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Smog episodes, fine particulate pollution and mortality in China

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ABSTRACT

Background: Starting from early January 2013, northern China was hit by multiple prolonged and severe smog events which were characterized by extremely high-level concentrations of ambient fine particulate matter ($PM_{2.5}$) with hourly peaks of $PM_{2.5}$ over 800 μg/m^3. However, the consequences of this severe air pollution are largely unknown. This study investigates the acute effect of the smog episodes and $PM_{2.5}$ on mortality for both urban and rural areas in northern China.
Data and methods: We collected $PM_{2.5}$, mortality, and meteorological data for 5 urban city districts and 2 rural counties in Beijing, Tianjin and Hebei Province of China from January 1, 2013 through December 31, 2013. We employed the generalized additive models to estimate the associations between smog episodes or $PM_{2.5}$ and daily mortality for each district/county.
Results: Without any meteorological control, the smog episodes are positively and statistically significantly associated with mortality in 5 out of 7 districts/counties. However, the findings are sensitive to the meteorological factors. After controlling for temperature, humidity, dew point and wind, the statistical significance disappears in all urban districts. In contrast, the smog episodes are consistently and statistically significantly associated with higher total mortality and mortality from cardiovascular/respiratory diseases in the two rural counties. In Ji County, a smog episode is associated with 6.94% (95% Confidence Interval, −0.20 to 14.58) increase in overall mortality, and in Ci County it is associated with a 19.26% (95% CI, 6.66–33.34) increase in overall mortality. The smog episodes kill people primarily through its impact on cardiovascular and respiratory diseases. On average, a smog episode is associated with 11.66% (95% CI, 3.12–20.90) increase in cardiovascular and respiratory mortality in Ji County, and it is associated with a 22.23% (95% CI, 8.11–38.20) increase in cardiovascular and respiratory mortality in Ci County. A 10 μg/m^3 increase in $PM_{2.5}$ concentration is associated with 0.88% (95% CI, 0.3–1.46) increase in overall mortality and 1.2% (95% CI, 0.55–1.85) in Ji County. A 10 μg/m^3 increase in $PM_{2.5}$ concentration is associated with 0.55% (95% CI, −0.02 to 1.13) increase in overall mortality in Ci County. The findings suggest that the smog episodes and fine particulate have bigger and more detrimental impacts on rural residents, especially for those living close to big and polluted cities.
Conclusions: The smog episodes and $PM_{2.5}$ are statistically associated with mortality in rural areas of China. The associations for urban areas are not statistically significant.

1. Introduction

Air pollution, undoubtedly, is one of China's most pressing public health issues today. Many industrialized countries have had their share of severe air pollution problems in the past (such as Meuse Valley in Belgium in 1930 (Nemery et al., 2001), Pennsylvania in 1948 (Schreniz et al., 1949), and London in 1952 (U.K. Ministry of Health, 1954)). However, the intensity of the recent

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serious air pollution events in China, their geographic extent, and the number of people affected are unprecedented.

Starting from early January 2013, Beijing experienced multiple prolonged periods of severe smog. An important measure of the intensity of these mixtures of smoke and fog is the peak hourly concentrations of ambient fine particulate matter ($PM_{2.5}$) which reached over 800 μg/m^3 or more than 32 times higher than the World Health Organization's (WHO) recommended level (25 μg/m^3). These smog episodes affected a region that extended far beyond the Beijing metropolitan area. There is growing awareness that these episodes can cause health problems. For example, as Beijing suffered a sixth day of hazardous-level air pollution in February 2014, the World Health Organization urged the residents of the capital city to stay indoors. However, the WHO officials cautioned that they could not link recent pollution levels with local media reports of specific cases of lung cancer and other ailments. “We know it has an impact on health, but we don't know how much”, said Shih Young-Soo, the WHO's Western Regional Director.

Did the high levels of air pollution during 2013 kill as many people as the 1952 London smog incident?[2] Indeed, the consequences of China's severe air pollution are largely unknown. Several previous studies have examined the associations between short-term air pollution and health outcomes in China (Aunan and Pan, 2004; Chan and Yao, 2008; Chen et al., 2012a, 2012b; Guo et al., 2009, 2013, 2010; He et al., 2002; Kan et al., 2008; Tao et al., 2012; Venners et al., 2003; Wong et al., 2008, 2002). These studies generally found that higher mortality rates were associated with elevated air pollution. However, previous studies either (1) used PM_{10} measure, (2) focused on a single city, (3) analyzed less polluted episodes, or (4) studied only urban areas. Their results may lack external validity because none of them analyzed the smog events from 2013, and none of them looked at the air pollution effects in both urban and rural areas.

Our study contributes to the literature by evaluating the acute effect of the smog episodes and $PM_{2.5}$ concentrations on mortality for 7 districts/counties in 3 northern Chinese provinces, where large-scale smog episodes took place in early 2013. To the best of our knowledge, this is the first study examining the relationship between air pollution and the health of rural residents in China. To estimate the health effects of the severe air pollution events in 2013, we combined the most recent $PM_{2.5}$ data published by the Ministry of Environmental Protection (MEP) with death records data from the Chinese Center for Disease Control and Prevention (CDC), and conducted this first study on estimating the health effects of the severe air pollution in 2013. In contrast to previous studies, all of which drew data only from cities, we include two rural counties to examine if differential air pollution effects exist. To control for possible confounding factors, we compared models on the bivariate association between air pollution and mortality with those containing other meteorological variables including daily temperature, humidity, dew point, and wind speed.

[2] During the 5-day London Smog episode from December 5 to 9, 1952, the daily number of deaths registered tripled. In the weeks that followed, the medical services compiled statistics and found that the fog had killed roughly 4000 people, and another 8000 died in the weeks and months that followed (Greater London Authority, http://legacy.london.gov.uk/mayor/environment/air_quality/docs/50_years_on.pdf).

2. Data and methods

2.1. Data sources

2.1.1. Mortality data

Mortality data are drawn from the Disease Surveillance Point System (DSPS) in the Chinese CDC. The DSPS, initiated in 1978, collected all death records for the surveillance locations each year. The data collected covered 71 districts/counties in 29 provinces from 1980 to 1989 and 145 districts/counties in 31 provinces from 1990 to 2000. The DSPS was overhauled following the SARS outbreak in 2003 and has since covered 161 districts/counties. In the event of a death, the doctor or decedent's family is required to fill out a death certificate and submit it to the DSPS. The mortality data includes basic demographic characteristics of the decedent and the cause of death. The causes of death are coded in the International Classification of Diseases 10 (ICD-10). Total mortality is classified by causes of death: cardiovascular diseases (I00-99), respiratory disease (J00-99), and all other diseases. For this study, we have daily number of deaths by age group, gender, and cause of death for all the DSPS districts/counties located in Beijing, Tianjin and Hebei Province.

2.1.2. Air pollution data

$PM_{2.5}$ concentrations are published by the MEP's ground monitoring stations and collected by the research team. In December 2012, $PM_{2.5}$ was included in the Chinese National Ambient Air Quality Standard (CNAAQS, GB3095-2012). Since then, 24-h $PM_{2.5}$ concentrations from all major Chinese cities have been published by the China National Environmental Monitoring Center (CNEMC) of MEP. We collected daily 24-h $PM_{2.5}$ concentrations from all the monitoring stations located in Beijing, Tianjin and Hebei Province, then matched the monitoring sites with DSPS points based on the geodesic distance calculated from the longitude and latitude coordinates. Each DSPS point is assigned to its nearest monitoring site. If the distance between a DSPS point and its nearest air quality monitoring station was more than 30 km, we dropped it.

2.1.3. Weather data

We collected daily weather information from January 1, 2013 to December 31, 2013, for all 7 city districts and counties in the study. These data were collected from The Weather Company's internet service known as the Weather Underground[3] which is the world's largest network of weather stations (almost 10,000 stations in the United States and over 3000 across the rest of the world). As such it provides the most localized weather data currently available. We downloaded the following data for each location: daily precipitation, daily minimum, maximum and mean temperature, dew point, humidity, visibility miles and wind speed.

2.1.4. Study area

We successfully matched mortality data, air pollution data and weather data for five city districts and two rural counties in Beijing, Tianjin and Hebei Province. Dongcheng District (city center) in Beijing (DC, BJ), Tongzhou District in Beijing (outer suburb) (TZ, BJ), Hongqiao District (inner city) in Tianjin (HQ, TJ), Haigang District in Qinhuangdao (HG, QHD), and Qiaodong District in Zhangjiakou (QD, ZJK) are urban the five city districts. Ji County in Tianjin (JC, TJ) and Ci County in Handan (CC, HD) are the two urban counties. The total populations in those districts/counties are 71,3602, 922,890, 647,673, 602,006, 287,249, 1,013,006, and 641,000 respectively for the year 2013. The male to female ratio ranges from

[3] The data are available at www.weatherunderground.com.