Relationship Between Ambient Air Pollution and Daily Mortality of SARS in Beijing[1]

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Objective To study the relationship between ambient air pollution and daily mortality of SARS in Beijing. **Methods** The approach of time-series Poisson regression was used to assess the relationship between daily SARS mortality, ambient air pollution, and other factors from April 25 to May 31, 2003 in Beijing. **Results** An increase of each 10 μg/m^3 over a 5-day moving average of PM_{10}, SO_2 and NO_2 corresponded to 1.06 (1.00-1.12), 0.74 (0.48-1.13) and 1.22 (1.01-1.48) relative risks (RRs) of daily SARS mortality, respectively. The relative risks (RRs) values depended largely on the selection of lag days. **Conclusion** The daily mortality of SARS might be associated with certain air pollutants in Beijing.

Key words: Air pollution; SARS; Beijing

INTRODUCTION

The relationship between ambient air pollution and daily mortality, especially mortality from cardiopulmonary diseases, has been proved in numerous studies worldwide[1]. In China, researches conducted in Beijing[2], Shanghai[3], Chongqing[4] and Shenyang[5] have also confirmed such a relationship. Severe acute respiratory syndrome (SARS), is a newly emerging infectious disease with 8 437 cumulative cases and 813 deaths around the world since November 2002. It was estimated by World Health Organization (WHO) that the SARS fatality rate reached 14%-15% globally, while the value was between 5% and 13% in China[6]. It was assumed that the age and underlying health conditions were the major factors determining the SARS fatality rate[6]. However, it still deserves further investigation whether other natural and social factors, e.g. ambient air pollution, might be associated with the death risk of SARS patients, since air pollution is a potentially preventable risk factor.

In Beijing, there have been 2 521 cumulative cases and 192 deaths reported up to now, accounting for 55.2% of China's total SARS cases[7]. In addition, there are complete air pollution and weather data in Beijing. Therefore, the information has made the current study possible to investigate the relationship between daily mortality of SARS and ambient air pollution based on the data in Beijing.

METHODS

Data Sources

Data from 25 April to 31 May 2003 in Beijing, including daily death number of SARS patients, meteorological, and air pollution data, were collected. Daily death number of SARS patients was collected from the database of the Ministry of Public Health, PRC[7]. Meteorological data (daily mean temperature, relative humidity, dew point) and air pollution data (daily PM_{10}, SO_2 and NO_2 concentrations) were extracted from the database of the State Meteorological Administration and the Beijing Bureau of Environmental Protection, respectively. The daily concentrations of PM_{10}, SO_2 and NO_2 were averaged from the results monitored by twelve fixed-site stations in Beijing. Considering the data reliability and statistical efficiency, we selected the period of 25 April to 31 May, 2003 as the research time.

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Statistical Analysis

We used the log-linear models to estimate air pollution/mortality relative risks (RRs), while accounting for long-term or middle-term trends of daily mortality counts of SARS, weather and "days of the week" effect. The core analysis was a generalized additive model (GAM) with log link and Poisson error that accounts for smooth fluctuations in mortality that may potentially confound estimates of the pollution effect and introduce autocorrelation in mortality series. We first fitted nonparametric smoothing (by means of the smoothing *spline* function) terms for trend on days (1–37) to account for the natural temporal trend of daily death number of SARS patients and other potential factors affecting the death risk of SARS patients. After the time, weather and day of week were controlled, each pollutant was introduced into the model. In addition, we also considered the lag effects of temperature, humidity and pollutant concentrations in building the models.

All analyses were carried out using S-PLUS 2000 software (Insightful Corp, Seattle, USA). Considering the fact that the default settings in the *gam* function of the S-Plus software package do not assure convergence of its iterative estimation procedure and can provide biased estimates of regression coefficients and standard errors[8], we analyzed the data with more stringent convergence parameters than the default settings when using the *gam* function.

RESULTS

Descriptive Analysis

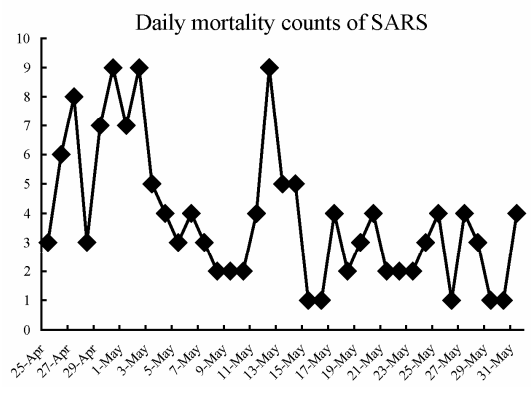
Summary statistics of mortality counts of SARS, air pollutant concentrations, and meteorological measures from 25 April to 31 May 2003 in Beijing are presented in Table 1.

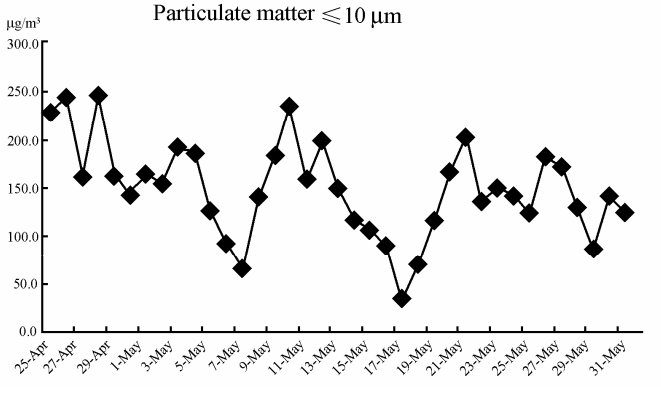
TABLE 1

Summary Statistics of Mortality Outcomes, Air Pollution Levels, and Meteorological Measures From 25 April to 31 May, 2003 in Beijing

	No (day)	Mean	SD	Min	P (25)	Median	P (75)	Max
SARS Mortality Counts	37	3.8	0.4	1	2	3	5	9
Meteorological Measures								
Temperature (℃)	37	20.8	0.4	14.7	18.7	20.9	23.2	24.5
Dew Point (℃)	37	1007.1	0.6	998.9	1004.9	1006.5	1009.9	1017.4
Relative Humility (%)	37	58.2	2.0	39	50	57	67	83
Air Pollutants Concentrations								
SO_2 (μg/m^3)	37	34.3	1.5	18	26	35	42	52
NO_2 (μg/m^3)	37	60.5	2.4	34	50	59.2	71	97
PM_{10} (μg/m^3)	37	149.1	8.1	34	120	150	183	246

Fig. 1 shows the temporal pattern of daily mortality counts of SARS and air pollutants concentrations in the study period. Roughly speaking, the daily death number of SARS patients had a declining trend in the meantime.





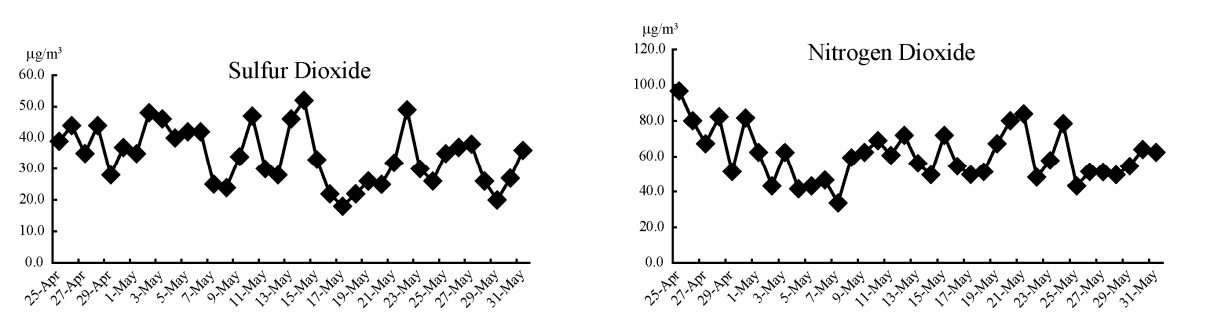


FIG. 1. Temporal pattern of daily mortality counts of SARS and individual air pollutant levels from 25 April to 31 May, 2003 in Beijing.

Regression Results

Table 2 shows the relative risks (RRs) of death among SARS patients per 10 μg/m^3 change in PM_{10}, SO_2 and NO_2 levels with different lag structures. The RRs were statistically significant for PM_{10} and NO_2 with a 4- or 5-day lag. However, we did not find any significant association of daily SO_2 concentration with SARS mortality with lags up to 6 days.

TABLE 2

Comparison of the Relative Risks (RRs) (95% Confidence Interval) of Death Among SARS Patients Per 10 μg/m^3 Change in PM_{10}, SO_2 and NO_2 Levels with Different Lag Structures

	Lag	Mean	95% CI
PM_{10}	0	0.99	0.96-1.03
	1	1.00	0.97-1.04
	2	1.02	0.98,1.06
	3	1.04	0.99-1.09
	4	1.06*	1.00-1.11
	5	1.06*	1.00-1.12
	6	1.05	0.98-1.12
SO_2	0	0.89	0.72-1.10
	1	0.85	0.67-1.09
	2	0.85	0.64-1.14
	3	0.85	0.60-1.20
	4	0.80	0.55-1.17
	5	0.74	0.48-1.13
	6	0.70	0.44-1.13
NO_2	0	1.04	0.92,1.16
	1	1.07	0.95-1.22
	2	1.12	0.97,1.29
	3	1.14	0.97-1.33
	4	1.19*	1.01-1.42
	5	1.22*	1.01-1.48
	6	1.24	0.98-1.55

DISCUSSION

Although the relationship between outdoor air pollution and daily mortality of non-infectious respiratory diseases, e.g., COPD, has been well established during the past decade, it is still unknown whether air pollution is associated with the death rate of infectious respiratory diseases, e.g., SARS. Evidence gained in this time-series study suggested that the PM_{10} and NO_2 levels in Beijing might be associated with the death rate of SARS. Our results are also consistent with the previous report by Cui *et al.*[9]. Using the ecologic design, Cui *et al.* found a positive correlation between air pollution level and SARS case fatality in different Chinese cities. Our study adds new evidence for the detrimental effect of air pollution on the prognosis of SARS patients, although such a correlation deserves further investigation.

We hypothesized that the underlying mechanism might be possibly compromised lung functions due to short-term exposure to certain air pollutants (PM_{10} and NO_2) and, consequently increased SARS death risk. In addition, air pollution may predispose the respiratory epithelia of SARS patients, leading to severe respiratory symptoms and an increased risk of death. In the current study, we failed to observe the relationship between SO_2 level and SARS mortality, which might be due to the relatively low level of SO_2 in the study period (mean 34.3 μg/m^3) and the fact that SO_2 is soluble and mainly affects the upper respiratory system.

In the present study the estimated effects of air pollutants on SARS mortality reached a maximum at a lag of 4-5 days. These observations are consistent with those of Wong *et al.* in Hong Kong[10], who reported that the effects increased from lag-day 0 to a maximum at lag-days 1-4 for NO_2, SO_2, and PM_{10}.

This study was subject to several limitations. Firstly, ecologic time-series study design was adopted in the study, which might be subject to ecologic

fallacy. Furthermore, we were unable to predict the direction and magnitude of the bias because of difficult access to the data at the individual level. Thirdly, exposure misclassification might have biased the study results due to the imprecise measurements. Nevertheless, this study showed that air pollution might be associated with the death risk of SARS patients in Beijing, which deserves further investigation and may have a certain impact on the study of SARS nature history.

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