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Season, sex and age as modifiers in the association of psychosis morbidity with air pollutants: A rising problem in a Chinese metropolis

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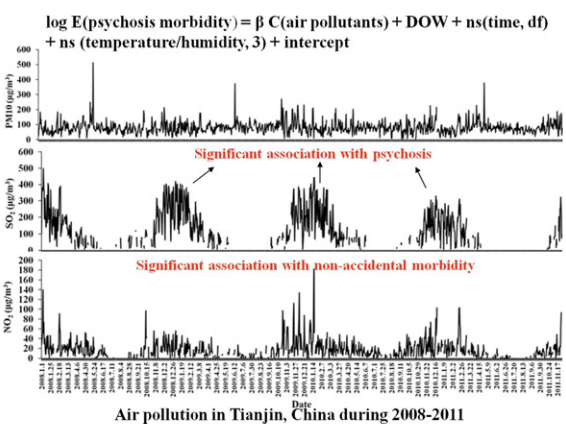
GRAPHICAL ABSTRACT



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ABSTRACT

Until now, epidemiological studies on the association between psychosis morbidity and air pollutants are scarce, especially in a developing country. Thus, a time-series analysis on the short-term association between the daily disease (psychosis and non-accidental) morbidity and air pollutants including particulate matter (PM) with diameters of 10 μm or less (PM_{10}), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) was firstly conducted. The association between daily psychosis morbidity stratified by sex and age, and outdoor air pollutants in Tianjin as an important metropolis in China was examined. The psychosis effect from air pollutants in the warm season (April–September) and the cool season (October–March) was also analyzed, respectively. An increase of 10 μg/m^3 in a 2-day average concentration of PM_{10}, SO_2, and NO_2 corresponded to an increase in all non-accidental morbidity of 0.15%, 0.49%, and 0.57%, respectively. The association between non-accidental morbidity and SO_2 in the cool season was significantly different from that in the warm season. These findings might have implications and references for local governments to make policies for air pollution control and management, and public health prevention.

Abbreviations: CI, confidential interval; df, degrees of freedom; DOW, day of week; ICD, international classification of diseases; NO_2, nitrogen dioxide, ns, natural splines; PACF, partial autocorrelation function; PM_{10}, particulate matter with diameters of 10 μm or less; SO_2, sulfur dioxide; WHO, World Health Organization; CDC, Centers for Disease Control.

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1. Introduction

Along with rapid economic development in China and other developing countries, air pollution is becoming severe and has brought decisive influences on human health (Chen and Liao, 2006; Zhang et al., 2007). For instance, particular matter (PM), SO_2 and NO_2 have harmful effects on the respiratory system and penetrated into lungs, then into the blood circulation system, resulting in cardiovascular and other diseases (Tong et al., 2014a, 2015; Zhou and Luo, 2001).

Besides harmful physiological effects and adverse health effects, air pollution also results in poor visibility, triggering depression, and severe psychological pressures. Air pollutants, especially PM, may greatly increase the risk of suicide attempt (Szyszkowicz et al., 2010) or suicide (Kim et al., 2010). Depressive symptoms might be associated with inflammatory processes induced by air pollutants (Block and Calderón-Garcidueñas, 2009; Raison et al., 2006), which cause vascular depression via damaging endothelial vasculature in the brain (Steffens et al., 2003). Besides, there is a growing link between mental diseases (Alzheimer' disease, Parkinson disease, etc.) and metals (Al, Mn, etc.) (Percy et al., 2011). Metals and hydrocarbons derived from air pollutants are associated with neurological diseases (Block and Calderón-Garcidueñas, 2009; Levesque et al., 2011).

Epidemiological studies have suggested a relationship between ambient air pollutants and mental disorders such as depression and suicides. These studies reported a short-term effect of PM_{10}, SO_2 and NO_2 through emergency department visits for depressive disorder (Szyszkowicz et al., 2009) and a long-term effect on depressive symptoms in the elderly (Lim et al., 2012). However, there is still insufficient epidemiological evidence to confirm the association between mental disorders and air pollutants, especially in developing countries. Understanding the concentration-response curves of principal air pollutants in the environment and their shapes are critical to public health policy making and air quality standards setting (Zhou et al., 2004; Zhou and Luo, 2001). It is of importance to investigate the effect of air pollutants on mental health of human beings and this is the aim of this study.

Tianjin is a typical metropolis in northern China, and one of the biggest industrial and commercial coastal cities in China, with a total population of over 10 million and an area of 11,919.7 km^2. In Tianjin, there are four distinctive seasons, and typical eastern Asia monsoon climates with cold, windy and very dry winters, and hot, humid and rainy summers. This important city consumes the majority of energy derived from coal combustion and is classified as one of the most polluted regions in the world, in particular, PM, SO_2 and NO_2 are considered to be the principal pollutants. Along with rapid economic growth, air pollution in the city is becoming more and more serious, and endangering human health and ecological safety (Hu and Zhou, 2013).

2. Materials and methods

2.1. Air pollution and relevant data

Daily air pollution data including PM_{10}, SO_2 and NO_2 were obtained from the database of the Tianjin Environmental Monitoring Center, the government agency in charge of collecting air pollutant data in Tianjin. The daily concentration for each pollutant was averaged on the basis of available monitoring results of 15 fixed site stations around the city and could reflect background levels of urban air pollution rather than pollution from local sources. These stations are mandated to be located in the places away from pollution sources such as roads, factories, and shopping centers. To allow the adjustment for effects of weather conditions on morbidity in the fitting model, daily mean temperature and humidity data were also collected from the China Meteorological Data Sharing Service System.

Daily non-accidental morbidity data from 1 January 2008 to 31 November 2011 were bought from the Centers for Disease Control (CDC) and the Prevention of Urban Districts in Tianjin. Information of patients including those under the age of 18 was anonymized. Data were validated each year by the China CDC and were coded according to the International Classification of Diseases (Revision 10, WHO, 1993) (ICD-10) and classified in line with all non-accidental causes (ICD-10 codes A00-R99) and psychosis diseases including schizophrenia, bipolar disorder, brain organic mental disorders, mania, depression and others (ICD-10 codes F00–F99). The ethical committee of the coordinating center of five urban CDCs in Tianjin approved the study (Full name of the committee is "the CDC biomedical ethics council"). Data information includes daily morbidity, individual characteristics (sex and age), and family address. The dates recorded in the system were hospital admission dates of the patients.

Besides seasonal analyses, data were also classified by sex and age (0–4, 5–44, 45–64, and ≥65 years) to examine the effect of individual features on the associations (Kan et al., 2008). Moreover, the association between depression and air pollutants was also examined.

2.2. Statistical analyses

Daily counts of morbidity approximate a Poisson distribution, and the relationship between morbidity and explanatory variables is mostly nonlinear. Thus, the time-series analysis was utilized to explore modification effects of season, age and sex on the association between air pollutants and morbidity in Tianjin from 2008 to 2011. All analyses were conducted with statistical software package SAS version 9.1. In details, a generalized linear model with natural spline (ns) functions of time and weather conditions accommodating nonlinear and non-monotonic relationships of morbidity with time and weather variables, and offering a flexible modeling tool (Kan et al., 2008) was used. In the basic model, various morbidity outcomes were included without air pollution variables. Residuals of the basic models were examined to determine whether there were discernible patterns and autocorrelation by means of residual plots and partial autocorrelation functions (PACF) plots. Day of the week (DOW) was considered as a dummy variable in the basic models. After the establishment of the basic model, PM_{10} and covariates (temperature, humidity, and SO_2 and NO_2 concentrations) were introduced and their effects on morbidity outcomes were analyzed. The selection of df (degrees of freedom) for time trends was done with the PACF (Kan et al., 2008; Klea et al., 2001). The 4 df per year for time trends was used for both non-accidental and psychosis morbidity; 3 and 4 lag-day auto-regression terms were used for non-accidental and psychosis morbidity, respectively. In addition, the 3 df (during whole period of study) for temperature and humidity was used. And if necessary, both over-dispersion and autocorrelation were further adjusted for using statistical procedures. This modeling procedure was carried out for each series study and the core models were assessed with plots of model residuals and fitted values as well as plots of the estimated partial autocorrelation functions.

The estimated pollution log-relative rate β is obtained through fitting of the following log-linear generalized linear model:

$$\log E(Yt) = \beta Zt + DOW + ns(time,\ df) + ns(temperature/humidity,\ 3) + intercept \quad (1)$$

where E(Yt) and β represent the expected number of morbidity at day t and the log-relative rate of morbidity associated with a unit increase of air pollutants, respectively; Zt indicates pollutant concentrations at day t; DOW is dummy variable for day of the week; ns (time, df) is the ns function of calendar time with 4 df to adjust for seasonality and other time-varying influences on admissions (e.g. influenza epidemics and longer-term trends); and ns (temperature/humidity, 3) is the ns function for temperature and humidity with 3 df.

Both all non-accidental and psychosis morbidities were assessed. The data were stratified by sex and age, respectively. The association was analyzed separately for the warm season (April–September) and the cool season (October–March) as well as the entire year (Kan et al., 2008). The basic models for seasonal analyses were different from