BIOMEDICAL AND ENVIRONMENTAL SCIENCES **15**, 209-214 (2002)

Impact of Long-term Exposure to Air Particulate Matter on Life Expectancy and Survival Rate of Shanghai Residents

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Objective To evaluate the impact of long-term air particulate matter exposure on the life expectancy and survival rate of Shanghai residents. **Methods** Epidemiology - based exposure-response function was used for the calculation of attributable deaths to air particulate matter in Shanghai, and the effect of long-term exposure to particulate matter on life expectancy and survival rate was estimated using the life table of Shanghai residents in 1999. **Results** It was shown that in 1999, the long-term air particulate matter exposure caused 1.34-1.69 years reduction of life expectancy and a decrease of survival rate for each age group of Shanghai residents. **Conclusion** The effect of long-term exposure to air particulate matter on life expectancy is substantial in Shanghai.

Key words: Particulate matter; Life expectancy; Survival rate; Shanghai

INTRODUCTION

Ever since the great smog disasters in the mid of last century[1-3], the association of high concentrations of air pollution and excessive human deaths has been established. Over the past decade, several dozen time-series studies spanning different countries have demonstrated associations between daily counts of mortality and daily or multi-day changes in air pollution, even at much lower concentrations compared with the past. Among these pollutants, particulate matter was measured as either TSP (total suspended particle) or PM_{10} (those less than 10 μm) and $PM_{2.5}$ (less than 2.5 μm) or black smoke appears to show the most consistent association with mortality.

Although such findings are important in their own right, time-series studies do not directly prove that long-term exposure to air pollution increases the prevalence of (chronic) diseases in the population, possibly leading to decreased survival and hence, reduced life expectancy. The associations found between day to day variations in mortality and air pollution may, for example, represent a "harvesting" effect, that is, an advancement of death by a few days or weeks in subjects already to die from other causes anyway. Clearly, such effects would not lead to discernible effects of long-term exposure to air pollution on life expectancy in the population.

However, there are some evidences from the prospective cohort mortality studies (e.g.,

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0895-3988/2002
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Dockery *et al*., 1993[4]; Pope *et al*., 1995[5]) that long-term exposure to relatively low concentrations of ambient air particulate matter leads to a measurable reduction of survival in the population. Compared with time-series studies, the cohort studies provide a more complete assessment of the impact from exposure to air pollution[6].

The concentrations of air particulate mater in Shanghai are much higher than those in the cities that were studied in the two cohort cities. Therefore, in order to illustrate the potential impact of long-term exposure to particles on mortality for Shanghai residents, the present study provides an estimate of the effect that long-term exposure to particles may have on life expectancy, based on the cohort studies.

METHODS

Design

Cases of deaths attributable to air particulate matter were applied to the 1999 life table for each age group of Shanghai residents, and the effect of exposure to particulate matter on life expectancy and survival rate was estimated[7].

Derivation of Attributable Number of Deaths

Since most of the studies linking air pollution and mortality were based on a Poisson model, as shown in Fig. 1, the number of deaths at a given concentration C, could be given by[4, 5]:

$$E = \exp [\beta \times (C - C_0)] \times E_0 \quad (1)$$

In the formula (1), C and C_0 are the actual concentration and the threshold level, respectively, and E and E_0 are the corresponding health effects under the concentration of C and C_0. Therefore, the attributable number of deaths is equal to the subtraction of E and E_0. It is clear that the value could be obtained if we have three data components: the exposure-response function (β), the actual mortality (E), the actual level of exposure (C) and the threshold concentration (C_0).

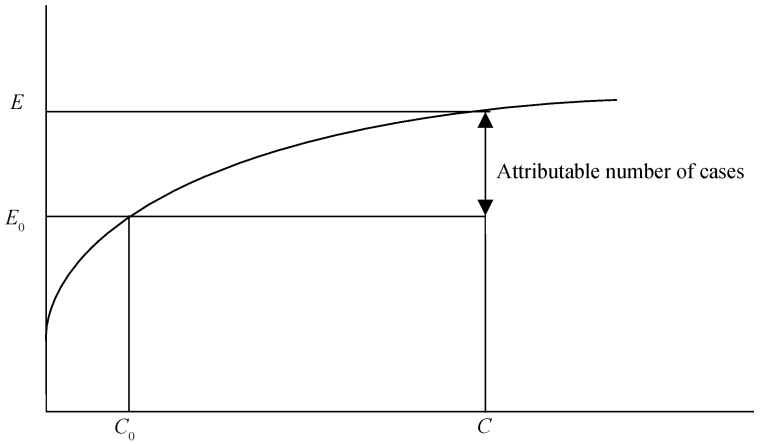

FIG.1. Model to derive number of deaths attributable to air particulate matter.

Exposure-response Function

The exposure-response function was a pooled estimate from the two cohort studies. It was calculated as the variance weighted average across the results of the studies. Studies with low standard errors had, therefore, more weight in the joint estimate. The coefficient could also be expressed as relative risk (RR) per g/m^3 increase.

Threshold Selection

Threshold concentration (C_0) means there is no observed effect of air particulate matter on mortality below it. Here we selected the natural background concentration of air particulate matter in Shanghai as the threshold[8].

Data Source

The mortality data were obtained from Shanghai Municipal Bureau of Public Health[9], and the particulate matter monitoring data were got from Shanghai Municipal Environmental Protection Bureau[10].

For TSP used as the particulate matter measure in Shanghai in 1999, the following conversion was applied for different particulate matter indicators[11]:

$$PM_{10}=TSP\times 0.65,$$
$$PM_{2.5}=PM_{10}\times 0.65.$$

RESULTS

Attributable Number of Deaths to Particulate Matter for Each Age Group of Shanghai Residents

In 1999, the annual daily average of TSP in Shanghai was 175 μg/m^3, and the natural background level was 127 μg/m^3. Based on Dockery and Pope's study, the pooled relative risk (95% CI) per 10 μg/m^3 PM_{10} was 1.043(1.026, 1.061).

Using the exposure-response function, mortality data, exposure concentration and the threshold, the attributable number of deaths to particulate matter for each age group of Shanghai residents we calculated (Table 1).

TABLE 1

Number of Attributable Deaths to Air Particulate Matter for Each Age Group of Shanghai Residents

Age	Population	Deaths	Attributable Deaths
0-	65 600	362	45
1-	1 263 277	263	33
10-	1 682 107	469	59
20-	1 657 157	774	97
30-	2 736 542	2 000	251
40-	2 357 050	5 311	667
50-	1 173 929	6 099	766
60-	1 276 353	15 535	1 950
70-	709 085	31 644	3 973
80-	211 767	32 621	4 096
Total	13 067 268	94 716	11 937

Estimated Effect of Exposure to Particulate Matter on Life Expectancy and Survival Rate of Shanghai Residents

The attributable deaths in the 1999 life table of Shanghai residents was investigated, thus producing a "hypothetical" life table in the case of lower particulate matter level. By comparing the life expectancy on the basis of the "actual" life table and the "hypothetical" one, the effect of particulate matter on life expectancy was estimated (Table 2). It could be seen that a difference of 1.34 -1.69 years existed between the two cases.

TABLE 2

The Effect of Air Particulate Matter on Life Expectancy of Shanghai Residents

Age	"Actual" Life Expectancy	"Hypothetical" Life Expectancy	Difference
0-	76.98	78.67	1.69
1-	76.40	78.09	1.69
10-	67.54	69.21	1.68
20-	57.71	59.37	1.66
30-	47.96	49.59	1.63
40-	38.27	39.88	1.60
50-	29.03	30.57	1.54
60-	20.31	21.76	1.45
70-	12.30	13.04	1.35
80-	6.49	7.84	1.34

Table 3 shows the impact of air particulate matter on the survival rate for each age group of Shanghai residents.

TABLE 3

Estimated Effect of Air Particulate Matter on the Survival Rate for Each Age Group of Shanghai Residents

Age	"Actual" Survival Rate	"Hypothetical" Survival Rate	Difference
0	0.99448	0.99460	0.00012
10	0.99722	0.99756	0.00035
20	0.99534	0.99592	0.00058
30	0.99272	0.99363	0.00091
40	0.97772	0.98049	0.00277
50	0.94936	0.95558	0.00622
60	0.88527	0.89894	0.01368
70	0.63515	0.67347	0.03833
80	0.00000	0.00000	0.00000

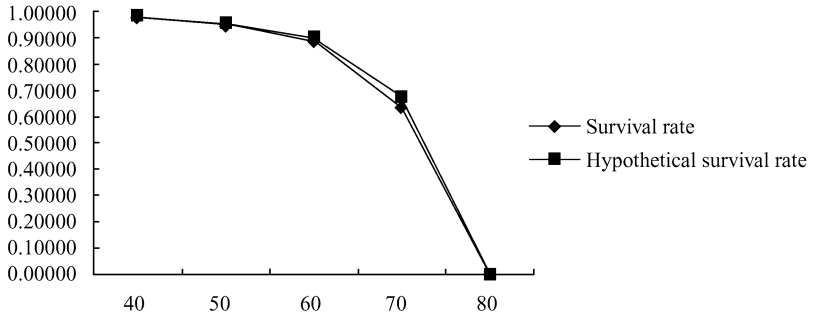

FIG.2. The impact of air particulate matter on the survival rate of Shanghai residents (age >40).

DISCUSSION

In the present study, the cohort-based study was used to estimate the impact of long-term exposure to air particulate matter on life expectancy and survival rate. Our decision was based on two reasons. First, it was inappropriate to use short-term studies for the impact assessment of annual mortality[12], which was necessary for life table and calculation of expectancy and survival rate; Second, reduced life-expectancy due to long-term morbidity enhanced by air pollution, might not be captured in the time-series; thus, the time-series-based impact assessment would be incomplete. Unfortunately, the only two available US studies had to be used, for no such studies existed in China and any other country.

The calculations performed in the present study suggested that the effect of long-term exposure to air particulate matter in Shanghai might lead to a reduction of life expectancy of more than one year, and a decrease of survival rate. However, there were still several uncertainties during the process of the calculation.

The exposure-response function adopted was based on the results of two US cohort studies. When they are applied to other regions, for example - Shanghai, they should be revised to take account of local conditions, such as the physical (size, etc.[13]) and chemical (components, etc.[14]) characteristics of particles, social-economical situations of local populations etc. However, no reference data is available for such a revise.

In addition, it is clear from the formula (1) that the results of our analysis are very sensitive to the change of selected threshold. Although in some epidemiological studies[15, 16], no threshold existed for the effect of particulate matter on mortality, the natural background level of particulate matter in Shanghai was used as the threshold in our analysis, because no people in Shanghai had ever lived below such a level. Maybe the definition "the lowest assessed level" is more appropriate than the threshold here.

In conclusion, effects of long-term exposure to air particulate matter on life expectancy of Shanghai residents are substantial.

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(*Received October* 17, 2001 *Accepted June* 26, 2002)