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Quantifying short-term and long-term health benefits of attaining ambient fine particulate pollution standards in Guangzhou, China

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HIGHLIGHTS

- Significant associations were observed between $PM_{2.5}$ and mortality in Guangzhou.
- Attaining daily standard of $PM_{2.5}$ would prevent 143 natural deaths each year.
- Attaining annual $PM_{2.5}$ standard would avoid 3875 natural deaths in Guangzhou.

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ABSTRACT

In 2012, Chinese Environmental Bureau modified its National Ambient Air Quality Standards to include fine particulate matter ($PM_{2.5}$). Recent air pollution monitoring data shows that numerous locations have exceeded this standard, which may have resulted in avoidable adverse health effects. For example, among the 74 Chinese cities with $PM_{2.5}$ monitoring data in 2013, only three cities attained the annual air quality standard (35 μg/m^3). This study aimed to quantify the potential short- and long-term health benefits from achieving the Chinese ambient air quality standard and WHO's air quality objectives. A generalized additive model was used to estimate the short-term association of mortality with changes in daily $PM_{2.5}$ concentrations, based on which we estimated the potential premature mortality reduction that would have been achieved during the period of 2012–2015 if the daily air quality standard had been met in Guangzhou, China; we also estimated the avoidable deaths if attaining the annual air quality standard using the relative risk obtained from a previous cohort study. During the study period, there were 160 days exceeding the national daily $PM_{2.5}$ standard (75 μg/m^3) in Guangzhou, and the annual average concentration (47.7 μg/m^3) was higher than the air quality standard of 35 μg/m^3. Significant associations between $PM_{2.5}$ and mortality were observed. An increase of 10 μg/m^3 in $PM_{2.5}$ was associated with increases in daily death counts of 0.95% (95% CI: 0.56%, 1.34%) in natural mortality, 1.31% (95% CI: 0.75%, 1.87%) in cardiovascular mortality, and 1.06% (95% CI: 0.19%, 1.94%) in respiratory mortality. The health benefits of attaining the national daily air quality standard of $PM_{2.5}$ (75 μg/m^3) would have prevented 143 [95% confidence interval (CI): 84, 203] fewer natural deaths, including 84 (95% CI: 48, 121) fewer cardiovascular deaths and 27 (95% CI: 5, 49) fewer respiratory deaths. Had the annual $PM_{2.5}$ levels been reduced to 35 μg/m^3, an estimated 3875 (95% CI: 1852, 6074) natural deaths, 2378 (95% CI: 800, 4230) cardiovascular deaths, and 227 (95% CI: -437, 1033) respiratory deaths could have been prevented. Even greater substantial mortality reductions could be achieved if the WHO's air quality objectives were met. Our study suggests that air pollution is significantly associated with mortality in Guangzhou, and

Abbreviations: $PM_{2.5}$, particulate matter with an aerodynamic diameter less than 2.5 μm; 95% CI, 95% confidence interval; df, degrees of freedom; AQG, air quality guidelines; ICD, International Classification of Diseases; DOW, day of the week; PH, public holiday.

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more stringent air quality standards would significantly reduce air pollution-related premature mortality.

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1. Introduction

Extensive epidemiologic studies have demonstrated that both short- and long-term exposures to elevated air pollution are associated with increases in morbidity and mortality, particularly from cardiovascular and respiratory diseases (Dockery et al., 1993; Dominici et al., 2006; Dockery and Stone, 2007; Qian et al., 2010). These findings have prompted the World Health Organization (WHO) and various countries to formulate and revise their air quality guidelines and standards (World Health Organization, 2006a,b). For example, WHO reviewed the scientific evidence that linked air pollution with human health, and recommended air quality guidelines (AQG, daily mean of 25 μg/m^3 and annual average of 10 μg/m^3 for $PM_{2.5}$) that would be useful to protect the public health worldwide (World Health Organization, 2006a,b). Interim targets were also proposed for air pollution control in more polluted areas to move toward the WHO AQG. For example, the loosest target (Interim target-1) for $PM_{2.5}$ was set as 75 μg/m^3 for daily concentration and 35 μg/m^3 for annual concentration (World Health Organization, 2006a,b).

Several efforts have been made to quantify the potential health benefits of reductions in ambient air pollution concentration, which expanded our understanding of the public health impacts from the improvement in air quality through the air pollution mitigation regulations (Bae and Park, 2009; Lin et al., 2014). Accountability analysis, the evaluation of the potential health benefits from various regulatory actions, has been viewed as a necessary component in formulating new regulations (Dominici et al., 2007; Henschel et al., 2012). The magnitude of estimated health benefits provide important information for the policy-makers to revise the air quality regulations.

A previous study conducted in South Korea estimated that about 964 and 329 premature deaths due to daily particulate matter less than 10 μm (PM_{10}) and ozone exposures, respectively, could be prevented annually if the air quality attained the WHO's AQG (Bae and Park, 2009). The potential benefit of a 5 μg/m^3 reduction in PM_{10} concentration was estimated to be a reduction between 3300 and 7700 deaths per year across 19 European cities (Medina et al., 2004). Similarly, Ostro, et al. reported that attainment of ambient ozone standard of 0.07 ppm would result in 630 fewer premature deaths annually in California (Ostro et al., 2006a,b). Bell and co-workers investigated the consequences of fossil fuel-related air pollution for three cities in Latin America, and estimated that about 156,000 premature deaths would be prevented if the air pollution control measures were adopted in the next 20 years (Bell et al., 2006). Another study reported that the effect of an air quality improvement program from 2001 to 2010 in Taiyuan, China potentially prevented 2810 premature deaths (Tang et al., 2014). Although the study areas, analysis of scenarios, and statistical methods are different across these studies, the results consistently indicate that enormous benefits in terms of mortality reduction, would result from a more rigorous air pollution control policy.

Along with the rapid economic development, air pollution concentration in many parts of China has far exceeded the WHO's air quality guidelines and presented a serious public health concern (Kan, 2009). For example, among the 74 Chinese cities with $PM_{2.5}$ monitoring data in 2013, only three cities attained the loosest target for annual $PM_{2.5}$ concentration (Interim target-1, 35 μg/m^3). In 2012, the Chinese government amended its National Ambient Air Quality Standard (CH-NAAQS) aiming to revise the standards and measurements for both gaseous and particulate matter air pollutants (Dong et al., 2013). However, fewer studies have been conducted to estimate the potential health benefits if air pollution concentrations attain the national and international ambient air quality standards in Chinese cities (Voorhees et al., 2014). This study aimed to fill this research gap by retrospectively estimating the short-term and long-term mortality benefits if the air pollution attains the China's national air quality standards and WHO's guideline for ambient $PM_{2.5}$ in Guangzhou, China.

2. Material and methods

2.1. Setting

The Pearl River Delta in Guangdong Province is among the four most polluted regions in China (Chan and Yao, 2008). Guangzhou, a core city of the Pearl River Delta, is the capital city of the Guangdong Province and the economic center of south China (Tao et al., 2015) (Fig. 1). It also experiences some of the worst air pollution among China's cities (Tao et al., 2015). In 2010, Guangzhou was home to about 12.7 million permanent residents. It has a typical subtropical humid-monsoon climate with an average annual temperature of 22 °C and average rainfall of 1500–2000 mm.

2.2. Mortality data

Daily mortality data from 1 May 2012 to 30 April 2015 were obtained from Guangdong Provincial Center for Disease Control and Prevention (GDCDC). The records provided information on

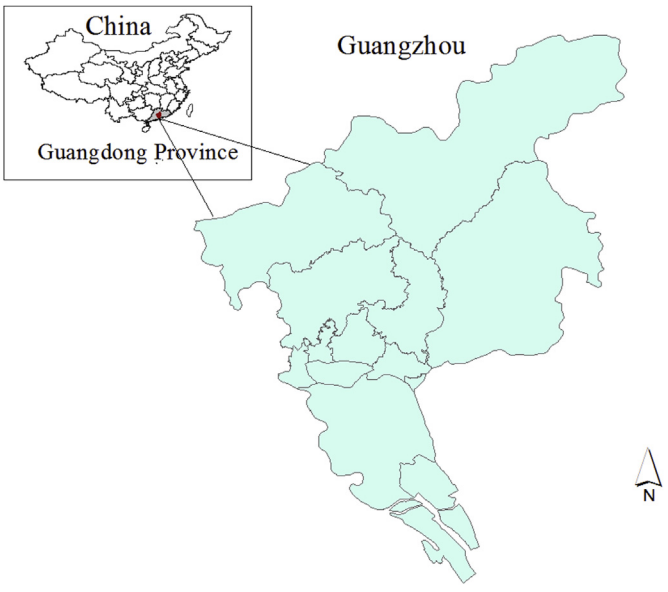

Fig. 1. Geographical location of Guangzhou in China and its district distribution.