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The association between ambient inhalable particulate matter and the disease burden of respiratory disease: An ecological study based on ten-year time series data in Tianjin, China

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ABSTRACT

There is limited evidence available worldwide about the quantitative relationship between particulate matter with an aerodynamic diameter of less than 10 μm (PM_{10}) and years of life lost (YLL) caused by respiratory diseases (RD), especially regarding long-term time series data. We investigated the quantitative exposure-response association between PM_{10} and the disease burden of RD. We obtained the daily concentration of ambient pollutants (PM_{10}, nitrogen dioxide and sulphur dioxide), temperature and relative humidity data, as well as the death monitoring data from 2001 to 2010 in Tianjin. Then, a time series database was built after the daily YLL of RD was calculated. We applied a generalized additive model (GAM) to estimate the burden of PM_{10} on daily YLL of RD and to determine the effect (the increase of daily YLL) of every 10 μg/m^3 increase in PM_{10} on health. We found that every 10 μg/m^3 increase in PM_{10} was associated with the greatest increase in YLL of 0.84 (95% CI: 0.45, 1.23) years at a 2-day (current day and previous day, lag01) moving average PM_{10} concentration for RD. The association between PM_{10} and YLL was stronger in females and the elderly (≥65 years of age). The association between PM_{10} and YLL of RD differed according to district. These findings also provide new epidemiological evidence for respiratory disease prevention.

1. Introduction

Air pollution affects a large group of people and is not easy to protect against; thus, it has become the focus of attention in recent years, and the research of air pollution on respiratory health is increasing (Guan et al., 2016).

A large number of studies have confirmed that air pollution will adversely affect the respiratory disease health of the exposed population. The National Morbidity Mortality and Air Pollution Study (NMMAPS) in the United States found that an increase in particulate matter with an aerodynamic diameter of less than 10 μm (PM_{10}) concentration (10 μg/m^3) was associated with an increase in respiratory mortality with an RR value of 1.013 (95% CI: 1.005–1.020) (USEPA, 2004). Similarly, a study in England and Wales demonstrated that PM_{10} exposure in 2001 was associated with respiratory and cardiovascular mortality in 2002–2009 with stronger associations for respiratory disease (OR 1.22 (95% CI: 1.04–1.44)) (Hansell et al., 2016). The results of the Chinese researchers also revealed the adverse effects of PM_{10} (Fang et al., 2016; Wang et al., 2016; Zhu et al., 2016). For example, China Air Pollution and Health Effects Study (CAPES) found a 10-ug/m^3 increase in 2-day moving-average PM_{10} was associated with a 0.56% (95% CI: 0.31, 0.81) increase of respiratory mortality (Chen et al., 2012).

Previous studies concerning the effect of PM_{10} on health have usually focused on the number of deaths, and less attention was paid to the age of death and composition ratio. Therefore, some information will be lost, and premature death due to the loss of life years (Years of Life Lost, YLL) can explain this discrepancy. Most studies have assessed the relationship between air pollution and total YLL/circulation system disease YLL. Zeng et al. found that the increase in PM_{10} was

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significantly associated with daily death and YLL in Tianjin (Zeng et al., 2016). A study in Guangzhou showed that a 10 μg/m^3 increase above the corresponding threshold of 40.4 μg/m^3 PM_{10} was related to a YLL increase of 2.8 years with a lag of 0–1 days for cardiovascular diseases (Yang et al., 2016). Kowalski M et al. reported that a reduction in short-term exposure to PM_{10} by 5 μg/m^3 resulted in a lower number of yearly non-external deaths (2.6–2.75 per 100,000 inhabitants) (Kowalski et al., 2016). Until now, few scholars have used YLL to evaluate the relationship between PM_{10} and respiratory system health in China. One study in Ningbo in southern China found that an increase of 10 μg/m^3 in PM_{10} was associated with an increase of 0.74 (95% CI: 0.00–1.48) in respiratory disease YLL (He et al., 2016). However, no similar study has been conducted in northern China.

The present situation of the environment in China is not optimistic, especially in three key areas, the Beijing-Tianjin-Hebei district, Pearl River Delta and Yangtze River Delta, where air pollution was significantly more severe than the national average (Ye et al., 2016). The Beijing-Tianjin-Hebei district is located in the heart of the Bohai Sea in northeastern China. Tianjin is the largest coastal city in northern China and is the most important industrial city in the Beijing-Tianjin-Hebei district. In this study, respiratory disease YLL was selected as the health effect indicator, using the atmospheric pollution and respiratory disease death monitoring data to explore the quantitative relationship between PM_{10} and the respiratory disease burden within the population. This study provides a scientific basis for regionalized environmental management policies and public health strategies for public health interventions in regions with high air pollution levels.

2. Materials and methods

2.1. Data

We collected the air pollutant monitoring data, meteorological data and mortality data from six urban districts in Tianjin (Fig. 1), including the Hedong district, Hebei district, Hexi district, Heping district, Nankai district and Hongqiao district, from January 1st, 2001 to December 31st, 2010.

The daily air pollutant monitoring data (including PM_{10}, nitrogen dioxide (NO_2) and sulphur dioxide (SO_2)) was obtained from the Tianjin Environmental Monitoring Center. Daily meteorological data (including temperature and relative humidity) were obtained from the Tianjin Meteorological Bureau. The daily mortality data regarding respiratory death (International Classification of Diseases 10th version (ICD-10: A00-R99)) were obtained from the Death Register and Report Information System, Tianjin Center for Disease Control and Prevention. The information on gender, age, date of death, cause of death and death code were included in this system. Years of Life Lost (YLL) is an indicator for the lost life year because of premature death. We used World Health Organization (WHO) standard life table (Supplemental Table S1), for the sake of comparing with the results in other country and district. YLL for each death was calculated by matching age to the WHO standard life table (Li et al., 2016). Daily YLL were calculated by summing the YLL for all deaths on the same day.

2.2. Statistical analysis

The time series study is used for its good performance in demonstrating the exposure-response association between air pollution and health effects. generalized additive model (GAM), a combination of the generalized linear model and additive model, has become a standard method in air pollution epidemiology. This model can fit the air pollutant with some unknown confounders using parametric and nonparametric approaches. For example, we can control the non-linear confounders such as temperature by using a smooth function to estimate the risk of pollutant flexibly.

The basic GAM is

$$g(\mu) = \alpha + \sum_{j=1}^{p} f_j(Xj)$$

where μ is the expectation of Y, or $\mu = E(Y/X_1,\ldots,X_p)$.

$g(\cdot)$ is a link function, α is the intercept.
$f_j(\cdot)$ is a one-variable function of every predictive variable.

The main aim of this study was to estimate the association between the concentration of PM_{10} and YLL of RD. Based on previous literature (He et al., 2016), the identity link function was used, and the basic

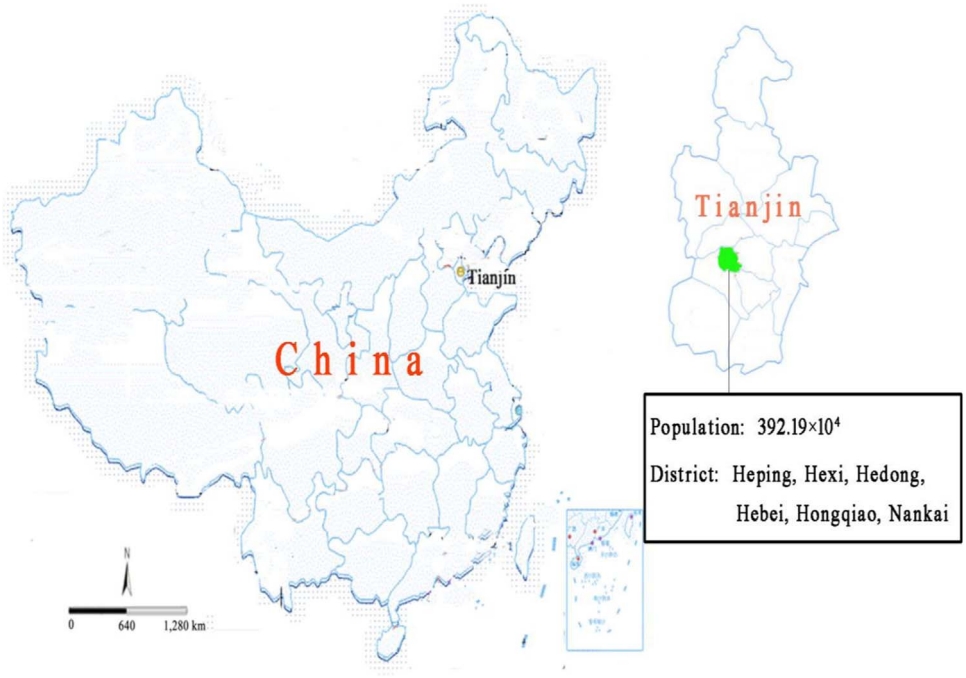

Fig. 1. Location of the target districts in Tianjin, China, 2001–2010.