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The effects of Sulphur dioxide on acute mortality and years of life lost are modified by temperature in Chengdu, China

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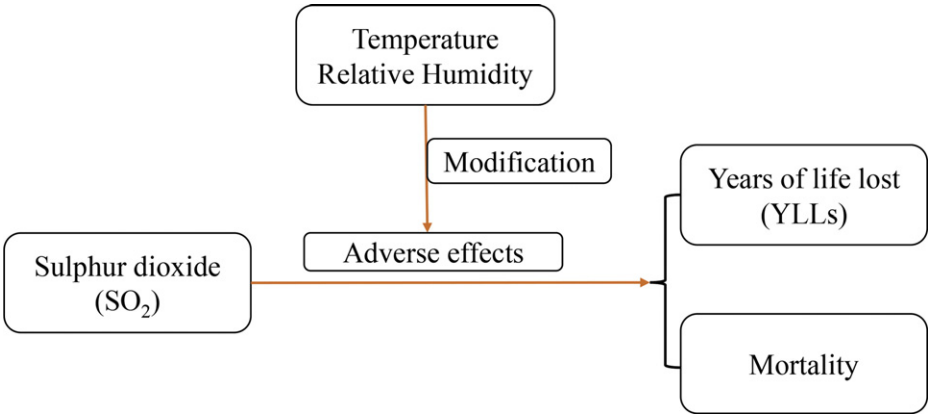
HIGHLIGHTS

- The effects of (SO_2) on mortality and YLLs depended on temperature at various lags, but did not depend on relative humidity.
- SO_2 exhibited larger adverse effects on mortality in high T level (22.8~29.4°C) days than in low T level (-0.3~ 9.3°C) days.
- SO_2 showed greater adverse effects on YLLs in low T days than in high T days.
- Policy makers should enhance the emission control of SO_2 in extreme T days in Chengdu, China.

GRAPHICAL ABSTRACT



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ABSTRACT

The effect modification of meteorological factors on the association between ambient Sulphur dioxide (SO_2) and mortality is critical for designing intervention policy. Existing studies did not result in consistent conclusions on the effect modification, and Years of life lost (YLLs) was rarely used as a health impact indicator to examine the modifying effect. This study aims to estimate the mean air temperature and relative humidity modification effects on the impact of SO_2 on daily mortality and YLLs in Chengdu, China. Mortality, YLLs, air pollution and meteorological data were collected for 2011–2014. Three analytical approaches based on generalized additive models (GAMs) were used, including bivariate response surface model, product term model, and stratification model. We found that the effects of SO_2 on mortality and YLLs depended on temperature at various lags, but did not depend on relative humidity. SO_2 exhibited larger adverse effects on mortality in high temperature level (22.8–29.4 °C) days than in low temperature level (−0.3–9.3 °C) days, with a 10 μg/m^3 increment in SO_2, non-accidental death increased by 0.8% (0.001, 0.015)at low temperature level, but increased by 1.4% (0.005, 0.024) at high temperature level. On the contrary, SO_2 showed greater adverse effects on YLLs in low temperature days than in high temperature days, with a 10 μg/m^3 increment in SO_2, non-accidental YLL increased by 40.580

Abbreviations: PM, particulate matter; PM_{10}, particulate matter with <10 μg/m^3 in aerodynamic diameter; NO_2, nitrogen dioxide; O_3, ozone; SO_2, sulphur dioxide; YLLs, years of life lost.

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(31.478, 49.682) at high temperature level, but increased by −2.703 (−14.668, 9.261) at low temperature level. We concluded that the effect of SO_2 on mortality and YLLs may depend on temperature in Chengdu, China. Our results highlight the importance of considering the interaction between SO_2 and temperature on health outcomes in future research. Also, policy makers should enhance the emission control of SO_2 in extreme temperature days in Chengdu.

1. Introduction

Independent adverse effects of air pollution and meteorological factors on human health have been established in a series of major epidemiological and observational studies all around the world (Chen et al., 2013; Lee et al., 2014; Ma et al., 2014a; Zanobetti and Schwartz, 2009). Recently, a great deal of research concerns interaction effects of meteorological factors and ambient air pollution on related population health outcomes (Li et al., 2015a; Li et al., 2015b; Lu et al., 2015; Pinheiro et al., 2014; Sun et al., 2015; Tong et al., 2014; Wilson et al., 2014). However, these studies mainly focus on particular matter (PM) and O_3, while few of them studied the effect of SO_2, and their major effect modifier is the season variable. Moreover, studies focusing on SO_2 usually present inconsistent conclusions and therefore, the exact role of SO_2 on mortality is still controversial (Analitis et al., 2014; Cheng and Kan, 2012; Lu et al., 2015; Park et al., 2011). Lu Feng (Lu et al., 2015) reported that the association between SO_2 and mortality was more pronounced in the warm season compared to that in the cool season, whereas Cheng (Cheng and Kan, 2012) found there was no significant interaction between SO_2 and temperature levels on mortality. On the other hand, as for health outcomes, most studies focused on the mortality, while few of them studied the adverse effect of SO_2 on YLLs. However, compared to the mortality, the YLLs considers the life expectancy at death and gives different weights to the death at different ages, which supply a complementary indicator to the excess deaths (Guo et al., 2013; Lu et al., 2015; Röösli et al., 2005). If these two health indicators were studied together, the conclusion would be more comprehensive and accurate. The effect modification of meteorological factors on the association between ambient SO_2 and mortality is critical for designing intervention policy. The purpose of this work is to estimate the air temperature and relative humidity modification effects on the impact of SO_2 on daily mortality and YLLs in Chengdu, China. The analysis can result in a better understanding for the modification effect of temperature and relative humidity on SO_2 to daily mortality and YLLs. Policy makers may greatly benefit from a clear and comprehensive understanding of the effect modification mechanisms, thereby proposing suitable intervention policies for different climatic conditions.

2. Material and methods

2.1. Study population and period

Chengdu is located in the southwest of China, which is the capital city of Sichuan province as well as one of the largest cities in Western China. It holds a total area of 12,121 km^2 and has a population of about 11.9 million currently. Besides, Chengdu has a distinctive ambient air pollution pattern which is easy to form while hard to disperse because of the typical geographic basin feature. According to the Chinese Statistical Yearbook in 2013 (China NBoSo, 2014), there were only 126 days in which the air quality in Chengdu reached the national environmental standard of 50 μg/m^3 (24 h average) for SO_2, and the number is less than those in most megacities in China, such as Beijing (170 days), Tianjin (148 days), Shanghai (249 days), and Guangzhou (260 days). However, studies focusing on the health impact of air pollution, including SO_2, are limited in Chengdu. There is a subtropical climate with hot summer and mild winter in Chengdu and it has a relatively calming wind speed with 1.07 m/s averagely. Thus, it is important to conduct relevant research and estimate the effect of meteorological factors and SO_2 on mortality and YLLs in Chengdu.

The study population comprised all residents in Chengdu. The study region consists of 10 districts, 4 county-level cities and 5 counties. In this study, we collected the data from January 1, 2011 to December 31, 2014.

2.2. Data

2.2.1. Mortality data

The death surveillance stations from Sichuan Center for Disease Control and Prevention distribute in all the 19 districts. Data on daily mortality for Chengdu were obtained from Sichuan Center for Disease Control and Prevention. Causes of death were coded according to the International Classification of Diseases, the tenth version (ICD 10). Daily counts of the total non-accidental deaths (ICD 10: A00-R99), the respiratory disease deaths (ICD 10: J00-J99) and the cardiovascular disease deaths (ICD 10: I00-I99) were calculated.

2.2.2. YLLs data

The data of population and mortality by sex and age were extracted from Tabulation on the 2010 Population Census of Sichuan Province (province Tcoos, 2012). Then, the life expectancy was calculated by abridged life table approach depending on the age-specific deaths and demographic data of Chengdu in 2010. Using the formula of World Health Organization (Murray, 1994), we calculated YLLs for each death by matching age and sex to the life tables and incorporated the discounting rate and age weight (Foxrushby and Hanson, 2001; Prüss-üstün et al., 2003). Discounting rate suggested that future gains and losses were counted less than if they had occurred today. The age weighting indicating YLLs due to premature death could give different weighting at different ages, which was a tradeoff of social roles and social value. Then we got the daily YLLs stratified by causes of death.

2.2.3. Air pollutant and meteorological data

There are totally 12 environmental monitoring stations supervised by Sichuan Environmental Monitoring Center, with most located in the urban areas (see Fig. 1) and the reported data from these monitoring stations can present the general exposure levels of population living in urban areas. The daily air pollutant data were obtained from Sichuan Environmental Monitoring Center, and the daily average concentrations of SO_2, PM_{10} and NO_2 were extracted. The daily average concentrations were obtained by averaging the daily mean values for the 12 monitoring station (Fig. 1), and it is believed that they are sufficient to reflect the general exposure levels of Chengdu. The selected monitoring stations must meet the following criteria: (1) it should not be located in the direct vicinity of traffic or industrial districts; (2) it should be far away from local pollution sources, and avoid buildings or housings and large emitters such as oil-burning boilers, furnaces, and incinerators. Besides, there are two meteorological monitoring stations in the suburban areas, and the two stations belong to China Meteorological Data Sharing Service System. We obtained the daily average temperature and relative humidity data by averaging the data of the two stations. In addition, there were no missing data for the two stations.