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Review

Health benefits from improved outdoor air quality and intervention in China☆

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ABSTRACT

China is at its most critical stage of outdoor air quality management. In order to prevent further deterioration of air quality and to protect human health, the Chinese government has made a series of attempts to reduce ambient air pollution. Unlike previous literature reviews on the widespread hazards of air pollution on health, this review article firstly summarized the existing evidence of human health benefits from intermittently improved outdoor air quality and intervention in China. Contents of this paper provide concrete and direct clue that improvement in outdoor air quality generates various health benefits in China, and confirm from a new perspective that it is worthwhile for China to shift its development strategy from economic growth to environmental economic sustainability. Greater emphasis on sustainable environment design, consistently strict regulatory enforcement, and specific monitoring actions should be regarded in China to decrease the health risks and to avoid long-term environmental threats.

1. Introduction

Ambient air pollution and its impact on population health is a significant issue in China, which has drawn large national and international attention. As the largest developing country in the world, China has experienced tremendous economic growth over the past decades (Zhu, 2012). However, the problem of air pollution along with economic expansion seems inevitable. Since the last century, urbanization, industrialization accompanied energy consumption especially coal combustion, increase in motor vehicles uses, and city planning and construction have all contributed to ambient air pollution increases in China (Chen et al., 2004). Both short-term and long-term health threats of air pollution posed on Chinese people are well recognised (Yang et al., 2012a), which include but not limited to mortality (Yang et al., 2012a; Breitner et al., 2011; Cao et al., 2011; Chen et al., 2010, 2011a, 2011b, 2012a, 2012b, 2012c, Chen et al., 2013; Dong et al., 2012; Guo et al., 2010a; Kan et al., 2003; Kan et al., 2004; Ma et al., 2011; Qian et al., 2007; Xu et al., 2000, 2014; Yang et al., 2012b; Zhang et al., 2011a), morbidity (Cao et al., 2009; Guo et al., 2009, 2010b, 2010c; Leitte et al., 2011; Liu et al., 2013; Qiao et al., 2014; Tao et al., 2014; Xiang et al., 2013; Xie et al., 2014; Zhang et al., 2011b, 2014a, 2014b; Zhao et al., 2014), changes in lung function (Baccarelli et al., 2014; Kasamatsu et al., 2006; Liu and Zhang, 2009), and adverse birth outcomes (Jiang et al., 2007; Zhao et al., 2015).

China is at the most critical stage of outdoor air quality management. In order to prevent the further deterioration of air quality and to protect human health, the Chinese government has made a series of attempts to reduce ambient air pollution (Wang and Hao, 2012). China's Five-Year Plans (FYP) is a national integrated plan system that constitutes specific targets and relevant supporting policies regarding economic development, energy conservation, and environmental protection for each following 5 years (Mao et al., 2014). Learning lessons from the implementation failure by main political focus on economic growth but less emphasis on sustainable energy consumption and environmental pollution of the National Environmental Protection 10th FYP (2001–2005) and facing the major air quality challenges, the government incorporated stringent goals into the 11th FYP (2006–2010) for National Environmental Protection — a 20% reduction in energy intensity and a 10% drop in sulphur dioxide (SO2) emissions in 2010 from the 2005 levels. Consequently, widely installations of flue gas desulfurization in coal-fired power plants resulted in a large decrease in ambient SO2 levels during the period (Wang et al., 2014). In the 12th FYP

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(2010–2015), Chinese national targets were expanded to16% and 17% cuts for energy and carbon dioxide (CO2) intensity and 8% and 10% declines in SO2 and nitrogen oxide (NOx) emissions (Mao et al., 2014). During this period, many power plants, iron and steel plants, and cement plants have been taken. The Ministry of Environmental Protection also released an "Emission Standard of Air Pollutants for Thermal Power Plants" (GB 13223-2011) in 2011 to further strengthen the nationwide controls and guarantee the achievement of the 12th FYP (Wang et al., 2014).

In addition, to effectively improve the regional air quality and lessen the interactive impacts of air pollution particularly within metropolitan areas, Chinese Ministry of Environmental Protection launched a "Joint Prevention and Control of Air Pollution" in 2011. The plan has established a joint air pollution prevention and control system and has been implemented in three main regions — the Beijing-Tianjin-Hebei Region, the Yangtze River Delta and the Pearl River Delta during the 12th FYP (Zhang et al., 2010). In fact, prior to this plan, China did demonstrate the extraordinary ability to ensure regional good air quality during temporarily critical periods, for example, the 2008 Beijing Olympic Games, the 2010 Shanghai Expo and Guangzhou Asian Games. And recently in 2014, though only for a short special time again, Beijing (the host city) and its surrounding areas have made tremendous efforts to guarantee the good air quality during the Asia-Pacific Economic Cooperation (APEC) summit. The phrase "APEC Blue" then became popular which describes the blue skies during and short after the summit.

Unlike previous literature reviews on the widespread hazards of outdoor air pollution on human health, this review article firstly focused on the evidence of health benefits from intermittently improved ambient air quality and intervention in China. This paper reviewed literature published since 1996 because no earlier studies were referenced referring the topic. In chronological order, firstly, we reviewed the evidence of health changes in Hong Kong since Hong Kong's 1990 low-sulphur fuel law, which was the initial air pollution restriction in China. Secondly, we reviewed the extensive health benefits from the drastic air pollution reduction around the period of 2008 Beijing Olympic Games. Thirdly, we briefly reviewed another two scientific literature on perinatal and children's positive health returns of Chinese national and regional regulations on power plants, respectively. Fourthly, we reviewed some population interventional studies that about the health enhancement when ambient air pollution levels remained high. Lastly, we summarized the current evidence, discussed the Chinese success and challenge in air pollution control to promote population health, and suggested the future research directions.

2. Search strategy and selection criteria

We used PubMed, Web of Science, Medline, and Scopus electronic databases to identify published studies from January 1, 1990, to September 15, 2015. Search terms used and the logical relations among them were: "China" and, "ambient" or "outdoor" and, "air pollution reduce" or "air pollution decrease" or "air quality improve" and, "health benefit" or "health change" or "health intervention" or "Beijing Olympic" or "Shanghai Expo" or "Guangzhou Asian Games" or "Beijing APEC". Full texts of references and citations in the articles retrieved were screened to further assess and ensure all relevant papers were included. The search was limited to original peer-reviewed journal articles of quantitative studies written in English language. Studies on health estimation, indoor air quality, and on tobacco smoking control were excluded from the reference list. A total of 18 articles were reviewed in this paper. These studies are summarized in Table 1 in ascending chronological order.

3. Health gains from the 1990's fuel restriction in Hong Kong

Hong Kong is a relatively small territory on the southern coast of China. A high industrial base within the territory, its dense infrastructure, and the subtropical climate made air pollution a serious problem in Hong Kong since the end of last century. Under the pressure of residents' complaints about the poor daily air quality, Hong Kong government implemented legislation from July 1990 that prohibited the use of fuel oil with a sulphur content of more than 0.5% by weight in all power plants and road vehicles (Hong Kong Government, 1990). The restriction consequently resulted in an immediate reduction of ambient SO2 by up to 80% in the most polluted areas (Peters et al., 1996).

A respiratory health study (Peters et al., 1996) was carried out during 1989–1991 on primary school children to observe the changes in their self-reported respiratory symptoms before and after the government fuel restriction law. The study recruited primary school children from the most polluted (Kwai Tsing) and the least polluted (Southern) districts in Hong Kong, and followed up the children and parents yearly in 1989, 1990, and 1991 using self-completed questionnaires. In Kwai Tsing, SO2 concentrations dropped from a peak of 88–101 μg/m3 in 1989 and 113–136 μg/m3 in 1990 to 23–26 μg/m3 in 1991. For comparison, in Southern, SO2 levels were much lower and stable both before and after the government legislation, that were from an estimated annual mean level of 11 μg/m3 in 1989 and the peak values of 7–9 μg/m3 in 1990 to 2–4 μg/m3 in 1991. In 1989, 1990, SO2 effects on respiratory symptoms (odds ratio [OR], 95% confidence interval [CI]) associated with living in Kwai Tsing compared with in Southern were: cough and sore throat (1.22, 1.05–1.42), wheezing (1.34, 1.09–1.66), and phlegm (1.11, 0.96–1.30). However, after the government air quality regulation in 1991, the excess risks for reported symptoms in the polluted compared with unpolluted district were reduced or eliminated: cough and sore throat (0.92, 0.73–1.15), wheezing (1.18, 0.89–1.47), and phlegm (0.88, 0.68–1.13).

Similarly, at the same two districts in the months before air quality control in 1990 and one and two years afterwards in 1991 and 1992, another study (Wong et al., 1998) observed the bronchial responsiveness in non-asthmatic and non-wheezing school-aged children. Bronchial hyper-reactivity (BHR) [a 20% decrease in forced expiratory volume in one second (FEV1) provoked by a cumulative dose of histamine less than 7.8 μmol] and bronchial reactivity (BR) slope [percentage change in logarithmic scale in FEV1 per unit dose of histamine] were used as the outcome variables. The study showed that, in Kwai Tsing and Southern, both BHR and BR slope declined from 1990 to 1991 but children's significant airway hyper-reactivity greater improvements only occurred in Kwai Tsing (more polluted district) in 1992. Measurements (95% CI) from 1990 to 1992 in Kwai Tsing were: BHR − 30.6% (17.7%, 43.5%), 17.8% (6.6%, 28.9%), and 10.9% (1.9%, 19.9%); BR slope − 0.53 (0.43, 0.62), 0.41 (0.31, 0.51), and 0.35 (0.29, 0.41); whereas measurements in Southern in the three years were: BHR − 22.7% (13.2%, 32.1%), 11.1% (3.9%, 18.4%), and 12.0% (4.6%, 19.4%); BR slope − 0.42 (0.37, 0.47), 0.38 (0.32, 0.44), and 0.36 (0.30, 0.41).

Study with Poisson regression models (Medley et al., 2002) on mortality trending changes for the entire Hong Kong during 1985–1995 indicated that the seasonal mortality rates fell immediately after the introduction of government fuel restriction, and that the restriction led to substantial declines in average annual proportional trend in deaths from all causes (2.1%, $p = 0.001$), respiratory diseases (3.9%, $p = 0.0014$), and cardiovascular diseases (2.0%, $p = 0.0214$). It also noted that the average personal life gains per year from exposure to reduced outdoor air pollution were 20 days for females and 41 days for males.