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$PM_{2.5}$ Concentrations Indoors and Outdoors in Heavy Air Pollution Days in winter

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Abstract

The epidemiological studies have indicated that $PM_{2.5}$ can increase morbidity and mortality, damage the respiratory system and the cardiovascular system, and affect the immune function. The objectives of this study are to understand $PM_{2.5}$ pollution status in the households when the heavy air pollution occurs in the winter and the correlation of indoor $PM_{2.5}$ pollution with outdoor, and to find out the effect of indoor human activities on the changes of indoor $PM_{2.5}$ concentrations. Indoor $PM_{2.5}$ concentrations were measured using CLH-2000 portable $PM_{2.5}$ detector in the four households in December 7-8, 2013. When sampling indoors, the pattern of activity questionnaire was completed. The results showed that the average of indoor $PM_{2.5}$ concentration is in the range of 112-416μg/m^3, and the pollution level is more serious at 4 homes in Beijing in winter. Outdoor pollution, human activities and behaviors are the sources of indoor $PM_{2.5}$ at homes. Human activities (cooking, smoking and cleaning) have more contribution to indoor $PM_{2.5}$ than outdoor pollution. In general, the effect of indoor human activities on $PM_{2.5}$ concentration is stronger than outdoor pollution and air cleaner.

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Keywords: $PM_{2.5}$; Indoors; Air pollution; I/O ratio; pattern of activity

1. Introduction

The epidemiological studies have indicated that $PM_{2.5}$ can increase morbidity and mortality, damage the respiratory system and the cardiovascular system, and affect the immune function and so on [1]. The research showed that the people spent more than 90% time indoors [2]. Indoor environment is particularly important to the human health. The research on indoor particulate matter is getting more and more attention.

The objectives of this study are to understand $PM_{2.5}$ pollution status in the households when the heavy air pollution occurs in the winter and the correlation of indoor $PM_{2.5}$ pollution with outdoor, and to find out the effect of indoor human activities on the changes of indoor $PM_{2.5}$ concentrations.

2. Methods

Outdoor sampling point is Guanyuan environmental pollution monitoring station, Xicheng district, Beijing. [1]Indoor sampling point is in the living room, about 1.5m height from the ground. The linear distance from indoor sampling point to outdoor sampling point is about 1km. The portable PM2.5 sampler (CLH-2000, the flow rate is

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500 mL/s; Xuzhou Environmental Protection Equipment co., LTD.) was used to measure indoor PM2.5 concentration. Sampling time was from 9:00 to 21:00. When measuring indoor PM2.5 concentration, the questionnaire was filled once every 30min. The investigation contents include the spent time indoors and outdoors for the study object, and indoor activity pattern (smoking, cooking, cleaning, and using air cleaner or not).

3. Results

During the sampling outdoor $PM_{2.5}$ concentration and meteorological parameters are shown in *Table 1*. Outdoor $PM_{2.5}$ concentrations varied a lot in 2d sampling period. In December 7 the wind speed was low, $PM_{2.5}$ concentration remained high level. In December 8 the wind speed was gradually strengthen and reached the maximum value-35m/s. The strong wind made $PM_{2.5}$ concentration to fall sharply (from 429μg/m^3 to 38μg/m^3). Therefore, the meteorological parameters have a significant impact on outdoor $PM_{2.5}$ concentration.

Table 1. The $PM_{2.5}$ concentration and meteorological parameters outdoors

Time	$PM_{2.5}$, μg/m^3		Temperature, ℃		Relative humidity, %		Wind speed, m/s	
	average	range	average	range	average	range	average	range
December 7	321	206-422	3.2	1-6	62.2	47-78	3.6	1-8
December 8	171	38-429	7.3	3-11	29.8	15-61	19.2	5-35

The average of indoor $PM_{2.5}$ concentration at home A, B, C and D was 375μg/m^3, 416μg/m^3, 112μg/m^3 and 382μg/m^3, respectively. The range was 193μg/m^3-600μg/m^3, 251μg/m^3-576μg/m^3, 32-294μg/m^3 and 240μg/m^3-571μg/m^3, respectively. Indoor $PM_{2.5}$ concentrations varied very much due to the differences of indoor environment and individual behavior, see Figure 1. In December 8, although outdoor $PM_{2.5}$ concentration was low, indoor $PM_{2.5}$ concentration reached 554μg/m^3 at home D. High particulate matter concentration may be associated with indoor emission source. Indoor $PM_{2.5}$ concentration at home C was lower three to four times than other three homes, and the reason is to use the air purifier equipment at home C.

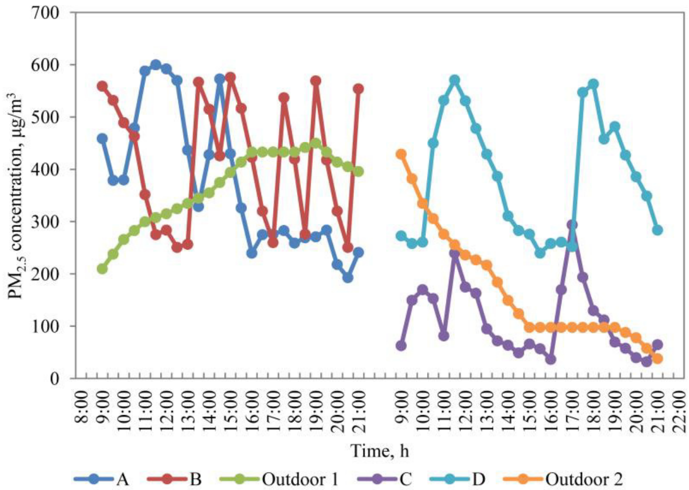

Figure 1. Indoor $PM_{2.5}$ concentration at homes

Combining with the questionnaire of human activity pattern, indoor activities can be classified into no people time, sleeping time, cleaning time, cooking time, and smoking time. Indoor $PM_{2.5}$ concentrations were obvious different for all kinds of activities. The average of indoor $PM_{2.5}$ concentration was 121μg/m^3 when no people indoors, the average of indoor $PM_{2.5}$ concentration was 347μg/m^3 when sleeping, the average of indoor $PM_{2.5}$ concentration was 394μg/m^3 when cleaning, the average of indoor $PM_{2.5}$ concentration was 408μg/m^3 during cooking, and the average of indoor $PM_{2.5}$ concentration was 524μg/m^3 when smoking. Therefore, indoor $PM_{2.5}$ concentration is correlated with human activities.

In general, the different homes have a similar trend of indoor $PM_{2.5}$ concentration in the similar activity time, such as the cooking, cleaning and smoking etc. From the low $PM_{2.5}$ concentration increasing to the maximum value, the time is about 1h. Because of the difference of preparation methods of foods and the using fuels, the peak concentrations was different, most of the peak concentrations were about 520μg/m^3, but the peak $PM_{2.5}$ concentration can be as high as 600μg/m^3 sometimes.

The I/O ratio (the ratio of indoor and outdoor $PM_{2.5}$ concentrations) in the different activity pattern can be seen in Table 2. The average of I/O ratio at home A, B, C and D was 1.1, 1.2, 0.84 and 3.1, respectively, and the range of I/O ratio was 0.48-2.2, 0.60-2.7, 0.18-3.0 and 0.75-7.5, respectively. The average of I/O ratio was 0.61, and the range was 0.55-0.64 when no people indoors for home A at 16:00-17:00; the average of I/O ratio was 0.21, and the range was 0.08-0.50 when no people indoors and using the air cleaner for home C at 12:30-16:00. The average of I/O ratio was 1.2, and the range was 0.64-2.1 when sleeping. The average of I/O ratio was 1.4, and the range was 0.40-2.0 when cleaning. The average of I/O ratio was 2.0, and the range was 1.2-4.9 when smoking. The average of I/O ratio was 2.3, and the range was 0.74-5.7 when cooking. Therefore, the human activities, cooking, smoking and cleaning are the main emission sources of indoor $PM_{2.5}$, and the source strength is cooking>smoking>cleaning.

Table 2. The I/O ratio in the different activity pattern

Home	Time	Indoor concentration, μg/m^3 (Smoking)	Outdoor concentration, μg/m^3	I/O ratio
B	9:00	559	210	2.7
	11:00	352	300	1.2
	13:30	567	345	1.6
	15:00	576	394	1.5
	17:30	537	433	1.2
	19:00	569	450	1.3
	21:00	554	396	1.4
D	19:00	482	98	4.9

Home	Time	Indoor concentration, μg/m^3 (Cooking)	Outdoor concentration, μg/m^3	I/O ratio
A	9:00	459	210	2.2
	9:30	379	238	1.6
	10:00	380	266	1.4
	14:00	428	355	1.2
	14:30	573	375	1.5
C	11:30	240	256	0.94
	12:00	175	236	0.74
	16:30	170	98	1.7
	17:00	294	98	3.0
D	11:30	571	256	2.2
	12:00	531	236	2.2
	17:30	547	98	5.6
	18:00	563	98	5.7

Home	Time	Indoor concentration, μg/m^3	Outdoor concentration, μg/m^3	I/O ratio

		(Cleaning)		
A	10:30	479	283	1.7
	11:00	588	300	2.0
	11:30	600	308	2.0
	12:00	592	315	1.9
	15:30	326	414	0.79
C	9:30	150	382	0.39
	10:00	170	335	0.51
	17:30	194	98	2.0
D	10:30	450	306	1.5

Home	Time	Indoor concentration, μg/m^3 (Sleeping)	Outdoor concentration, μg/m^3	I/O ratio
A	12:30	570	325	1.8
	13:00	437	335	1.3
B	12:30	251	325	0.77
	13:00	257	335	0.77
D	9:00	273	429	0.64
	9:30	258	382	0.68
	10:00	261	335	0.78
	13:00	429	217	2.0
	13:30	387	184	2.1

Home	Time	Indoor concentration, μg/m^3 (No people)	Outdoor concentration, μg/m^3	I/O ratio
A	16:00	240	433	0.55
	16:30	275	433	0.64
	17:00	276	433	0.64
C	9:00	63	210	0.30
	12:30	163	325	0.50
	13:00	95	335	0.28
	13:30	72	345	0.21
	14:00	64	355	0.18
	14:30	49	375	0.13
	15:00	66	394	0.17
	15:30	57	414	0.14
	16:00	37	433	0.09

4. Discussion

Most of the research showed that indoor human activities were the main source of indoor particulate matter concentrations [3-6]. Human activities, such as cleaning [7, 8] and cooking [9] are the main sources of indoor $PM_{2.5}$. This study showed that indoor human activities have more contribution to indoor $PM_{2.5}$ pollution than outdoor pollution, and it is similar results with other studies [10, 11]. By the rough estimation, cooking may make indoor $PM_{2.5}$ concentration to increase 3.4 times, cleaning can make indoor $PM_{2.5}$ concentration to increase

3.2 times, and smoking can make indoor $PM_{2.5}$ concentration to increase 4.3 times. Other studies also proved this point [12, 13].

Both outdoor and indoor $PM_{2.5}$ concentrations exceeded the national standard in Beijing at the heating season in the most cases, and $PM_{2.5}$ pollution is serious. $PM_{2.5}$ pollution has a greater impact on the health of the elderly and children. Therefore, $PM_{2.5}$ pollution should be caused more attention by all of us.

5. Conclusions

Indoor $PM_{2.5}$ concentration average is in the range of 112-416μg/m^3, and the pollution level is more serious at 4 homes in Beijing in winter. Outdoor pollution, human activities and behaviors are the sources of indoor $PM_{2.5}$ at homes. Human activities (cooking, smoking and cleaning) have more contribution to indoor $PM_{2.5}$ than outdoor pollution. When no people indoors, outdoor pollution is the main contribution of indoor $PM_{2.5}$.

The average of I/O ratio was in the range of 0.84-3.1 at 4 homes. The I/O ratio is much less than 1 when no people indoors. Indoor human activities, such as smoking, cooking and cleaning, can increase indoor $PM_{2.5}$ concentration to higher level, so the I/O ratio is much more than 1 when cooking, smoking and cleaning. Indoor air cleaner can decrease the I/O ratio when there is no people. In general, the effect of indoor human activities on $PM_{2.5}$ concentration is stronger than outdoor pollution and air cleaner.

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