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Establishment of Exposure-response Functions of Air Particulate Matter and Adverse Health Outcomes in China and Worldwide[1]

HAI-DONG KAN[*,2], BING-HENG CHEN[*], CHANG-HONG CHEN[#],
BING-YAN WANG[#], AND QING-YAN FU[†]

[*]*Department of Environmental Health, School of Public Health, Fudan University, Shanghai 200032, China;* [#]*Shanghai Academy of Environmental Science, Shanghai 200233, China;* [†]*Shanghai Environmental Monitoring Center, Shanghai 200030, China*

Objective To obtain the exposure-response functions that could be used in health-based risk assessment of particulate air pollution in China. **Methods** Meta analysis was conducted on the literatures on air particulate matter and its adverse health outcomes in China and worldwide. **Results** For each health outcome from morbidity to mortality changes, the relative risks were estimated when the concentration of air particulate matter increased to some certain units. **Conclusion** The exposure-response functions recommended here can be further applied to health risk assessment of air particulate matter in China.

Key words: Air pollution; Particulate matter; Meta analysis; Exposure-response function

INTRODUCTION

Numerous epidemiologic studies during the past 10-20 years have confirmed that exposure to air pollution contributes to mortality and morbidity, both in China and worldwide[1]. Among the air pollutants, particulate matter appears to show the most consistent association with mortality. As evidence of the adverse health effects of air pollution has accumulated, quantification of the impact of air pollution on public health and the subsequent cost-benefit analysis have increasingly become a critical component in policy discussion and priority setting. In fact, several studies have estimated the health damage due to air particulate matter, both in physical and monetary terms[2]. They all highlighted the impact of particulate air pollution on public health.

Exposure-response functions are related to air quality changes and heath outcomes, thereby providing key information for health impact assessment of air pollution. Previously, we collected Chinese literatures and did a meta analysis of exposure-response functions of air particulate matter and adverse health outcomes in China[3]. In the present analysis, we tried to make use of available epidemiologic literatures both in China and worldwide to derive the exposure-response functions and the respective measures of precision (95 percent confidence interval or standard error). With many studies providing information on the same exposure-response associations, a meta analysis of their results was also conducted to derive a common estimate, which could be further applied to health risk assessment of air particulate matter in China.

MATERIALS AND METHODS

Data Source

By searching the Chinese Biomedical Litera- ture Database and PubMed, we collected the epidemiologic literatures on particulate air pollution and its adverse health effects in China and worldwide published from 1990 through 2002. The exposure-response coefficients and their 95% confidence interval (CI) were extracted from the literatures.

Considering the data availability in Shanghai and

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[2]Correspondence should be addressed to Hai-Dong KAN, Department of Environmental Health, School of Public Health, Fudan University, Box 249, 138 Yixueyuan Road, Shanghai 200032, China. Tel: 0086-21-54237908. Fax: 0086-21-64046351. E-mail: hdkan@shmu.edu.cn

Biographical note of the first author: Hai-Dong KAN, born in 1974, male, Ph. D., research focuses on environmental epidemiology and health risk assessment.

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China, PM_{10} was selected as the indicator particulate matter. Although PM_{10} was selected as the indicator of air pollution in this analysis, some studies using TSP and $PM_{2.5}$ for exposure assessment were also included in the analysis. The following conversion factors were applied for different particulate matter indicators:

PM_{10}=TSP×0.65 and $PM_{2.5}$=PM_{10}×0.65[4]

Selection of Literatures

Particle-related effects were summed up on a series of health outcomes in different exposure levels, ranging from morbidity to mortality changes. The following criteria were used in selecting literatures for this analysis.

1. Studies conducted in China were preferred. When those widely accepted health outcomes associated with particulate air pollution were not available in Chinese literatures, e.g., long-term effect on mortality, the results from international literatures were used.

2. Quantitative exposure-response relationships between air particulate matter and health outcomes were established (in the form of either slope or relative risk).

3. Sub-clinical effects, such as lung function changes, were not included in this assessment, because it was difficult to translate them into long-term health impact and monetary values based on current knowledge.

Based on the above criteria, the selected health outcomes associated with particle exposure used in this analysis were as follows:

- Mortality (Long-term change)
- Morbidity
  - Chronic bronchitis
  - Hospital admission (respiratory and cardiovascular systems)
  - Outpatient visits (internal medicine and pediatrics)
  - Other illness (acute bronchitis, asthma attack)

Meta Analysis

If there were several studies describing the exposure-response function for the same health endpoint, we used the pooled estimate to get the mean and 95 percent confidence interval (CI) of the coefficient. This meta analysis method was based on the variance weighted average across the results of studies with available quantitative effect estimates (coefficients or relative risks). Studies with lower standard errors had more weight in the resulting joint estimate.

We used the META command in STATA to perform the process described above.

RESULTS

Effect Estimates of Each Health Outcome

Long-term effect on mortality Exposure-response function of ambient particulate matter and long-term mortality was only studied in two US cohort studies[5-6]. These cohort studies gave the additional number of deaths per person-year which might be directly applied to the per year impact assessment. Recently, Pope *et al.* reported the latest results of the latter study providing longer follow up and more data on air particulate matter[7]. Therefore, the current analysis was based on the long-term effects of air particulate matter on mortality rate in adult populations as reported in the two US studies[5-7].

In the two US cohort studies we selected, the large cohort of the American Cancer Society (ACS) [7] investigated the survival of 500 000 persons in relation to the air pollution exposure for metropolitan areas throughout the United States of America, and found an increase of 4.0% in mortality risk with each increase of 10 ì g/m^3 PM_{10}. The effect estimate of the smaller Harvard 6 cities cohort study (n=8 111) was much higher (8.5% with each increase of 10 ì g/m^3 PM_{10})[5].

As the result of the meta analysis, a joint estimate of 1.0430 (95% CI 1.0260, 1.0610) for total long-term mortality was calculated from the results of these two US cohort studies.

Morbidity

Chronic bronchitis Two studies conducted in China described the association between chronic bronchitis and long-term exposure to particulate air pollution. Using the ecological cross-sectional design, Jin *et al.* investigated the effect of ambient air pollution on the new occurrence of cases of chronic bronchitis (incidence) in Benxi, China[8] (Jin *et al.*, 2000). Another similar study was conducted by Ma *et al.* in Shanghai[9]. It was observed that the incidence rate of chronic bronchitis increased 3.0% and 2.9% respectively in Benxi and Shanghai with each increase of 10 ì g/m^3 TSP.

A joint estimate of 1.046 (1.015, 1.077) per 10 ì g/m^3 PM_{10} was calculated from the two studies mentioned above.

Hospital admission The association between air pollution and hospital admission was confirmed in North American and Europe. In China, however, there were no studies to report the relationship. Therefore, we had to rely on international peerreviewed papers.

a) *Respiratory hospital admission* For the endpoint of respiratory hospital admission, a joint estimate of 1.008 (95% CI 1.004-1.012) with each increase of 10 ì g/m^3 PM_{10} was calculated from three European studies[10-12]. Also, a joint estimate of 1.017 (95% CI 1.013-1.020) with each increase of 10 ì g/m^3 PM_{10} was derived from eight US and Canadian studies[13-20].

For all European, US and Canadian studies, an effect estimate of 1.013 (95% CI 1.010-1.015) per 10 ì g/m^3 PM_{10} was calculated.

b) *Cardiovascular hospital admission* For the endpoint of cardiovascular hospital admission, a joint estimate of 1.013 (95% CI 1.007-1.019) with each increase of 10 ì g/m^3 PM_{10} was calculated from four European studies[11-12, 21-22]. Similarly, a joint estimate of 1.008 (95% CI 1.004-1.011) per 10 ì g/m^3 increase PM_{10} was derived from three US and Canadian studies[20, 23-24].

For all European, US and Canadian studies, an effect estimate of 1.009 (95% CI 1.006-1.013) per 10 ì g/m^3 increase of PM_{10} was calculated.

Hospital outpatient visits There was only one study in China to study the association between air pollution and outpatient visits. In Beijing, Xu X. *et al*. reported an increase of 3.4% (95% CI 1.9%-4.9%) and 3.9% (95% CI 1.4%-6.4%) for outpatient visits to internal medicine and pediatrics departments respectively, with each 10 ì g/m^3 increase of PM_{10}[25].

Acute bronchitis One study was conducted in China on air pollution and acute bronchitis[8]. With each 10 ì g/m^3 increase of PM_{10}, the incidence rate of acute bronchitis increased 4.6% (95% CI 0.0-9.2%).

Asthma

Asthma in children (≤*15 yrs*) Wei *et al*. investigated the relationship between air pollution and asthma in children in four Chinese cities (Lanzhou, Guangzhou, Wuhan and Chongqing), and found that the incidence rate of asthma in children increased 6.95% with each 10 ì g/m^3 increase of PM_{10}[26].

Asthma in adults (>*15 yrs*) Three European panel studies on asthma in adults[27-29] were selected to derive a joint estimate of 1.039 (95% CI 1.019-1.059) per 10 ì g/m^3 increase of PM_{10}. The joint estimate from two US panels[30-31] showed an effect estimate of 1.002 (95% CI 0.998-1.006) in adult asthma per increase of 10 ì g/m^3 PM_{10}.

Combining all European and US studies on adult asthma, the joint estimate on asthma was 1.004 (95% CI 1.000-1.008) per 10 ì g/m^3 increase of PM_{10}.

Table 1 summarized the results of meta analysis, expressed as relative risk of each health endpoint associated with 10 ì g/m^3 increase of PM_{10}.

TABLE 1

Relative Risk of Each Health Endpoint Associated With Each Increase of 10 ì g/m^3 PM_{10} (mean and 95%CI)

Health Endpoints	Population	Relative Risk (95%CI)
Total Mortality	Adults (≥30 yrs)	1.0430 (1.0260, 1.0610)
Chronic Bronchitis	Total Population	1.0460 (1.0150, 1.0770)
Respiratory Hospital Admission	Total Population	1.0130 (1.0010, 1.0250)
Cardiovascular Hospital Admission	Total Population	1.0095 (1.0060, 1.0130)
Outpatient Visits (internal medicine)	Total Population	1.0034 (1.0019, 1.0049)
Outpatient Visits (pediatrics)	Total Population	1.0039 (1.0014, 1.0064)
Acute Bronchitis	Total Population	1.0460 (1.0000, 1.0920)
Asthma	Children (≤15 yrs)	1.070*
Asthma	Adults (≥15 yrs)	1.0040 (1.0000, 1.0080)

Note. *95%CI were not provided in the original paper.

DISCUSSION

Mortality is often considered as the most important endpoint associated with air particulate exposure. Dozens of epidemiologic studies have measured increases in mortality associated with particulate air pollution. For short-term effects, air pollution levels of a given day or a short period of days may trigger an increase in deaths within days or weeks. Most of the literatures on the short-term effects of air pollution are based on time-series or case-crossover studies. In terms of long-term effects of air pollution on mortality, the cohort studies revealed that long term exposure to air pollution might lead to a measurable reduction of survival in the population. Generally, the prospective cohort studies reported a substantially larger effect for long-term exposure than that reported by daily time-series studies. Since the cohort studies provided a more complete assessment of the impact from exposure to air pollution than that from time-series studies[32], we decided to use cohort-based exposure-response functions in the current analysis. Unfortunately, we had to rely on the results of two US cohort studies, because no such study was available in China.

Some exposure-response functions employed in this analysis were not available in Chinese studies. So we had to rely on international studies, conducted mostly in the USA and Western Europe. As an example, we compared the effect of exposure to air particulate matter on mortality changes (both short-term and long-term) in China and developed countries. Fig. 1 describes the relative risks of total mortality in response to an increase of 10 ì g/m^3 PM_{10}, among which the acute effects of air particulate matter were derived from a meta analysis of 109 literatures[33] and a pooled estimate of Chinese literatures[34], and the chronic effects were estimated from two US cohort studies for developed countries and one cross-sectional study in China. Compared with the studies in the USA and Europe, the Chinese studies generally reported lower coefficients for the exposure-response relationships between air pollution and acute/chronic mortality changes.

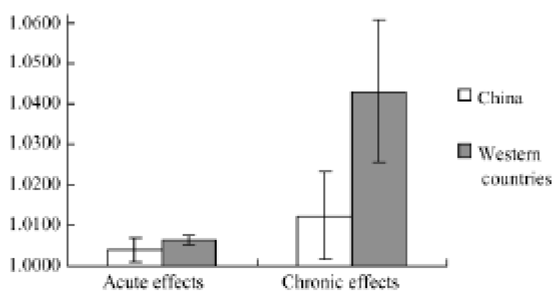

FIG. 1. Relative risk of mortality in China and Western countries with 10 ì g/m^3 increase of PM_{10}.

The probable reasons might include different levels of air pollution, local population sensitivity, age distribution and especially different air pollutant components. For instance, the composition of motor vehicle emission in Western Europe and USA, where most of the epidemiological studies were performed, differs substantially from that in China. This, together with other differences as the predominant use of coal in China, implies that the air pollution mixture differs substantially between China and the areas where most epidemiologic studies were conducted. Therefore, conceptually, when exposure-response functions from developed countries are applied to other regions, for example China, they should be revised, taking account of local conditions, such as physical (diameter, *etc*.) and chemical (components) characteristics of particles, social-economical status of local populations, *etc*. However, no reference data are available for such a revision.

In summary, the exposure-response coefficients recommended here can be applied to health risk assessment of air particulate matter in China.

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