

Disease Burden Attributable to PM_{2.5} Exposure in China from 2000 to 2016

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Abstract: Long-term exposure to ambient fine particulate matter (PM_{2.5}) has slowly increased both the morbidity and mortality among Chinese people; becoming a leading problem for public health efforts. In this study, the exposure-response function was used to derive the spatial-temporal dynamics of disease burden attributable to PM_{2.5} pollution in China. It was found that the economic loss attributable to PM_{2.5} increased by 93% from 35 billion Chinese yuan to 536 billion Chinese yuan within the period of 16 years. Digging further, a substantiate level of regional differences was discovered with the disease burden being the most severe in East China and the least severe in Northwest China. This article can provide more insights for future air pollution control in China.

Keywords: Health effects; PM_{2.5}; Exposure-response; China

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1. Introduction

Long-term exposure to ambient fine particle air pollution (PM_{2.5}) has caused 4.2 million deaths globally and 103.1 million lost years of healthy life in 2015; ranking the fifth as a global risk factor [1-3]. As a representative of high-concentration PM_{2.5} pollution [4,5], cities in China have far more cases of diseases due to PM_{2.5} than those in other countries. In order to effectively improve the problem of PM_{2.5} pollution, and to protect more urban residents from being harmed by PM_{2.5} pollution, the Chinese government has formulated a series of corresponding policies and measures. The exposure-response model has been widely adopted among scholars [6-11] yet higher levels of exposure-response coefficient should be used in areas exposed to high concentrations of PM_{2.5}. China, with a relatively high-level pollution, had also studied the burden of disease caused by air pollution [12-15]. The exposure-response coefficients were obtained from the epidemiological studies in China. Combined with the exposure-response coefficient and the data of PM_{2.5} in the cities of China from 2000 to 2016, exposure-response function was used to estimate the amount of disease burden attributed to PM_{2.5} during those years; thus, quantifying the health effects of PM_{2.5} pollution on the Chinese cities and the corresponding economic losses. Furthermore, based on the geographical area of each city, this study divided the cities of China into seven regions. There were some regional differences in the losses caused by PM_{2.5} pollution [16,17]. Through spatial-temporal dynamic assessment of the disease burden attributed to PM_{2.5} in the cities of China from 2000 to 2016, a basis for the design and improvement of policies can be provided to control the pollution in China.

2. Methodology and data

2.1. Data

The PM_{2.5} concentration data were obtained from the National Aeronautics and Space Administration's

(NASA's) medium resolution imaging spectrometer (MODIS), multi-angle imaging spectrometer (MISR), and sea-viewing wide field-of-view sensor (SeaWiFS) global annual PM_{2.5} raster data aerosol optical depth (AOD).

This article comprehensively selected the exposure-response coefficients obtained from the comprehensive analysis of the epidemiological cohort in China [5,14]. The base incidence rate of different health endpoints in the cities came from the statistical yearbooks of various cities and China Health Statistical Yearbook.

For the economic loss caused by premature death, this study used the willingness to pay (WTP) method to evaluate [18,19]. The value of statistical life (VSL) was used to express the willingness of individuals to pay. In this article, the benefit conversion method was used to adjust different VSL values caused by city differences. This article selected deaths by respiratory diseases and cardiovascular diseases as the research subject for the endpoint of deaths [20,21].

The per capita hospitalization cost, per capita outpatient cost, and average hospitalization days were obtained from China Health Statistics Yearbook, and the average hospitalization day was taken as the time of lost work. Referring to the unit economic value of asthma and acute bronchitis in 2009 at Beijing, after income adjustment, the unit economic loss of the disease endpoints in various cities was obtained [14]. There was a risk trade-off between inflammation and premature death. The unit economic loss of chronic bronchitis was 32% of VSL [22,23].

The population and per capita of gross domestic product (GDP) data were derived from China City Statistical Yearbook, and the per capita disposable income data came from the statistical yearbooks of each city.

2.2. Methodology

The basic model sets the health risk of the population of the actual concentration of PM_{2.5} for a selected health terminal as:

$$I = \exp(\beta \times (C - C_0)) \times I_0$$

Where C is the actual PM_{2.5} concentration, C_0 is the threshold level of PM_{2.5} (10 ug/m³), I is the health risk of the population at PM_{2.5} at C concentration, I_0 is the health risk of the population at C_0 concentration, and β is the corresponding exposure-reaction coefficient.

The change in health risk attributable to PM_{2.5} contamination is:

$$\Delta I = I - I_0 = I(1 - 1/\exp(\beta \times (C - C_0)))$$

Thus, the health effects from PM_{2.5} are calculated as:

$$E = P \times \Delta I = P \times I(1 - 1/\exp(\beta \times (C - C_0)))$$

Where P is the number of exposed people.

$$VSL_n = VSL_{BJ} \times \left(\frac{I_n}{I_{BJ}} \right)^e$$

Where VSL_n and VSL_{BJ} are VSL values for city n and Beijing, respectively whereas I_n and I_{BJ} are per capita disposable income of city n and Beijing, respectively, and e is income elasticity (generally, $e = 1$).

The basic formula for the cost of illness (COI) is defined as:

$$C_i = (C_{pi} + GDP_p \times T_{Li}) \times E_i$$

Where C_i is the total cost of additional health expenditure for $PM_{2.5}$ to health endpoint i , C_{pi} is the unit economic loss of health endpoint i , GDP_p is the daily average of GDP per city, T_{Li} is the number of days of missed work due to health endpoint i , and E_i is calculated as a health effect related to $PM_{2.5}$.

3. Results

The health effects (and 95% CI) of $PM_{2.5}$ exposure in the cities from 2000 to 2016 have been estimated. It has been discovered that the proportion of premature deaths increased gradually from 2000 to 2010 (0.004% to 0.008%) while it decreased in 2015, and then climbed a little in 2016. Meanwhile, the proportion of disease kept increasing from 2000 to 2016 (0.49% to 1.45%). 210 cities were divided into 7 groups based on the seven geographical regions of China's eight administrative regions. **Figure 1** shows the proportion of premature deaths caused by $PM_{2.5}$ as a percentage of the population density. It was discovered that the regions with higher proportions in 2000 and 2010 were in the north and midlands. However, the regions with higher proportions in 2015 and 2016 were in the north and east. Death from $PM_{2.5}$ in the east, north, south, and northwest were increasing gradually each year. This article illustrated the number of disease losses due to $PM_{2.5}$ in each region. The proportion of diseases in each region to the regional population density is illustrated in **Figure 2**. It can be noted that the regions with a large proportion of diseases from 2000 to 2010 were the east, midlands, and north. Kruskal-Wallis test was used to compare the health effects of $PM_{2.5}$ in seven regions, and it is that there were significant differences in the health effects of the seven regions at 1% level.

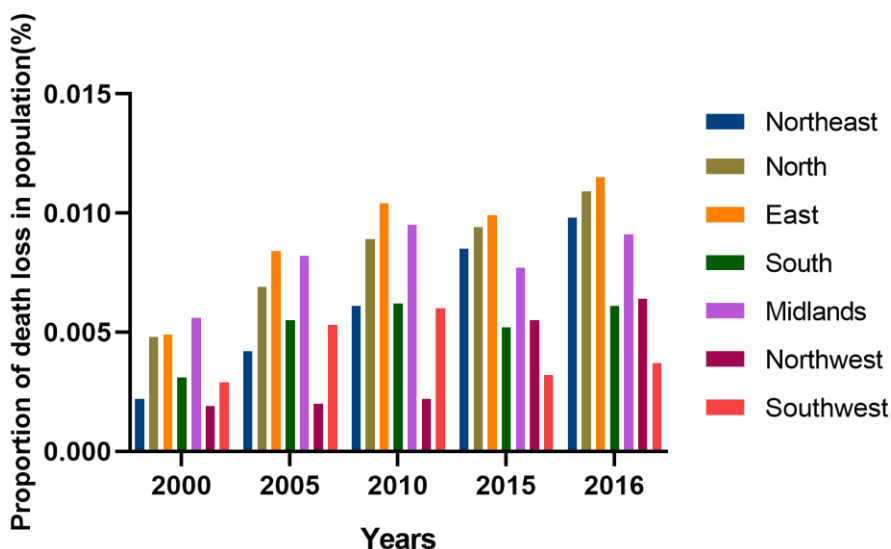


Figure 1. Proportion of premature deaths attributed to $PM_{2.5}$ exposure in different regions

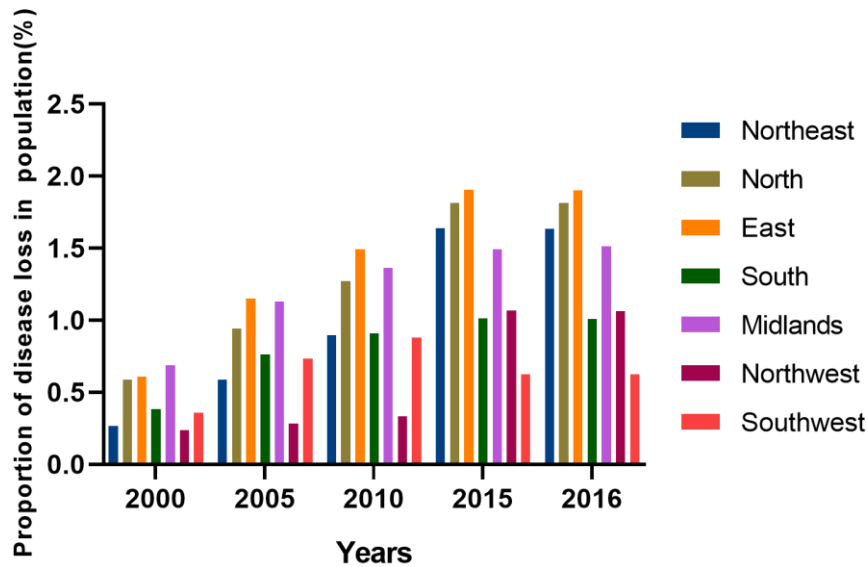


Figure 2. Proportion of diseases attributed to PM_{2.5} exposure in different regions

The economic losses as a share of GDP increased in 2005 (1.62%) from 2000 (0.87%). It declined in 2010-2015 (1.27%), and slightly increased in 2016 (1.33%). The spatial distribution of the economic losses caused by PM_{2.5} pollution in 210 cities in China from 2000 to 2016 is illustrated in **Figure 3**. It can be appreciated that the economic losses of most cities gradually increased over the years. The economic losses related to PM_{2.5} pollution were listed from 2000 to 2016 for the seven regions, and Kruskal-Wallis test was conducted on health-related economic losses due to PM_{2.5} in the seven regions where there were significant differences in the health-related economic losses at 1% level.

4. Discussion

This study provided a quantitative assessment on the burden of disease attributed to PM_{2.5} exposure across cities in China from 2000 to 2016 using the exposure-response model to provide a more comprehensive estimate of the disease burden. From 2000 to 2016, the disease burden attributed to PM_{2.5} in these cities had dynamic changes in the spatial-temporal level. The economic losses from the health effects of PM_{2.5} increased from 35.7 billion yuan in 2000 to 538 billion yuan in 2016 in which the city with the highest disease burden changed from Tianjin in 2000 to Shanghai in 2016. China's disease burden due to PM_{2.5} has improved during recent years ^[21-24]. The realization of the policy requires a medium to long-term process. China needs to formulate a more systematic control strategy, and to establish a comprehensive prevention and control system for PM_{2.5} pollution. It is noted that the health effects and economic losses caused by PM_{2.5} in the north were higher than those in the south ^[16,17,25,26]. In order to alleviate the serious air pollution problem in the north, it is necessary not only to effectively control the burning of coals but also to use clean energy to replace them. Clean domestic heating fuel has now become part of China's northern policy, which is gradually being implemented throughout the country for heating and solid fuel cooking ^[13]. There is still a need to establish and improve a more rationalized and differentiated air pollution policy in conjunction with the current regional air pollution control mechanism.

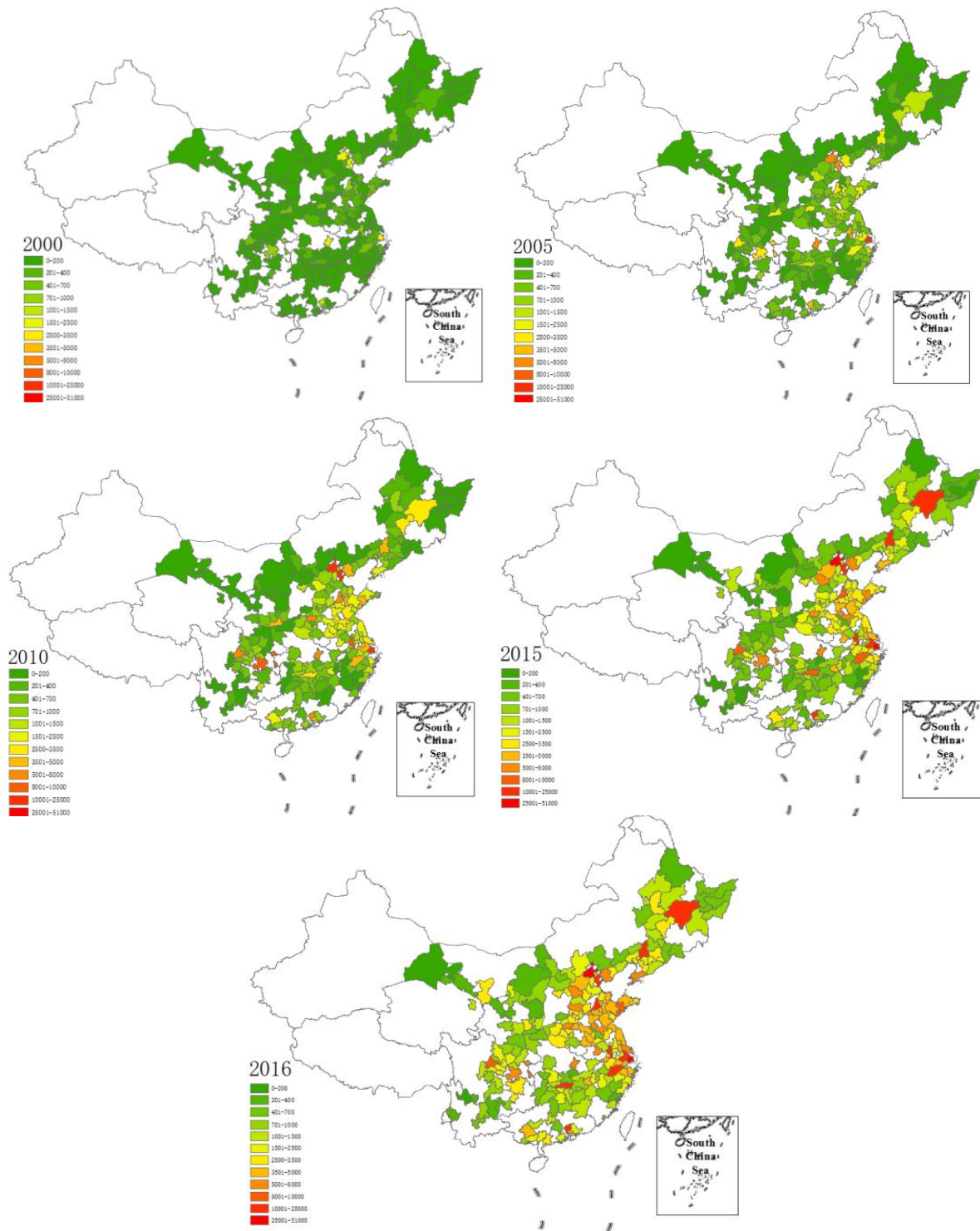


Figure 3. Spatial distribution of health-related economic losses (¥) attributed to PM_{2.5} exposure

Disclosure statement

The author declares that there is no conflict of interest.

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