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Effect of ambient air pollution on emergency room admissions for respiratory diseases in Beijing, China

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ABSTRACT

Ambient air pollution is considered as one of the greatest environmental risk factors to public health due to its correlation with the onset of respiratory and cardiovascular diseases. Beijing, the capital of China, is one of the most severely haze-polluted metropolis in the world; the entire city faces air pollution-related heath risks on a frequent basis. The goal of this study is to evaluate the short-term effect of ambient air pollution on emergency room (ER) admissions for respiratory disesases in Beijing, China. We used a generalized additive model to study a total of 274,627 ER admission cases for respiratory diseases from 2009 to 2012. We analyzed the correlations between three major ambient air pollutants (including PM_{10}, SO_2, and NO_2) and the ER admissions for different age and gender subgroups. The results showed that: a) the effects of PM_{10} and SO_2 are stronger in males than in females and in the elders (age ≥ 65years) than younger people; b) the effect of NO_2 is stronger in children (age ≤ 15years) than older people; c) for per 10μg/m^3 increase in ambient PM_{10}, SO_2, and NO_2 concentration, the greatest increase persentage (IP) of ER admissions was 2.8% (95% CI: 2.3–3.4%), 3.6% (95% CI: 1.4–5.8%), and 7.7% (95% CI:7.0–8.4%), respectively; d) increases in the three major ambient air pollutant concentrations affected ER admissions for respiratory diseases the most at lag 0–1 day. In particular, the elderly and females were relatively more sensitive to the three outdoor air pollutants, and were affected right away after the air pollutant concentration went up.

1. Introduction

Ambient air pollution is the greatest environmental risk to public health. In 2015, the reported ambient-air-pollution-caused death was 4.2 million in the world (about 38% were in China) (Forouzanfar et al., 2016; Landrigan, 2016). Ambient air pollution affects the morbidity and mortality of both cardiovascular and respiratory diseases (WHO, 2013; Larrieu et al., 2007; Brook et al., 2010; Shali et al., 2014; Khaniabadi et al., 2017). For example, particulate matter can cause acute asthma (Kanatani, 2010) and chronic obstructive pulmonary disease (COPD) (Qiu et al., 2013), as well as increase hospital emergency room (ER) visits for respiratory diseases (Krall et al., 2017; Ma et al., 2016). In addition, gaseous pollutants can affect hospital ER admissions (Goudarzi et al., 2016; Ghozikali et al., 2015; Reyes et al., 2014; Tao et al., 2014) and mortality (Carugno et al., 2016; Chiusolo et al., 2011; Cao et al., 2009; Zhang et al., 2011; Yu et al., 2012; Analitis et al., 2006) for respiratory diseases.

Researchers have conducted studies on the associations between ambient air pollution and respiratory diseases in Europe (Wanka et al., 2014; Chiusolo et al., 2011), the United States (Pride et al., 2015; Kim et al., 2012), and some Asian countries (Geravandi et al., 2015; Dobaradaran et al., 2016; Vodonos et al., 2014; Ueda et al., 2012). In Munich, Germany, the number of outpatient visits for respiratory diseases would go up by 3.99% and 0.82% for per 10μg/m^3 increase in NO_2 and PM_{10} concentrations (Wanka et al., 2014). In Ahvaz, Iran, the number of hospital admissions for respiratory diseases went up by 3.4% for per 10μg/m^3 increase in SO_2 concentration (Goudarzi et al., 2016). In China, researchers have conducted similar studies in the mainland, Hong Kong and Taipei, Taiwan. In the mainland of China, changes in daily NO_2 concentration were associated with that in respiratory mortality in a total of 17 large cities (Chen et al., 2012). A multi-city study in the mainland of China showed that respiratory mortality would increase by 2.52% for per 10μg/m^3 increase in two-day moving average of NO_2 concentration (Chen et al., 2012). In Shanghai, total number of outpatient visits would increase by 0.11%, 0.34%, and 0.55% for per 10μg/m^3 increase PM_{10}, SO_2, and NO_2 concentrations, respectively

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(Cao et al., 2009). In Beijing, the non-accidental mortality went up by 1.52% and 0.19% for per 10μg/m^3 increase in $PM_{2.5}$ and PM_{10} (Li et al., 2015). In Hong Kong and Taipei, Taiwan, the associations between daily air pollutant concentrations for NO_2, SO_2, PM_{10} and CO and respiratory mortality were statistically significant among the elderly (Qiu et al., 2013; Wong et al., 1999; Liang et al., 2009).

The overall goal of our work is to evaluate the effects of ambient air pollutant concentrations (including SO_2, NO_2 and PM_{10}) on hospital ER admissions for respiratory diseases from 2009 to 2012 in Beijing, China. Specially, we categorized the whole study group into five different gender and age sub-groups.

2. Data and methods

2.1. Study area and data

In this study, the research area is in Beijing (39°54′N and 116°23′E), which is in the most severely haze-polluted area in China (Rohde and Muller, 2015). Local climate is temperate, with a typical continental monsoon climate. The resident population in Beijing is very large, with a total of 21.8 million in 2015. A total of three large general top-level hospitals that are located in the metropolitan area of Beijing were chosen for this study (Fig. 1). At each of the study hospitals, daily ER admissions for respiratory diseases were documented with the code from International Classification of Diseases Revision (ICD 10: J00-J99) for the study period of 2009–2012. The patients are categorized into different age (≤15years, 15–65 years, and ≥65years) and sex (male and female) groups.

Daily mean air pollutant concentration data for PM_{10}, SO_2, and NO_2 were obtained from Beijing Municipal Environmental Monitoring Center, including for eight fixed monitoring stations that are scattered in the urban area (Fig. 1). In this study, we used the composite (i.e., agrythmic mean of the value for the eight fixed monitoring stations) air pollutant concentrations for PM_{10}, SO_2, and NO_2. Miss values for each stations are less than 1%. Daily meteorological data were provided by Beijing Meteorological Bureau, including average temperature, relative humidity, and wind speed.

2.2. Methods

A generalized additive regression model (GAM), based on Poisson distribution, was used in performing a time series analysis on hospital ER admissions for all types of respiratory diseases that are caused by ambient air pollution. Cubic smoothing functions were applied to control multi-annual and seasonal trends, as well as the weather elements (i.e., air temperature and relative humidity). Degrees of freedom (df) was selected by minimizing the absolute values of sums of partial autocorrelation function (PACF) for lags up to 30, and an annual df of 6 was used for time trend analysis. A df of 5 and 6 was used for temperature and relative humidity, respectively. The core model (Eq. (1)) included both Holiday and DOW as covariates, was fitted with the Akaike's Information Criterion (AIC) (Guo et al., 2014); and was modified for each of the age-sex groups as mentioned in Section 2.1. For a 10μg/m^3 increase in daily air pollutant concentration, daily respiratory ER admission was estimated in the form of increase percentage (IP%) and 95% Confidence Intervals (CI). Due to the inherent interactions of these three air pollutants (Table 2), we evaluated the increase percentage by adding the air pollutants one at a time. Single- and multiple-pollutant models were fitted to evaluate the effects of the three main air pollutants on ER admissions. In addition, lag effects of air pollutants (i.e., PM_{10}, SO_2, and NO_2) are performed with different lag days, including single-day lags (from lag0 to lag6) and cumulative-day lags (from lag01 to lag06). Single-day lags were air pollutant concentrations of the same day (Lag 0) and the past one to six days (Lag 1–6). Cumulative-day lags were moving-average air pollutant concentrations of the same day and the previous days; for example, lag 02 indicated air pollutant concentrations of a three-day moving-average of that day and the previous two days. All of the analysis for our work was conducted with the Mixed GAM Computation Vehicle (MGCV) package in R 3.1.3.

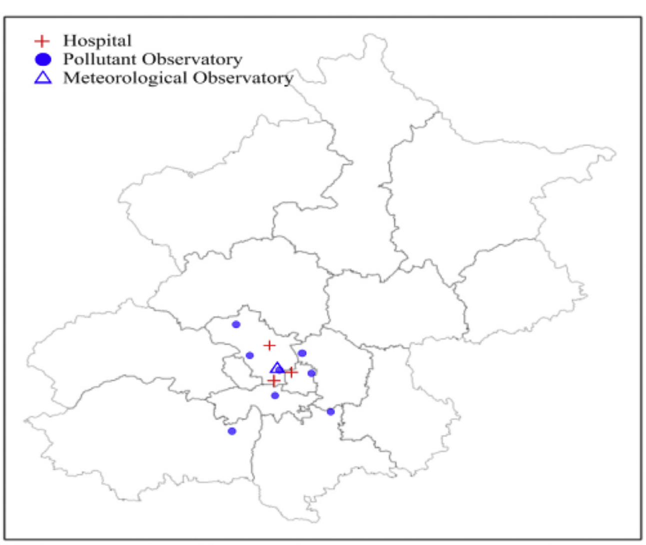

Fig. 1. Locations of the eight fixed air pollutant monitoring stations, the meteorological station, and the three hospitals in Beijing, China.

Table 1
Daily statistics (including mean, standard deviation, minimum value, 25th percentile value, median, 75th percentile value, and maximum value) of weather elements (including air temperature, relative humidity, and wind speed), air pollutant (including PM_{10}, SO_2, and NO_2) concentrations, and hospital ER admissions for respiratory diseases during the study period of 2009–2012 in Beijing, China.

Variables	Mean	SD	Minimum	P25	Median	P75	Maximum
Environmental variables							
Air temperature (°C)	13.1	11.6	−12.5	1.7	15.1	24.0	34.5
Relative humidity (%)	50.8	20.1	9	34.0	52.0	67.0	97
Wind speed(m/s)	2.2	0.92	0.5	1.6	2.1	2.7	6.4
SO_2(μg/m^3)	26.6	27.2	0	8.0	17.0	34.7	234
NO_2(μg/m^3)	57.5	25.6	11.0	38.4	52.5	71.3	242
PM_{10}(μg/m^3)	133.1	86.9	6.5	69.0	115.0	175.0	563.3
Hospital ER admissions for respiratory diseases							
All	188	67	51	146	177	218	644
Females	83	32	15	62	78	97	266
Males	105	37	35	81	99	122	378
Age≤15yrs	57	31	1	38	55	72	327
15–65 yrs	117	45	34	89	107	133	417
Age≥65 yrs	14	6	0	9	13	17	46

Table 2
Correlation coefficients between meteorology factors (i.e., air temperature (T), relative humidity (RH), and wind speed (WS)) and the three air pollutants (PM_{10}, SO_2, and NO_2) in the study.

Elements	PM_{10}	SO_2	NO_2	T (°C)	RH (%)	WS (m/s)
PM_{10}	1					
SO_2	0.355**	1				
NO_2	0.609**	0.550**	1			
T (°C)	0.130**	−0.619**	−0.220**	1		
RH (%)	0.325**	−0.167**	0.225**	0.360**	1	
WS (m/s)	−0.246**	−0.218**	−0.510**	0.012	−0.451**	1

Note: ** indicates $p < 0.01$, and this indication is also used in the remaining tables.