control methods of capitalist countries, Xi'an is striving to find a suitable environmental protection path for itself. For example, adjusting energy structure, formulating perfect laws, strengthening people's environmental awareness, and promoting industrial transformation are all feasible approaches to solve the problem of urban smog. It is our common responsibility and goal to dispel the smog, create a green living environment, and build a beautiful environment for our common homeland. The transformation from industrial civilization to ecological civilization is imperative. In 1981, the American scholar Brown first used and expounded the new viewpoint of "sustainable development" in his book "Building a sustainable society" (Brown 1981). In the face of the "black crisis" brought by smog, we should explore a sustainable development path that adapts economic development, resources and the environment. The green development path where people and ecological environment coexist harmoniously is our goal.

At present, although smog still occurs in the winter of Xi'an city, after a series of governance measures, the air quality in Xi'an has been improved. Urban smog is closely related to the process of industrialization. In the process of increasing industrial production, waste emissions are one of the main reasons for urban smog. With the development of industrialization and urbanization, the increase of urban population leads to an increase in the number of private cars, therefore, automobile exhaust emissions are another cause of smog outbreak. In the measures of smog control, we find that increasing the utilization rate of new energy vehicles and reducing exhaust emissions are new effective measures to reduce the urban smog. This measure applies not only to Xi'an, but also to other parts of the world where urban smog erupts.

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