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Current and future emissions of primary pollutants from coal-fired power plants in Shaanxi, China

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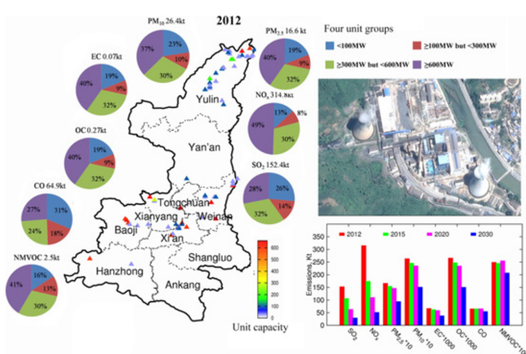
HIGHLIGHTS

- Emission inventory of pollutants from coal-fired power plants in Shaanxi was created for 2012.
- Emission factors from official promulgation were adopted for SO2, NOx, PM2.5 and PM10.
- Decontamination efficiency, coal quality and unit capacity in reality were used and their effects were analyzed.
- SO_2, NO_x, $PM_{2.5}$ and PM_{10} from coal-fired power plants have decreased since 2012.

GRAPHICAL ABSTRACT



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ABSTRACT

A high-resolution inventory of primary atmospheric pollutants from coal-fired power plants in Shaanxi in 2012 was built based on a detailed database compiled at unit level involving unit capacity, boiler size and type, commission time, corresponding control technologies, and average coal quality of 72 power plants. The pollutants included SO_2, NO_x, fine particulate matter ($PM_{2.5}$), inhalable particulate matter (PM_{10}), organic carbon (OC), elemental carbon (EC), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC). Emission factors for SO_2, NO_x, $PM_{2.5}$ and PM_{10} were adopted from standardized official promulgation, supplemented by those from local studies. The estimated annual emissions of SO_2, NO_x, $PM_{2.5}$, PM_{10}, EC, OC, CO and NMVOC were 152.4, 314.8, 16.6, 26.4, 0.07, 0.27, 64.9 and 2.5 kt, respectively. Small units (<100 MW), which accounted for ~60% of total unit numbers, had less coal consumption but higher emission rates compared to medium (≥100 MW and <300 MW) and large units (≥300 MW). Main factors affecting SO_2, NO_x, $PM_{2.5}$ and PM_{10} emissions were decontamination efficiency, sulfur content and ash content of coal. Weinan and Xianyang were the two cities with the highest emissions, and Guanzhong Plain had the largest emission density. Despite the projected growth of coal consumption, emissions would decrease in 2030 due to improvement in emission

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control technologies and combustion efficiencies. SO_2 and NO_x emissions would experience significant reduction by ~81% and ~84%, respectively. $PM_{2.5}$, PM_{10}, EC and OC would be decreased by ~43% and CO and NMVOC would be reduced by ~16%.

1. Introduction

Air pollution in China receives increasing attention as severe regional and inter-regional pollution events occurred frequently in recent years (Ji et al., 2012; Wang et al., 2014a; Wang et al., 2014b). Power plants account for approximately half of the total coal consumption in China and emit masses of air pollutants regionally and nationwide (Chen et al., 2014; Liu et al., 2015; Streets et al., 2006). About 33% of NO_x, 23% of SO_2, 8% of particulate matter (PM), 3% of CO, and <1% of NMVOC emissions were contributed by power plants in China in 2012 (Huang et al., 2016). Shaanxi province, located in northwestern China (Fig. 1), is one of the areas suffering serious air pollution. Guanzhong Plain is in central Shaanxi and surrounded by the Loess Plateau to the north and Qingling Mountains to the south. Large amounts of air pollutants emitted from intensive industrial operations (including coal-fired power plants) and large residential activities in Guanzhong Plain are often trapped in the basin and cause severe air pollution (Feng et al., 2015; Wang et al., 2014a; Wang et al., 2012; Wang et al., 2014b).

Several studies have been conducted to build air pollutant emission inventories for the coal-fired power sector in China (Kato and Akimoto, 1992; Klimont et al., 2001; Ohara et al., 2007). However, large difference of the net emission rates exists because these studies used fixed average emission factors with rough allocation of boiler type or unit capacity, and ignored the equipped decontamination technologies. Recently, technology-based emission estimation methodologies with local emission factors have been widely used in China to improve the accuracy of the magnitudes and trends in power plants emissions, especially for SO_2 and NO_x (Klimont et al., 2009; Klimont et al., 2013; Lei et al., 2011; Tian et al., 2013; Zhang et al., 2007; Zhao et al., 2012b). Using the unit-level coal consumption and decontamination facility information was firstly applied by Zhao et al. (2008) to calculate SO_2, NO_x and PM emissions from coal-fired power sector in China. Zhao et al. (2010) then developed a database of emission factors of SO_2, NO_x and PM for Chinese coal-fired power plants based on field measurements and literature data. Boiler type and coal quality were considered in studying SO_2 emission factors. Unit groups and installation of low nitrogen burners (LNB) were also considered for NO_x emission factors. Ash content of coal (ACC) and ash retention were considered for $PM_{2.5}$ and PM_{10}, emissions from different boiler types. The emission factors database or unit-level method has been adopted by several studies in recent years (Chen et al., 2014; Liu et al., 2015; Tian et al., 2013; Xiong et al., 2015).

However, after analyzing the regional and national emissions inventories for coal-fired power plants in Shaanxi (Li et al., 2015; Liu et al., 2015; Wang et al., 2012), several shortcomings are identified: (1) sulfur retention (SR) (the ratio of sulfur retained by coal ash when burning) in ash of pulverized coal (PC) boilers and circulating fluidized bed (CFB) boilers varies from 5% to 15% and 15%–35%, respectively, which poses a large uncertainty in SO_2 emission rates; (2) NO_x emission factors are so diverse that in different studies, leading to large variations in the estimated NO_x emissions; (3) provincial average value of sulfur content of coal (SCC) and ACC are used to calculate emission factors of SO_2 and PM, without considering the variation of these properties in different cities; and (4) no research captures the influence of the latest emission control policies after 2010 and predicts the future trends for Shaanxi. The Chinese government has issued a national policy on improving and reforming energy saving and emission reduction during 2014–2020. The aim of average coal consumption of per unit power production is <300 and 310 g/kWh for the units ≥600 MW and ≥300 MW respectively, and the emission should be reduced to gas turbine limitation (i.e., with an oxygen content of 6%, the emission concentration of PM, SO_2, and NO_x are not higher than 10, 35, 50 mg/m^3, respectively.) (NDRC, 2014). In addition, Shaanxi government has also drawn up air pollution control targets from 2013 to 2017. The annual monitoring values of PM_{10} and NO_2 in the ambient air are expected to decrease by 15% and 10% respectively by 2017 from the base values of 2012 in the

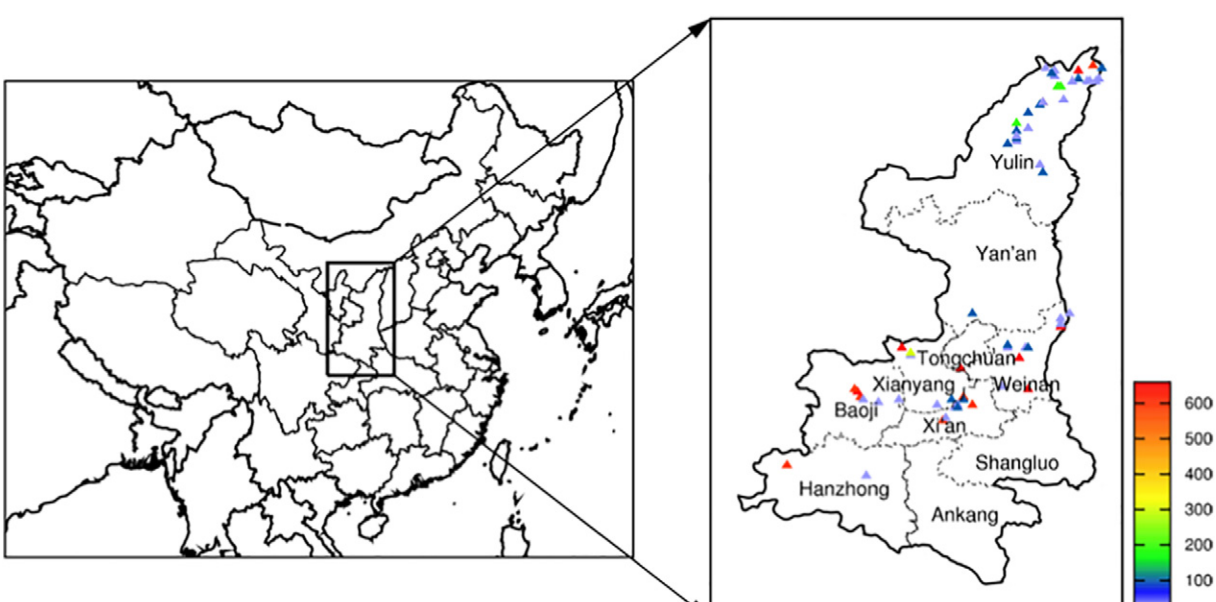

Fig. 1. Study domain and the location of plants in Shaanxi and their corresponded unit capacity (Units: MW).