Analysis of the Influencing Factors of Industrial Air Pollution in Shenzhen

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Abstract. As one of the central cities of the Guangdong-Hong Kong-Macao Greater Bay Area (GBA), Shenzhen has excellent air environment performance. Based on the construction of Kaya identity and LMDI method, this paper decomposes the SO₂ emission of Shenzhen industry in 2009-2016 and explores the impact of seven factors on the SO₂ emission change of Shenzhen, including population, development level, industrial structure, energy structure, energy consumption intensity, energy pollution intensity and end treatment. The results show that: population and development level factors have the effect of increasing emissions, industrial structure and energy structure factors have less impact, while energy consumption intensity, energy pollution intensity and end treatment factors have the obvious effect of reducing emissions. Combined with the current situation of development, it is suggested that Shenzhen should promote the upgrading of industrial structure and energy structure, promote the progress of production technology, and strengthen the end treatment. Other cities in GBA should actively learn from the relevant measures and governance experience taken by Shenzhen to improve the capacity of industrial air pollution reduction.

1. Introduction
In the latest report of the 19th national congress, China has officially listed “pollution prevention” as one of the three key battles. According to the 2013-2018 report on China's air quality improvement issued by the Ministry of ecological environment, China's GDP in 2018 increased by 39% compared with that in 2013, the concentration of a number of air pollutants decreased, and the blue sky defence war made phased progress, but the air pollution situation is still severe, and the environmental governance work still has a long way to go. SO₂ is one of the most important air pollutants. Since the implementation of the total amount control plan for major pollutants in 1996, it has always occupied an important position in the total amount control of pollutants [1], which fully shows the importance of SO₂ pollution control in China. In this context, the decomposition analysis of pollutant emission and its influencing factors has become a hot research issue in the field of Environmental Science in China.

According to the data of China's urban statistical yearbook, among the 292 cities above prefecture level in 2009-2015, Shenzhen has the highest emission reduction rate of industrial SO₂, with the emission reduction rate of 86.48%. The Guangdong-Hong Kong-Macao Greater Bay Area (GBA) is one of the regions with important strategic position since China's reform and opening up, which has a high degree of openness and rapid economic growth. With the national pollution prevention and
control work gradually entering the "critical period", accelerating the improvement of ambient air quality has become an important task of the ecological environment construction in the GBA. As one of the central cities in GBA, Shenzhen not only takes the lead in economic development in other cities, but also takes an example in pollution prevention and control. Therefore, it is of great practical significance to study the influencing factors of industrial SO$_2$ emission in Shenzhen, which can provide experience for other cities of GBA.

In the existing research on the influencing factors of SO$_2$ emission, decomposition model method and measurement analysis method are mainly adopted. LMDI is built on the basis of decomposition model by Ang et al. [2]. LMDI does not generate decomposition residuals, and has high data tolerance, so it is widely used. While in the econometric analysis method, panel data can more accurately reflect the inherent economic laws of the data. For example, Xin Sun et al. used panel data model method to analyze the influencing factors of the whole process of SO$_2$ emission reduction rate of panel data of 30 provinces and cities in China. They found that energy saving rate, technological progress rate, proportion of tertiary industry, environmental management and environmental governance can promote SO$_2$ emission reduction [3].

At present, most research decompose SO$_2$ emission into economic scale growth, industrial structure, energy structure and technological progress. The main conclusions are as follows: SO$_2$ emission will increase with the expansion of industrial production scale and economic development, the optimization and adjustment of industrial structure will promote the emission of SO$_2$, while the progress of production technology and the improvement of energy utilization rate are the main factors of SO$_2$ emission reduction [4, 5, 6, and 7].

However, there are still many deficiencies in the existing research: from the perspective of research scale, the research is mainly focused on the whole country or region, with less research on the municipal level; from the perspective of influencing factors, the research indicators of SO$_2$ driving force are not comprehensive enough. The analysis of population factors is less, and the technical factors are all single analysis of production technology or emission reduction technology, without decomposing the two at the same time [8]. In this study, LMDI method will be used to analyse the contribution of factors affecting the change of industrial SO$_2$ emission in Shenzhen, so as to provide suggestions and experience for the reduction of industrial air pollution in Shenzhen and other cities of GBA.

2. Model method and data source

2.1. LMDI decomposition model

On the basis of Kaya identity, this paper uses LMDI method to decompose the total amount change of industrial SO$_2$ emission in Shenzhen into 7 influencing factors such as population, development level, industrial structure, energy structure, energy consumption intensity, energy pollution intensity and end treatment, so as to measure and analyze the influence of each factor on industrial SO$_2$ emission in Shenzhen.

Firstly, the Kaya identity expansion model of industrial SO$_2$ emission in Shenzhen is constructed as follows:

$$C = P \times \frac{GDP}{P} \times \frac{GDP_{en}}{GDP} \times \frac{E_{en}}{E_{en}} \times \frac{E_{co}}{E_{co}} \times \frac{S}{S} \times \frac{C}{S}$$

(1)

In formula (1), $C$ is the emission of industrial SO$_2$; $P$ is the number of permanent residents in the region; $GDP_{en}$ is the added value of regional industry; $E_{en}$ is the total consumption of regional industrial energy; $E_{co}$ is the consumption of regional industrial energy, i.e. the energy with high sulphur or sulphur production; $S$ is the production of industrial SO$_2$.

Further, after simplifying equation (1), we can get:
\[ C = P \times A \times G \times I \times E \times W \times K \]  

(2)

In formula (2), \( P \) represents the population factor; \( A \) is the per capita GDP, representing the development level factor; \( G \) is the proportion of industrial added value to GDP, representing the industrial structure factor; \( I \) is the energy consumption per unit industrial added value, representing the energy consumption intensity factor; \( E \) is the proportion of pollution energy consumption to all industrial energy consumption, representing the energy structure factor; \( W \) is the production of \( \text{SO}_2 \) by unit industrial pollution energy consumption, which represents the energy pollution intensity factor; \( K \) is the ratio of industrial \( \text{SO}_2 \) emission and production, i.e. 1-emission reduction rate, which represents the end treatment factor.

According to formula (2), the change trend of industrial \( \text{SO}_2 \) emission from \( T-1 \) to \( t \) year is as follows:

\[ \frac{c^t}{c^{t-1}} = \frac{p^t \cdot A^t \cdot G^t \cdot I^t \cdot E^t \cdot W^t \cdot K^t}{p^{t-1} \cdot A^{t-1} \cdot G^{t-1} \cdot I^{t-1} \cdot E^{t-1} \cdot W^{t-1} \cdot K^{t-1}} \]  

(3)

According to LMDI decomposition method, the expression of contribution degree of each influencing factor can be obtained by decomposing equation (3), as follows:

\[ \Delta C_{P}^{t-1} = \frac{c^t - c^{t-1}}{\ln c^t - \ln c^{t-1}} \cdot \ln \frac{p^t}{p^{t-1}} \]  

(4)

\[ \Delta C_{A}^{t-1} = \frac{c^t - c^{t-1}}{\ln c^t - \ln c^{t-1}} \cdot \ln \frac{A^t}{A^{t-1}} \]  

(5)

\[ \Delta C_{G}^{t-1} = \frac{c^t - c^{t-1}}{\ln c^t - \ln c^{t-1}} \cdot \ln \frac{G^t}{G^{t-1}} \]  

(6)

\[ \Delta C_{I}^{t-1} = \frac{c^t - c^{t-1}}{\ln c^t - \ln c^{t-1}} \cdot \ln \frac{I^t}{I^{t-1}} \]  

(7)

\[ \Delta C_{E}^{t-1} = \frac{c^t - c^{t-1}}{\ln c^t - \ln c^{t-1}} \cdot \ln \frac{E^t}{E^{t-1}} \]  

(8)

\[ \Delta C_{W}^{t-1} = \frac{c^t - c^{t-1}}{\ln c^t - \ln c^{t-1}} \cdot \ln \frac{W^t}{W^{t-1}} \]  

(9)

\[ \Delta C_{K}^{t-1} = \frac{c^t - c^{t-1}}{\ln c^t - \ln c^{t-1}} \cdot \ln \frac{K^t}{K^{t-1}} \]  

(10)

Equation (4) - (10) can be used to calculate the contribution of population factor, development level factor, industrial structure factor, energy consumption intensity factor, energy structure factor, energy pollution intensity factor and end treatment factor to the change of industrial \( \text{SO}_2 \) emissions.

2.2. Data source and data processing

In this paper, industrial \( \text{SO}_2 \) emission in Shenzhen is taken as the research object, and the research range is 2009-2016. In terms of data sources, the data of industrial \( \text{SO}_2 \) emissions, population, GDP, industrial added value and industrial energy consumption in Shenzhen are all from Shenzhen statistical yearbook, and the data of industrial \( \text{SO}_2 \) production is from China urban statistical yearbook.

In terms of data processing, Shenzhen's GDP and industrial added value data are all adjusted based on 2009, and the energy consumption data is converted into standard coal according to the general principles for calculation of comprehensive energy consumption (GBT 2589-2008), and the industrial energy consumption is calculated. It should be noted that the industrial energy consumption data used
in this paper is actually the energy consumption of all industrial enterprises provided in Shenzhen statistical yearbook. In addition, the pollution energy data used in this paper refers to the total data of raw coal and fuel oil.

3. Empirical analysis
According to the statistical yearbook data of Shenzhen, the industrial SO$_2$ emission of Shenzhen in 2009-2016 shows a significant downward trend, from 32300 tons to 4700 tons. The industrial SO$_2$ emission in 2016 is 85.45% lower than that in 2009, with an average annual decline rate of 24.07%, as shown in Figure 1.

![Figure 1. The industrial SO2 emission of Shenzhen in 2009-2016](image)

According to formula (1) - (10), the factors of SO$_2$ emission change in Shenzhen from 2009 to 2016 are decomposed year by year, and Figure 2 shows the contribution degree of each influencing factor year by year.

![Figure 2. Contribution of industrial SO2 emission factors in Shenzhen.](image)
According to the decomposition results, population and development level are the obvious factors of increasing emissions. However, due to the decrease of marginal benefit, the gradual slowdown of population growth, and the continuous decline of per capita GDP growth, the role of population and development level factors in increasing emissions is also becoming smaller year by year.

Industrial structure factors and energy structure factors have little impact, and there are small fluctuations. In general, the emission contribution of industrial structure factors is directly proportional to the proportion of industrial added value in GDP of Shenzhen. In 2010, the proportion of industrial raw coal and fuel oil consumption in Shenzhen increased more than that in the previous year, and the contribution of energy structure factors in 2010-2011 was also positive. This shows that the decline of industrial pollution energy consumption can promote emission reduction.

Energy consumption intensity is an important emission reduction factor, and its decomposition results are all negative. From 2010 to 2011, the energy consumption intensity factor has the highest contribution to emission reduction, reaching 11300 tons. The intensity of energy pollution also promotes the emission reduction, but the contribution of factors also changes with the energy pollution coefficient. These two factors can be used to characterize the situation of production technology. According to the above results, we can know that production technology has a great impact on the change of air pollution emissions in Shenzhen.

There are great fluctuations in the impact of end treatment factors on emission reduction. From 2010 to 2011, the emission reduction effect of end treatment is obvious, and the industrial SO2 emission reduction in Shenzhen in that year is up to 11400 tons. Since then, the emission reduction effect of end treatment has gradually weakened. By 2015-2016, the contribution of the end treatment is positive, which means end treatment begins to have a restraining effect on emission reduction.

4. Conclusions and suggestions

According to the above analysis results, combined with the actual development status, we can know that: population growth and economic development have a certain role in increasing air pollution emissions in Shenzhen. Energy consumption intensity and energy pollution intensity have the greatest contribution to emission reduction, which means the progress of production technology and end treatment are still the main means of emission reduction. And industrial structure and energy structure have little impact on emissions.

Shenzhen, as one of the most developed cities in China, should pay attention to environmental protection while its population and economy are developing rapidly, instead of following the old road of “first pollution, then governance”. Shenzhen should increase investment in technology research and continuously improve the ability of scientific and technological innovation on the basis of continuing to promote the end treatment. In addition, the transformation of mode and structure has become a new trend of air pollution control in China. Shenzhen should improve its industrial structure and energy structure.

Other cities in GBA should actively learn from the governance experience of Shenzhen to improve the capacity of industrial air pollution reduction, by taking effective end treatment, publishing relevant policies to guarantee the management work, improving the industrial and energy structure to improve the energy utilization efficiency.

References
[1] GAO Cailing, GAO Ge, Feng Aiyun. Decomposition Analysis of Regional SO2 Emissions in China Based on LMDI Method [J]. Ecology and Environment, 2012, 21(3): 470-474.
[2] Ang B W, Zhang F Q. A Survey of Index Decomposition Analysis in Energy and Environmental Studies [J]. Energy, 2000, 25(12): 1149-1176.
[3] SUN Xin, LEI Huaiying. Empirical Research on The Effect of Whole Process Pollution Reduction in China---Take The Provincial SO2 Reduction as An Example [J]. East China Economic Management, 2012(7): 58-61.
[4] LI Yanmei, ZHANG Lei. Reason Analysis of Energy Consumption Increase and Discussion of Energy Saving Approach [J]. China Population, Resources and Environment, 2008, 18(3): 83-87.

[5] LI Mingsheng, ZHANG Jianhui, LUO Haijiang, et al. Sulphur Dioxide Reduction and Potential in China [J]. Scientia Geographica Sinica, 2011, 29(9): 1065-1071.

[6] HOU Guiguang, WU Shunze, XU Yi, et al. Quantitative Investigation On Correlative Mechanism Between Energy Structure and CO2 Emission [J]. Environmental Pollution & Control, 2015(3): 16-21.

[7] XU Jian, LI Li, An Jingyu, et al. Comparison of Economic, Energy and Traffic Structure in Three Major Regions in China and Its Impact on Air Pollution [J]. Chinese Journal of Environmental Management, 2018, 10(1): 43-55.

[8] WEN Yang, MA Zhong, WU Yuhan, et al. Factors Decomposition of Industrial Air Pollutant Emissions in Beijing-Tianjin-Hebei Region and Surrounding Areas Based on LMDI Model Analysis [J]. China Environmental Science, 2018(12).