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Impacts of power generation on air quality in China—part I: An overview

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ABSTRACT

As the fast growth of China's economy, power generation has greatly increased in past decades. Majority of power generation in China is from coal-fired power plants. Large and still increasing amount of coal combustion for power generation emits numerous pollutants into atmosphere. Combining with emissions from other sources, power generation contributes to the severe air pollution in recent years. In this study, the historic trends and current status of the impact of power generation on air quality in China are overviewed. In 2012, the power sector contributed 30% of CO_2, 33% of NO_x, 23% of SO_2, 8% of particulate matter (PM), 3% of CO, and less than 1% of VOCs emissions in China. The power sector contributed 15% of NO_x, 13% of SO_2, 27% of O_3, 26% of fine particulate NO_3^- and 22% of fine particulate SO_4^{2-} ambient concentrations. Coal consumption for power generation is keeping growing. Tremendous efforts have been made to limit emissions from power generation by installing flue-gas desulphurization systems on coal-fired power plant, resulting in reduction of SO_2 and PM emissions recently. However, emissions of NO_x, CO_2, CO, and VOCs are still increasing. Over half of the power emissions and concentrations are distributed in East and North China, which include the Yangtze River Delta and the North China Plain, the two most developed and populous regions in China. Emissions from power generation contribute significant fractions of NO_x, SO_2, and particulate NO_3^- in winter, and significant fractions of O_3 and particulate SO_4^{2-} in summer.

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1. Introduction

The power generation in China has been increasing significantly to support the rapid economic growth and will continue to increase for many years (Yue, 2012). Due to the significant use of coal, natural gas, and biomass, power generation is a main contributor to air pollution in China (Hu et al., 2015; Zhao et al., 2013). Coal combustion is the major source of sulphur dioxide (SO_2), nitrogen oxides (NO_x), mercury, and particulate matter (PM). Natural gas and biomass burning emits large amount of NO_x and volatile organic components (VOCs). Coal-fired power plants contribute to 74% out of the total power generation of 5.3×10^{12} kWh in 2013, followed by hydropower (17%), nuclear and wind power (5%), and the combustion of oil, natural gas, biomass, and other power generation (4%). SO_2, NO_x, PM, and carbon monoxide (CO) are the criteria pollutants that are regulated by the National Ambient Air Quality Standards of China (MEP, 2012). In addition to their own environmental concerns, some of the pollutants, such as SO_2, NO_x, and VOCs, are also precursors of secondary pollutant of ozone (O_3) as well as secondary PM components of sulfate (SO_4^{2-}), nitrate (NO_3^-), and secondary organic aerosols (SOA). These pollutants are the major components forming photochemical smog and haze pollution, causing severe damage to public health (Anenberg et al., 2010; Chen et al., 2011; Dockery et al., 1993; Kan et al., 2008; Laurent et al., 2014; Ostro et al., 2015; Pope, 2000).

The emissions from power generation in China not only affect local air quality but also transport over long distance and cause regional/global environmental issues. Pollutants from East Asia have been reported to travel across the Pacific Ocean and increase O_3 concentrations in Western United States (Lin et al., 2012; Wang et al., 2009). The PM emissions also can affect the climate change by absorbing and/or scattering solar radiation (Wang et al., 2014b; Zhang et al., 2014a), and by influencing the cloud formation (Fan et al., 2014). Considering the large fraction of coal-fired power generation in China and its important contribution to air pollutants, it is essential to have a comprehensive understanding of the impacts on

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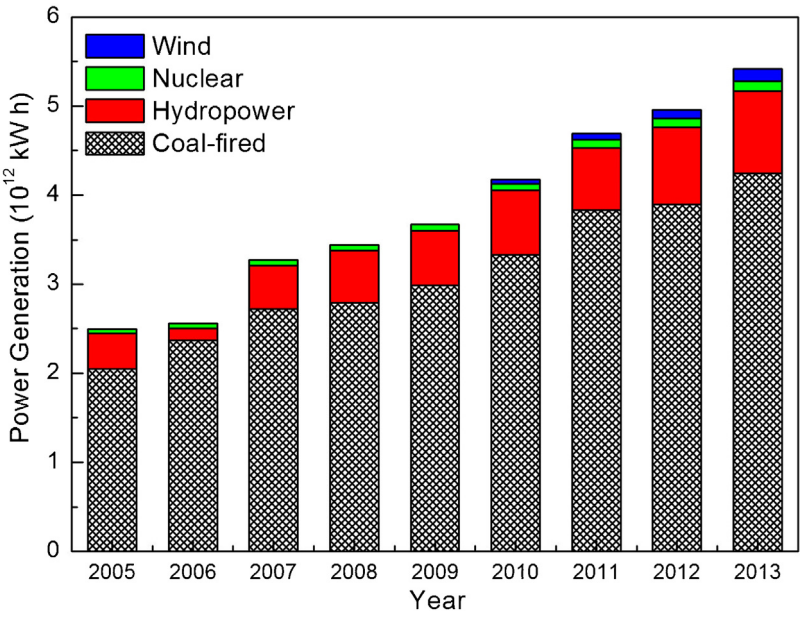

Fig. 1. Trend of power generation by coal-fired, hydropower, nuclear and wind technologies in China during the period of 2005–2013.

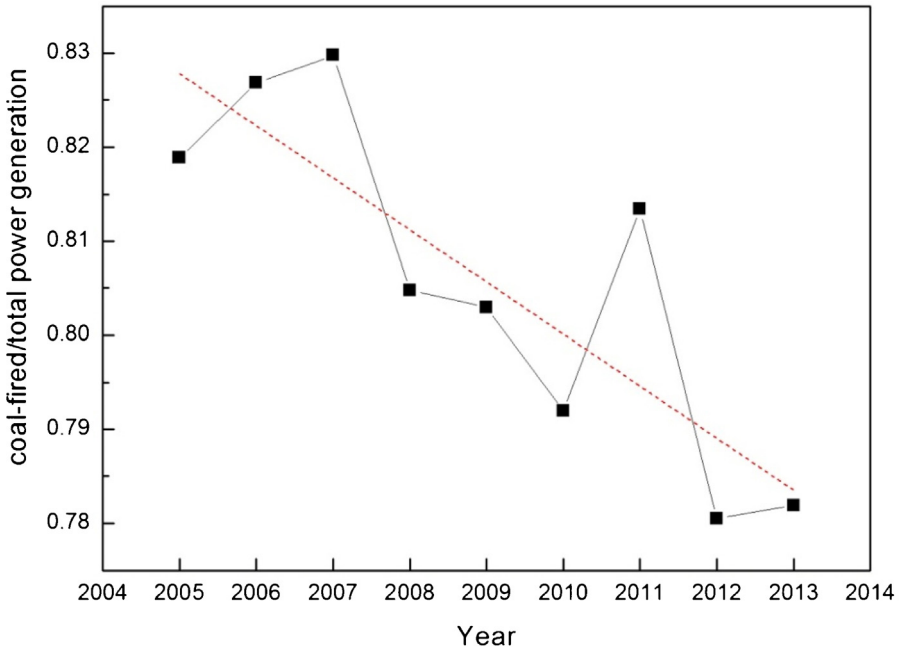

Fig. 2. Trend of the ratio of power generated by coal-fired technology over total power generation in China during the period of 2005–2013.

air quality in China, in order to develop effective control programs to improve air quality.

Previous studies have reported the contributions of power generation (coal combustion) to emissions and ambient air pollutants in China. Liu et al. (2015) reported that a 479% growth in coal consumption from 1990 and 2010, and emissions from coal-fired power plants increased by 56% and 335% for SO_2 and NO_x, while decreased by 23% and 27% for $PM_{2.5}$ and PM_{10}, respectively. Using receptor models, Zhang et al. (2013) estimated that coal combustion (including power generation and residential activities) contributed 14% of $PM_{2.5}$ in Beijing. Tao et al. (2014) found that coal combustion contributes to 20% to $PM_{2.5}$ in Chengdu, a megacity in Southwest China. Chemical transport models (CTM) were also used with different source apportionment techniques. A reactive tracer based technique showed that power sector is a major contributor to particulate SO_4^{2-} and NO_3^- in China (Zhang et al., 2012a) and inter-regional transport is significant (Ying et al., 2014). An complete source apportionment of both primary and secondary $PM_{2.5}$ in Xi'an, a metropolitan in Northwest China showed that power generation contributed to 5% during an extremely polluted month in January 2013 (Wang et al., 2014a). Although these studies provide some valuable information in understanding the impacts of power generation to air quality in certain cities/regions or specific seasons, a systematic overview of the current status in China is highly valuable for power system planning and emission control.

China has been experiencing extreme air pollution problems due to fast economic and social development in recent decades (Chan and Yao, 2008; Hu et al., 2014; Wang et al.,

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