A health-based economic assessment of $PM_{2.5}$ pollution in Chinese major cities

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ABSTRACT: $PM_{2.5}$ particulate pollution is becoming an important risk factor for the health of urban residents in China. In order to quantitatively evaluate the health effects and economic losses of atmospheric particulate matter pollution on residents，this study uses exposure-response relationship based on the epidemiological studies to estimate the death and incidence caused by $PM_{2.5}$ in 2013; on this basis, combined with the economic value of unit health effect, the corresponding economic losses are calculated. The results show that China's current $PM_{2.5}$ particulate pollution has caused obvious harm and economic loss to the residents' health.

THE RECENT $PM_{2.5}$ POLLUTION IN CHINA

Greenpeace organization released the annual average $PM_{2.5}$ concentration of Chinese 74 cities in 2013. In the 74 cities, nearly 92% of the cities could not reach the national standard, where the annual average $PM_{2.5}$ concentration of 32 cities was more than 2 times of the national standard, while the top 10 cities was nearly 3 times of the standard. In the top 10 cities of annual average $PM_{2.5}$ concentration in 2013, seven are located in Hebei Province. Among them, the annual average $PM_{2.5}$ concentration of Xingtai and Shijiazhuang was as high as 155.2μg/m^3 and 148.5μg/m^3, more than four times of the national standard. The air pollution in the Yangtze River Delta region has become increasingly serious.10 cities had an average annual concentration of more than twice the national standard in Jiangsu province; most cities was nearly twice of the national standard in Zhejiang province; the annual concentration of Shanghai was 60.7μg/m^3. In December 2013, the maximum daily average concentration of Shanghai, Nanjing and Hangzhou, respectively reached 421,312and 361μg/m^3, 4-5 times of the national daily $PM_{2.5}$ standard. The central and western provinces also had serious air pollution problem. The annual average $PM_{2.5}$ concentration OF Xi'an, Zhengzhou, Wuhan, Chengdu, Urumqi, Hefei, Taiyuan and other cities exceeded twice of the national standard. The $PM_{2.5}$ concentration of 190 cities in China was published in 2014,and the annual average concentration was 60.8μg/m^3. Among them, only 18 cities meet the national secondary standard, 90% cities exceeded the standard while a quarter of the city's $PM_{2.5}$ concentration even reached more than twice of the standard. In the worst 10 cities, seven are located in Hebei Province, and Beijing and Tianjin is still the country's most serious air pollution regional. In addition, the annual average $PM_{2.5}$ concentration of some cities in Shandong, Henan, Hubei, Anhui, Shaanxi, Jiangsu and other provinces are also very high, even more than twice of the national standard.

DATA AND METHODS

Exposure population and exposure levels

In this study, of the city's resident population is exposed as exposure populations of $PM_{2.5}$ pollution, and exposure levels are based on the data released by the Greenpeace Organization.

Health endpoints and exposure- response relationship

Taking the difficulty of obtaining the population baseline incidence data and the unit value of every health endpoint into account, this study evaluates the following health endpoints: the hospitalizations of the cardiovascular and respiratory disease, the cute bronchitis and asthma， the pediatric and medical clinic. What's more，the selection of dose-response relationship coefficient β is according to the epidemiological data in China, taking into account the sensitivity of different races and ethnic to the atmospheric particle pollution and the differences between domestic and international air pollution. Only when the corresponding information on domestic health endpoints is absent, similar foreign study data would be chosen. For a particular health effect endpoint, if more studies exsit, this study will conduct a comprehensive Meta analysis to get its mean and 95% confidence limits.

The population baseline incidence of health endpoints

Since each city's health baseline data is difficult to obtain, this study uses a unified national urban average incidence of every health endpoint. According to China Health Statistics Yearbook 2013 and the 3rd, 4th national health service survey，Chinese urban residents' baseline incidence of each health endpoint in 2013 can be directly found out or calculated.

Table 1 Exposure-response coefficients, population baseline incidence rates and unit values for various health endpoints

Health endpoints	$PM_{2.5}$ dose-response relationship coefficient β（95%CI）($\times10^{-3}$)
cardiovascular disease hospitalization	1.09（0,2.21）
respiratory disease hospitalization	0.68（0.43,0.93）
pediatric clinic	0.56（0.20,0.90）
medical clinic	0.49（0.27,0.70）
cute bronchitis	7.86（2.70,1.30）
asthma	2.10（1.45,2.74）
population baseline incidence rates ($\times10^{-3}$)	unit value (10^4yuan)
6.36	0.67
14.28	1.04
580	0.0256
142	
37.2	0.11
9.4	0.0822

The health loss of PM2.5 air pollution

Epidemiological studies of air pollution are usually based on the Poisson model. In this study, the following formula are used to calculate the effects value of human health:

$$E=Exp[\beta*(C-C_0)]*E_0$$

In the above formula, β is the dose-response relationship coefficient between the $PM_{2.5}$ concentration and health endpoints. C and C_0 are the actual $PM_{2.5}$ concentration and the threshold concentration value which does not produce health effects; E and E_0 corresponding population health effects of concentration. E is the baseline value of a particular healthy endpoint, equal to the product of the exposed population number and the baseline incidence of this healthy endpoint. Visibly, the health effects of fine particulate matter $PM_{2.5}$ is the difference between E and E_0, consistent with the method adopted by the World Health Organization. After β, E, C, C_0 known, E_0 can be calculated, and then the difference between E and E_0 is obtained.

Unit value of every health endpoint

For the outpatient and inpatient, no relevant domestic and international WTP were reported. As an alternative, we use the cost method illness (COI). The total cost of the disease includes the direct medical costs and indirect social costs. According to the National Health Service Chief Investigator and World Bank calculation methods， Chinese urban residents’ cost of medical clinic， cardiovascular and respiratory disease hospitalizations in 2013 are estimated.

Economic costs of healthy loss

The population attributable financial loss of every healthy endpoint is the unit value multiplied by ΔE. The sum of every healthy endpoint’ economic loss is the total crowd economic losses caused by $PM_{2.5}$ pollution in the atmosphere. To quantitatively describe the uncertainties in calculation process， 95% CI is also calculated in addition to the average of the total loss.

RESULTS AND DISCUSSION

Health effects of PM2.5 air pollution

Table 2 lists the total occurrence number of each health endpoint the in 74 cities. It is seen from the data that the $PM_{2.5}$ air pollution is a greater threat to the health of Chinese urban residents.

Table2 Attributable number of cases and associated economic loss (mean and 95%CI) due to particulate air pollution in 74 Chinese cities in 2013

healthy endpoint		attributable number of healthy endpoint($\times10^4$)
hospital ization	cardiovascular disease	213041(0,431945)
	respiratory disease	298412(188702,408123)
	cute bronchitis	8985554(3086641, 14861603)
	asthma	606634(418866, 791513)
clinic	pediatric	9981490(3564818,16041681)
	medical	2138276(1178234,3054680)
economic loss (mean and 95%CI, $\times10^8$yuan)		proportion of the total losses (%)
14.27(0,28.94)		7.92
31.04(19.63,42.44)		17.23
98.84(33.95,163.48)		54.86
4.99(3.44,6.51)		2.77
25.55(9.13,41.07)		14.18
5.47(3.02,7.82)		3.04

Economic evaluation of PM2.5 air pollution health

Table 3 lists the TOP 10 economic loss (mean and 95%CI)due to the $PM_{2.5}$ air pollution in 74 Chinese cities. It is seen that, the higher of $PM_{2.5}$ concentration, the more of the urban population, the healthy economy loss is greater.

Table3 The TOP 10 economic loss (mean and 95%CI) in 74 Chinese cities

City	$PM_{2.5}$concentration($\mu g/m^3$),Population ($\times10^4$)	Economic loss（$\times10^8$yuan）
Beijing	90.1,2115	9.31(3.57,11.21)
Chongqing	63.9,2970	8.51(3.27,13.72)
Shijiazhuang	148.5,1050	8.22(3.15,13.24)
Baoding	127.9,1142	7.56(2.90,12.17)
Tianjin	95.6,1472	6.96(2.67,11.21)
Chengdu	86.3,1635	6.83(2.62,11.01)
Shanghai	60.7,2415	6.47(2.48,10.42)
Handan	127.8,93	6.17(2.37,9.93)
Xingtai	155.2,722	5.93(2.28,9.56)
Zhengzhou	102.4,919	4.71(2.52,7.59)

Discussion

Epidemiological studies of acute and chronic health effects of $PM_{2.5}$ air pollution in China are still very penurious. Due to the $PM_{2.5}$ exposure-response relationship based on limited epidemiological studies, it is difficult to fully and truly reflect the status of exposed urban population. Thus, more epidemiological studies on $PM_{2.5}$ air pollution should be carried out. In this study, lack of limited health endpoints data, the estimates are still not comprehensive enough, and there are still some limitations in the he $PM_{2.5}$ health economics loss. For example, although studies suggest that the atmospheric pollution are related to the reduced lung function, adverse reproductive outcomes and so on, the domestic epidemiological research and basic health information is in lack in these fields. Therefore, this study may underestimate the health harm and economic loss of atmospheric pollution caused by the particulate matter $PM_{2.5}$.

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