Indoor air pollution and respiratory health of the peoples in Beijing: a community-based pilot study

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ABSTRACT

In this study, we attempt to investigate the level of indoor air pollution and to evaluate its health effects on the subjects exposed to pollution in Beijing. About 270 households (90 per district) were selected randomly from three districts (90 per district), representing the industrial, old downtown and cultural/educational areas of Beijing. The concentrations of PM_{10}, $PM_{2.5}$ and SO_2 in indoor air were measured in the bedroom and the kitchen of the subjects' homes. Simultaneously, about 3000 individuals aged from 18 to 65 years from the study households and their neighbours were interviewed by questionnaire for their respiratory health.The results showed that the average levels of $PM_{10}/PM_{2.5}$ in indoor air were from 200 to 600 μg/m^3, and associated with different seasons and the activities for cooking and heating in these houses (P<0.01). But we have not found that the health effect of the subjects were associated with the concentration of $PM_{10}/PM_{2.5}$ in indoor air.

INDEX TERMS

Particulate matter; Cooking; Respiratory symptoms

INTRODUCTION

As the capital of China, Beijing's GDP increased from 28.08 billion RMB to 180.75 billion RMB from 1986 to 1997, urban area extended by 28.4% and the average annual growth rate for coal consumption was 31.9%. Coal accounts for more than 70% in Beijing's energy mix. Up to now, the urban area of Beijing is only 6% of the total. However, it concentrated 50% of population, 80% of buildings and 80% of energy consumption, which caused very serious air pollution (particulate, SO_2, NO_x and PM_{10}) in downtown. Nowadays more and more people living in urban areas of Beijing spend the greatest part of their time indoors, where concentrations of many air pollutants are higher than outdoors (Carrer *et al.*, 1997). In recent years, indoor environments in Beijing have changed enormously with the fast development of the domestic economy and as many new fitments, such as soft furnishings, fitted carpets and mechanical air ventilation systems, are introduced into more and more households in Beijing.

Today, indoor air pollutions are playing an important role in affecting human health and concern over the health effects of poor quality indoor air is increasing (Infante-Rivard, 1993). But it has not been known at what levels indoor air pollutions are maintained and what effects they have on human health in Beijing. The present study is aimed to measure the level of

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indoor air pollution in different households and evaluate its health effects on the subjects exposed to pollution in Beijing.

METHODS

Participants

The study field was located in three districts of urban area, representing the industrial area, the old downtown and the cultural–educational area of Beijing. About 270 households (90 per district) were selected randomly as our subjects of indoor air monitoring, about 3000 individuals aged from 18 to 65 years from the study households and their neighbours were interviewed by questionnaire for their respiratory health.

Exposure

The survey was conducted in 2000–2001. The mass concentration of particles smaller than 10–2.5 μm in diameter (PM_{10}/$PM_{2.5}$) and sulphur dioxide (SO_2) was measured in the bedroom and kitchen of the study households in real-time twice a day for 2 weeks, respectively, in winter and summer. We measured the pollution in actual conditions of use everyday and simultaneously recorded the location and activities of all the household members—especially activities such as cooking time that would facilitate exposure to pollution. We also interviewed household members about household energy-use appliances and their time–activity patterns. We estimated the profiles of exposure for every subject, which accounted for daily and day-to-day variability of exposure and time–activity pattern.

Health

The health questionnaire was based on that of the British Medical Respiratory Committee and revised according to the different statuses of the study field in Beijing. It consisted of age, gender, education, occupation, general health status, living habits, and exposure to indoor microenvironment factors, cooking, smoking, respiratory symptoms and other daily activities. The trained students of a medical college conducted the health survey with the questionnaire by face-to-face interview.

Determination and Data Analysis

The determination of levels of PM_{10}, $PM_{2.5}$ and SO_2 was taken with standardized procedures. The *t*-test and chi-square test were used for estimates of variances of the pollutants level. Effect size of various factors for respiratory symptoms and lung function were estimated with two models. First is a linear model with an ordinary least-squares regression of symptom rates. We accounted for clustering of observations in units of Household. Second, we used a logistic probability model $y = F(X \times \beta + u)$: y, X, and β are defined as in the linear model; F = cumulative logistic distribution, $F(z)=\exp(z)$ divided by $[1 + \exp(z)]$. Because the data of indoor air pollution were all lognormal distributions, the data of indoor air monitoring were shown with geometric mean ± standard deviations.

RESULTS

The Daily Average Levels of PM_{10} and $PM_{2.5}$ in Indoor Air of Study Households

Average levels of PM_{10} and $PM_{2.5}$ in indoor air for various bedrooms and kitchens of the households in different districts are listed in Table 1 and 2. They showed PM_{10} and $PM_{2.5}$ levels of old downtown (Dong Cheng) were significantly higher than that of the industrial area (Shi Jing Shan), which was different from the outdoor air and PM_{10} and $PM_{2.5}$ levels had no significant differences between the bedrooms and kitchens of the subjects. It suggested that the source of indoor air PM is unlikely from outdoor air in Beijing.

Table1 Indoor air PM_{10} level daily among three districts in Beijing (mg/m^3)

	Dong Cheng		Shi Jing Shan		Hai Dian		Total	
	B	K	B	K	B	K	B	K
Ave.	0.519	0.481	0.284*	0.255*	0.666	0.669	0.478	0.456
Med.	0.442	0.496	0.151	0.126	0.535	0.589	0.347	0.333
SD	0.450	0.319	0.354	0.301	0.545	0.650	0.476	0.471
Min.	0.044	0.044	0.038	0.039	0.057	0.043	0.038	0.039
Max.	3.208	1.680	1.803	1.790	3.602	4.169	3.602	4.169
Count	93	93	101	101	84	84	278	278

*$P<0.01$ (*t*-test).
B, bedroom; K, kitchen.

Table 2 The indoor air $PM_{2.5}$ level among three districts in Beijing (mg/m^3)

	Dong Cheng		Shi Jing Shan		Hai Dian		Total	
	B	K	B	K	B	K	B	K
Ave.	0.502	0.465	0.246*	0.207*	0.614	0.593	0.443	0.410
Med.	0.412	0.462	0.124	0.096	0.510	0.543	0.315	0.303
SD	0.495	0.404	0.319	0.242	0.489	0.599	0.463	0.457
Min.	0.039	0.021	0.023	0.022	0.038	0.036	0.023	0.021
Max.	3.080	2.417	1.731	1.469	3.188	4.025	3.188	4.025
Count	93	93	101	101	84	84	278	278

The Annual Average Levels of SO_2 in Indoor Air of Study Households

Average levels of SO_2 in indoor air for various bedrooms and kitchens of the households in the three districts are listed in Table 3.

Table 3 The indoor air SO_2 level among three districts in Beijing (mg/m^3)

	Dong Cheng		Shi Jing Shan		Hai Dian		Total	
	B	K	B	K	B	K	B	K
Ave.	0.073	0.171	0.053	0.094	0.108	0.408*	0.078	0.220
Med.	0.040	0.075	0.006	0.006	0.049	0.161	0.019	0.034
SD	0.103	0.318	0.271	0.359	0.189	0.661	0.200	0.484
Min.	0.004	0.004	0.001	0.001	0.006	0.004	0.001	0.001
Max.	0.845	2.181	2.434	2.417	1.099	3.461	2.434	3.461
Count	99	98	99	100	94	93	292	291

Table 3 showed that the SO_2 levels in indoor air were relatively lower and meet the national air quality standard of China in general.

The Profile of $PM_{2.5}$ in Indoor Air Measured by Real-Time Monitoring 24 h Continuously

Figures 1 and 2 show that indoor air $PM_{2.5}$ levels vary much from time to time in each day and were closely associated with cooking activity of the subjects' indoors, while the peak level of $PM_{2.5}$ appeared at the time around breakfast, lunch and dinner for cooking. No differences of $PM_{2.5}$ level had been found between the bedrooms and kitchens of the study households.

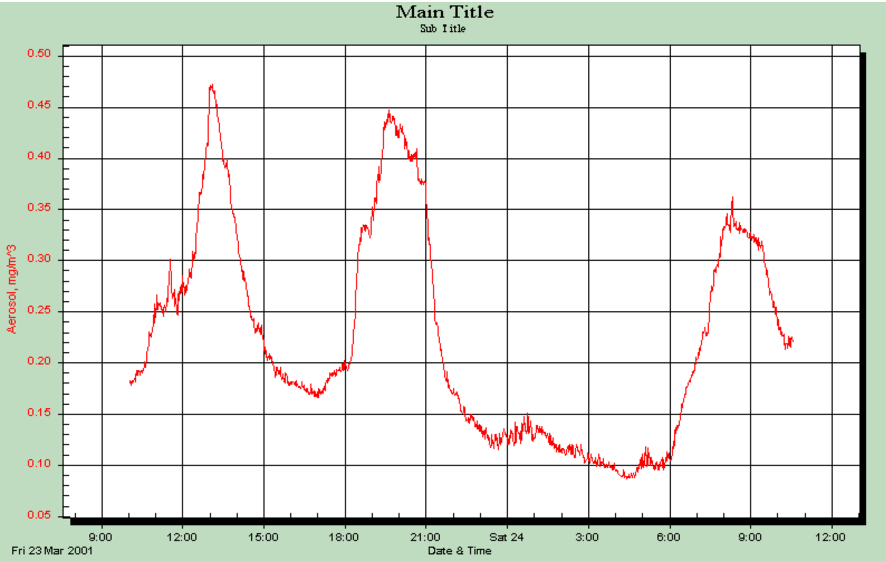

Figure 1 $PM_{2.5}$ level in 24 h in a bedroom in Shi Jing Shan district in Beijing (in winter)

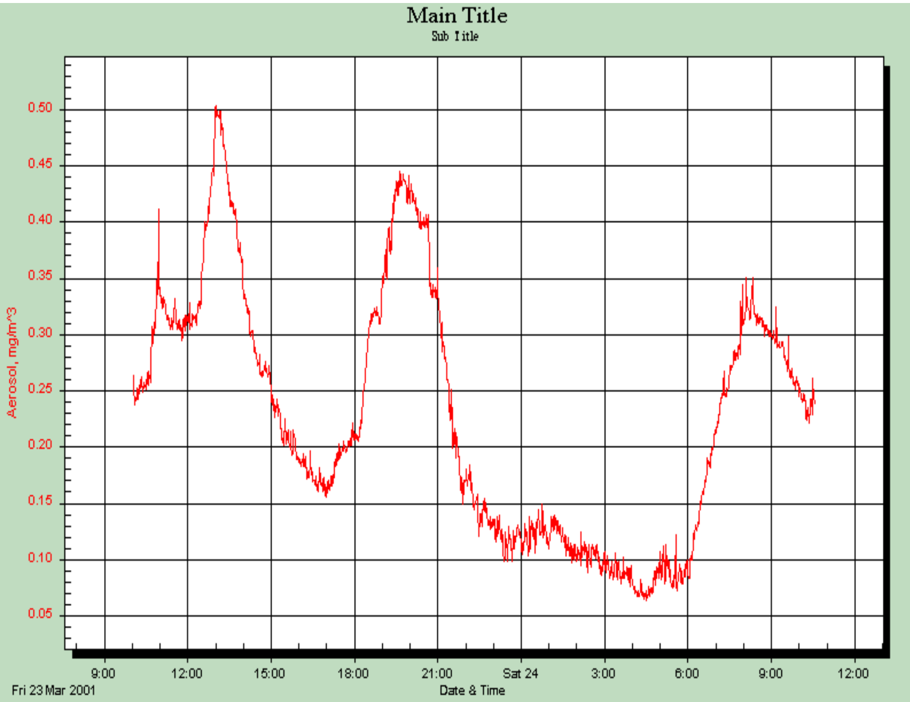

Figure 2 $PM_{2.5}$ level in 24 h in a kitchen in Shi Jing Shan district in Beijing (in winter).

The Effects of Indoor Air Pollution on Respiratory Symptoms of the Subjects with Logistic Regression Analysis

We could see from Table 4 that the concentrations of indoor air PM_{10}, $PM_{2.5}$ and SO_2 were not significantly associated with respiratory symptoms of the subjects in our study, but smoke and cooking indoors were positive correlated with asthma and breathing hard.

Table 4 Coefficients of logistic regression for respiratory symptoms and indoor air pollution and other environmental factors

Variables	Cough	Phlegm	Asthma	Breathing short
Intercept	–2.3494	–1.4326	–2.5023	–1.8412**
PM_{10}	0.5473	–0.1010	1.5789	1.4811
$PM_{2.5}$	–0.3231	0.4700	–2.7718	–1.6727
SO_2	–0.0267	–0.0394	–0.1220	1.0048
Exp. to occup. dust		0.4816**	0.6822*	0.1579
Exp. to chemicals	0.5650**	0.3329	0.2164	–0.0642
Smoking	0.6498**	1.0195**	0.4245	–0.4009*
Passive smoking	0.4653**	–0.0201	0.2571	0.2228*
Much time to cooking	0.000928	–0.00069	0.0119*	0.00711**
Smoke exhauster in kitchen	–0.2730	–0.4170**	–0.0809	0.4238**
Cooking oil indoors	–0.2569	0.1618	–0.2516	0.4215*

$*P<0.05$; $**P<0.01$.

DISCUSSION

Indoor Air Level of PM_{10} and $PM_{2.5}$ in Urban Areas of Beijing and its Character

Recently, studies focusing on health effects of the fine particulate ($PM_{2.5}$) have become a hotspot of air pollution research in developed countries. But there are also few studies reporting on the level of indoor air PM_{10} and $PM_{2.5}$ right now in China, especially for $PM_{2.5}$. The results of our study suggest that there is serious indoor air pollution of PM_{10} and $PM_{2.5}$ in the households of urban areas in Beijing, with about two-thirds of the PM_{10} average level in bedrooms and kitchens of the subjects being over the national air quality standard of China. It was strongly associated with cooking, smoking and heating indoors. No difference has been found about the PM_{10} and $PM_{2.5}$ levels between the bedrooms and the kitchens of the households, the reasons for it should be further studied in future.

The Relations between the Indoor Air Pollution and Respiratory Symptoms

Recent epidemiological studies have demonstrated that increased exposure to PM_{10}/$PM_{2.5}$ can increase the frequency of respiratory diseases such as asthma, acute respiratory infections, but similar result has not been found in our study. Our study has found that smoking, cooking and occupational exposure to dust were associated significantly with cough, phlegm and asthma attack and breathing short, which is consistent with studies in the developed countries (Viegi *et al.*, 1991). The reason for this is because of at least two points: one is data of PM_{10} and $PM_{2.5}$ levels are not suitable to logistic analysis; another is the sample sizes of PM_{10} and $PM_{2.5}$ are not good enough for so much variances of the measure.

CONCLUSION

The level of indoor air PM_{10} and $PM_{2.5}$ are relatively higher in urban areas of Beijing, but it was statistically significant with respiratory symptoms of the subjects.

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