Asian Journal of Atmospheric Environment
Vol. 11, No. 1, pp. 33-36, March 2017
doi: https://doi.org/10.5572/ajae.2017.11.1.033
ISSN (Online) 2287-1160, ISSN (Print) 1976-6912

Air Quality Improvement Scenario for China during the 13^{th} Five-Year Plan Period

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ABSTRACT

China is suffering from severe air pollution especially fine $PM_{2.5}$ pollution. In 2015, the annual average $PM_{2.5}$ concentration of the 338 municipal cities was 50 μg/m^3, 78% cities at or above the prefectural level failed to comply with the $PM_{2.5}$ concentration standards. The 13^{th} Five-Year Plan for National Economic and Social Development set the goal that the annual average concentration of $PM_{2.5}$ in the municipal cities which failed to attain the ambient air quality standards shall be decreased by 18% by 2020 (CCCPC, 2016). In this study, an air pollution control scenario during the 13^{th} Five-Year Plan period was proposed and the SO_2, NO_x and PM emission reductions in response to different measures in 31 provincial-level regions mainland China by 2020 were estimated. The air quality in the target year (2020) was simulated using the WRF-CMAQ model. The results showed that by 2020, the emissions of SO_2, NO_x and primary PM in mainland China will be reduced by 4.19 million tons, 3.94 million tons and 4.41 million tons, a drop of 23%, 21% and 25% respectively compared with that in 2015, and the annual average concentration of $PM_{2.5}$ will decrease by 19%. Coal-fired power plant contributes the most pollutant emission reduction.

Key words: Air quality, $PM_{2.5}$, Pollutants emission reduction, Air pollution prevention, 13^{th} Five-Year Plan

1. INTRODUCTION

China has been experiencing heavy air pollution problems due to fast economic and social development and dramatic increase in energy consumption in the recent decades (Sheng and Tang, 2016; Chan and Yao 2008). The ambient air quality in many cities exceeds both national standards and international guidelines (WHO, 2005). Frequent regional haze and fog episodes have caught the attention nationwide and all over the world.

To improve the air quality, Chinese government has put great efforts. The Environmental Protection Law and the Atmospheric Pollution and Control Law were amended and provide a legal base for air pollution prevention (Feng and Liao, 2016). The new national ambient air quality standards (China MEP and AQSIQ, 2012) were promulgated in 2012 and have been implemented by cities stage by stage. By the end of 2014, 1436 monitoring sites have been put in use in accordance with the new ambient air quality standards in 338 cities at or above the prefecture level to enforce the new air quality standards (China MEP, 2014). The Action Plan for the Prevention and Control of Air Pollution (hereafter referred to as 'the Action Plan') was issued and circulated by the State Council in 2013. The 'most stringent' plan set the roadmap for air pollution prevention and control in China in the next five years and the targets for air quality improvement by 2017 are clarified. Regional cooperation mechanism has been established and enhanced to fight for regional air pollution and it was also used successfully in air quality assurance during the big events, such as the Beijing APEC Summit, Nanjing Youth Olympic Games and Commemoration of 70th Anniversary of the Victory of Chinese People's War against Japanese Aggression and the World Anti-Fascist War (Wang *et al*., 2016; Shen, 2016). As a result, the main air pollutants emissions have been reduced significantly and the air quality has been improved. The total emission of SO_2 and NO_x were reduced by 18% and 18.6% respectively compared with 2010 (China MEP, 2015). The mean annual concentrations of SO_2, NO_2 and $PM_{2.5}$ in the 74 cities scheduled to enforce the new ambient air quality standards at Stage I were reduced by 37.5%, 11.4% and 23.6%, respectively, from 2013 to 2015 (China MEP, 2015).

However, the air pollution is still severe. In 2015, only 73 out of 338 (21.6%) cities at or above the prefecture level were able to attain the atmospheric air quality standards. Particulate matters, especially $PM_{2.5}$

are still major pollutants. Further air quality improvement is an urgent and essential task. The 13^{th} Five-Year Plan for National Economic and Social Development (hereafter referred to as 'the 13^{th} Five-Year Plan') set the goal that the annual average concentration of $PM_{2.5}$ in the municipal cities which failed to attain the ambient air quality standards shall be decreased by 18% by 2020. In this study, a series of air pollution control measures were proposed and the main pollutants emission reductions by 2020 were calculated and the air quality improvement was estimated. Suggestions and recommendations were also included.

2. METHODOLOGY

This study predicted the reduction potential of atmospheric pollutants emissions in China under a series of control measures using a scenario analysis from 2016-2020. The pollutants include SO_2, NO_x, PM and VOCs. The emission inventory of the base year (2015) was established based on the published statistical data (China NBS, 2016) and field investigation. An air pollutants emission control scenario during the 13^{th} Five-Year Plan period was proposed. The emission inventory of the target year (2020) was derived based on the base year inventory and the estimation of pollutants emission reduction due to the control measures under the scenario. Finally, the air quality in the target year was simulated using a CMAQ model.

In the emission control scenario, both restructuring measures and end-of-pipe control measures were proposed. Most of them shall refer to the Action Plan and the 13^{th} Five-Year Plan. The details are as follows:

1. Industrial structure adjustment: Strictly control 'high pollution and high energy-consuming' industries and phase out all outdated production systems.
2. Cleaner energy structure: Total coal consumption control and clean energy substitution for coal.
3. Comprehensive control on industrial enterprises: In the 3 key regions (Beijing-Tianjin-Hebei region, Yangtz River Delta region and Pearl River Delta region), the air pollutants emissions of 100 MW or above coal-fired power generator must meet the ultra-low emission standards. Other power generators and other industries must meet the special atmospheric pollutants emission limits. In other regions, the air pollutants emissions of 300 MW or above coal-fired power generator must meet the ultra-low emission standards. Other power generators and other industries must meet air pollutant emission standards for key industries by the MEP.
4. Effective control on transportation pollution: Promote emission control standards for vehicles and fuel quality standards. Eliminate yellow-label vehicles and old vehicles
5. Comprehensive VOCs emission control in key industries, such as petrochemicals, organic chemicals, surface coating, packaging, printing, etc.

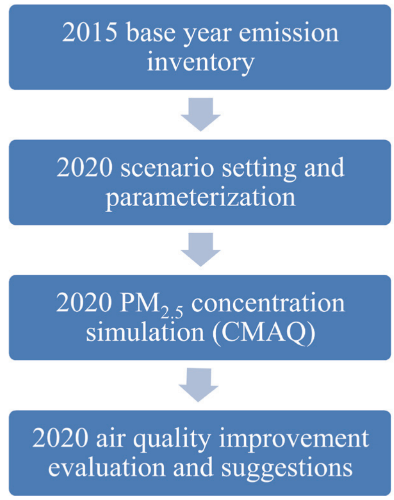

Fig. 1. Methodology.

3. RESULTS AND DISCUSSION

3.1 Main Sources of Conventional Atmospheric Pollutants Emissions

According to the emission inventory in the base year, the emissions of SO_2, NO_x, primary PM and VOCs in mainland China were 18.59 million tons, 18.52 million tons, 17.41 million tons, and 31.02 million tons. Coal-related sectors are the major sources of SO_2, NO_x and primary PM emissions. In China, electricity, industrial process, coal-fired boiler and household coal burning are the 4 main coal consuming sectors, which contribute to 93% of total SO_2 emission, 63% of total NO_x emission and 78% of total primary PM emission, respectively (see Fig. 2). As for industrial process, emissions mainly come from the iron and steel, cement, plate glasses, coke, and other industries. Road vehicles are the second largest contributor to NO_x emission, which accounts for 31%.

3.2 Emission Reductions of Pollutants under the Scenario

The emission reductions of the four pollutants: SO_2, NO_x, primary PM and VOCs were calculated by analysing the pollution prevention and control measures under the scenario. By 2020, the emissions of SO_2,

NO_x, primary PM and VOCs in mainland China will be reduced by 4.19 million tons, 3.94 million tons, 4.41 million tons and 4.38 million tons respectively, a drop of 23%, 21%, 25% and 14% from the 2015 levels.

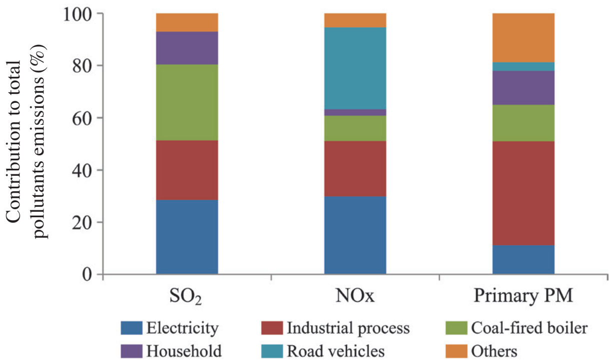

Fig. 2. Contributions of different sectors to the total pollutants emissions in 2015.

The contributions of emission reduction from different sectors under the proposed scenario are shown in Fig. 3. The controls in electricity generation sector contribute maximally to the emission reduction of SO_2 and NO_x, 59% and 67%, respectively. The most effective measure is compliance of the ultra-low emission standards. Strictly implementation of emission standards in key industries contributes most to the reduction of primary PM emission, which is 41%. The control measures in coal-fired boiler sector mainly include elimination of small scale boilers, making good use of centralized/district heating, and promoting clean energy substitution, including 'coal to gas' and 'coal to electricity'. They contribute to 16% of SO_2 reduction, 2% of NO_x reduction and 16% of primary PM reduction, respectively.

3.3 Analysis of Air Quality Improvement during the 13th Five-Year Plan Period

The pollutants emission inventory in 2020 was est-

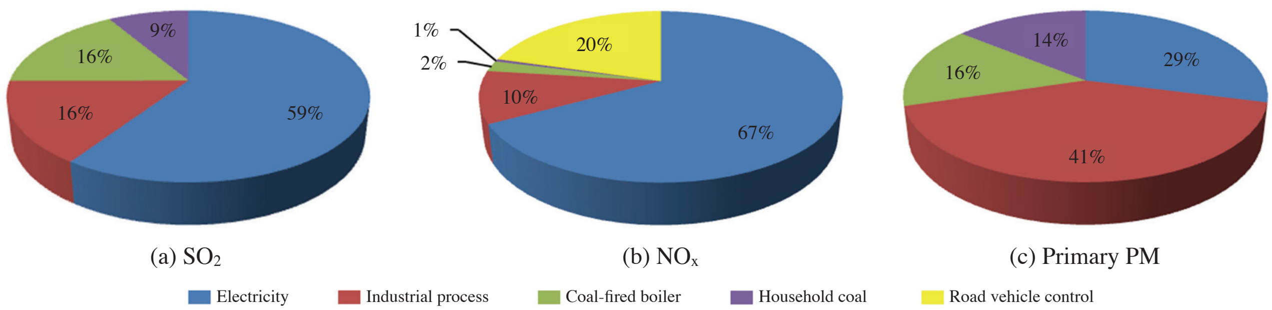

Fig. 3. Contributions of emission reduction from different sectors under the scenario.

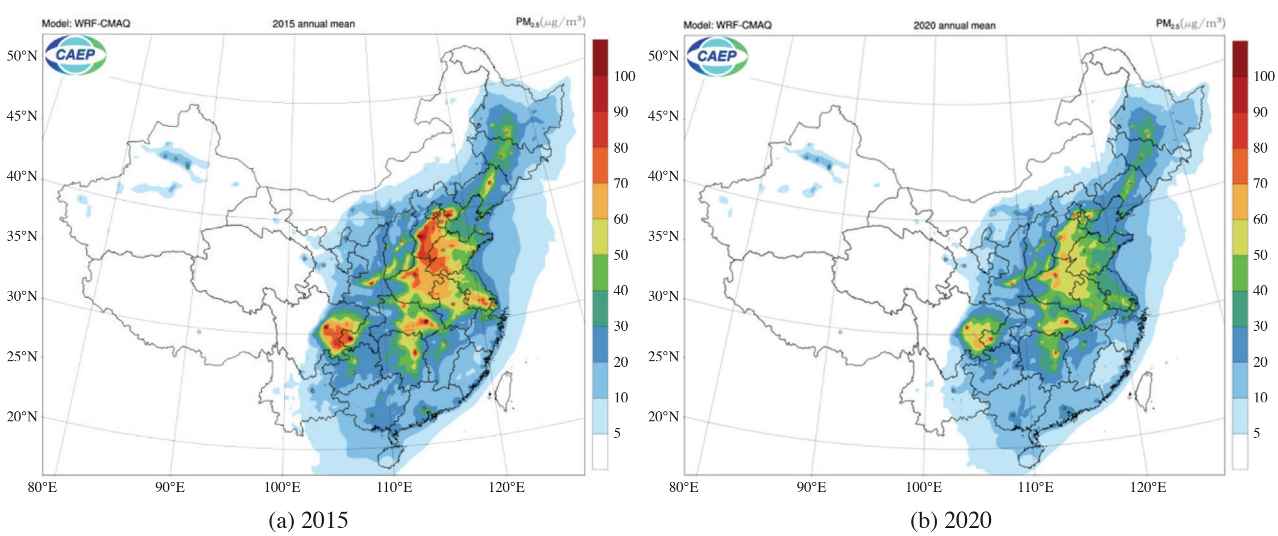

Fig. 4. Spatial distribution of the annual average concentration of $PM_{2.5}$ in China in 2015 and 2020.

ablished based on the emission inventory in 2015 and the emission reduction calculated under the pollution prevention and control scenario. CMAQ model was used to simulate $PM_{2.5}$ concentration in 2020. The meteorological conditions in the target year were assumed to be the same as the base year. The simulation results showed that the mean annual $PM_{2.5}$ concentration in China in 2020 will decrease by 19%.

The spatial distributions of annual average $PM_{2.5}$ concentrations in China in the base year and the target year can be seen in Fig. 4. Generally speaking, the annual average $PM_{2.5}$ concentrations in 2020 decrease throughout the country compared with 2015. The heavily polluted areas showed more significant air quality improvement. By the end of the 13th Five-Year Plan period, many cities in China are able to comply with the national atmospheric $PM_{2.5}$ concentration standard, including all the 9 cities in the Pearl River Delta region. However, there are still cities in Beijing-Tianjin-Hebei region, Yangtz River Delta Region, southwest, northeast and other areas failed to attain the standard. More efforts are still in need to further improve the air quality in those areas.

4. CONCLUSION AND SUGGESTIONS

a. Under the proposed air pollution prevention and control scenario, the emissions of SO_2, NO_x, PM and VOCs in China will decrease by 23%, 21%, 25% and 14%, respectively by 2020. The annual average concentration of $PM_{2.5}$ will decrease by 19%, accordingly.
b. Control measures listed in the scenario will significantly reduce the pollutants emissions, but not sufficient enough for all cities in China to attain the national atmospheric air quality standards by 2020.
c. For further air quality improvement and to attain the air quality standards in the long run, more efforts are required. End-of-pipe control measures are not enough, and substantial adjustments to industrial and energy structures are essential.
d. VOCs and NH_3 are key precursors to secondary aerosol formation. Emission reduction of VOCs and NH_3 must be strengthened to mitigate the $PM_{2.5}$ pollution. However, we are still lack of sound VOCs emission standards and monitoring systems, and NH_3 emission control is even at the very early stage. There are no specific programmes, regulations or standards in NH_3 control. VOCs emissions standards for key industries should be issued and on-line monitoring system should be developed. Measures to enhance ammonia emission management and control should be proposed and effectively implemented.

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(Received 25 November 2016, revised 19 January 2017, accepted 19 January 2017)