

A cross-sectional study on levels of second-hand smoke in restaurants and bars in five cities in China

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ABSTRACT

Objectives: To assess indoor second-hand smoke (SHS) exposure in restaurants and bars via PM_{2.5} (fine particles 2.5 µm in diameter and smaller) level measurements in five cities in China.

Methods: The study was conducted from July to September in 2007 in Beijing, Xi'an, Wuhan, Kunming and Guiyang. Portable aerosol monitors were used to measure PM_{2.5} concentrations in 404 restaurants and bars. The occupant density and the active smoker density were calculated for each venue sampled.

Results: Among the 404 surveyed venues, 23 had complete smoking bans, 9 had partial smoking bans and 313 (77.5%) were observed to have allowed smoking during sampling. The geometric mean of indoor PM_{2.5} levels in venues with smoking observed was 208 µg/m³ and 99 µg/m³ in venues without observed smoking. When outdoor PM_{2.5} levels were adjusted, indoor PM_{2.5} levels in venues with smoking observed were consistently significantly higher than in venues without smoking observed ($F = 80.49$, $p < 0.001$). Indoor PM_{2.5} levels were positively correlated with outdoor PM_{2.5} levels (partial $\rho = 0.37$, $p < 0.001$) and active smoker density (partial $\rho = 0.34$, $p < 0.001$).

Conclusions: Consistent with findings in other countries, PM_{2.5} levels in smoking places are significantly higher than those in smoke-free places and are strongly related to the number and density of active smokers. These findings document the high levels of SHS in hospitality venues in China and point to the urgent need for comprehensive smoke-free laws in China to protect the public from SHS hazards, as called for in Article 8 of the Framework Convention on Tobacco Control, which was ratified by China in 2005.

Second-hand smoke (SHS) is the combination of smoke emitted from a cigarette or other burning tobacco products and the smoke exhaled by the smoker. SHS is a complex mixture of gases and particles, with the particles of fine to ultrafine size ranging from 0.02 µm to 2 µm.¹ These particles can be easily inhaled deep into lungs causing various diseases to multiple systems and organs in humans. Although not specific to SHS, large quantities of respirable particles (RSP) are emitted from burning cigarettes. Xiu *et al* found that indoor RSP levels in offices with smoking occurring were three times higher than levels with no smoking.² Alpert *et al* also found that 93% of the indoor RSP were attributable to tobacco smoke during active smoking.³ Measuring the concentration of indoor fine particles with mean aerodynamic diameter no more than 2.5 µm (PM_{2.5}), which are recognised

as a significant threat to public health, offers another assessment of indoor air pollution.⁴⁻⁶

SHS exposure is a completely preventable health risk factor, and there is no known safe level of SHS exposure.⁷ In May 2003, the member countries of the World Health Organization (WHO) adopted a historic tobacco control treaty, the Framework Convention on Tobacco Control (FCTC). Article 8 of FCTC calls for the expansion of smoke-free places at the national and other jurisdictional levels in signatory countries to protect people from SHS hazards. On 4 July 2007, the second session of Conference of the Parties to the WHO FCTC drew up Guidelines on Protection from Exposure to Tobacco Smoke to assist parties in meeting their obligations under Article 8 of the WHO FCTC and to identify key elements of legislation necessary to effectively protect people from exposure to SHS.

In China, there are 350 million smokers. The overall prevalence is 35.8% (66.0% of males and 3.1% of females),⁸ which means that the risk for non-smokers to be exposed to SHS is very high. Some national prevalence studies in China reported that 53.0% of non-smokers in China were regularly exposed to SHS in 1996,⁹ and 51.9% in 2002.⁸ SHS exposure occurs in various places, and the National Prevalence Survey in 2002 showed 82% of those passive non-smokers reported their SHS exposure in homes, 67% in public places and 35% in workplaces.⁸

Hospitality venues—restaurants, bars and night-clubs, for example—are both workplaces for hospitality workers and places where the public spend, potentially, a considerable amount of time. Due to the lack of smoking regulations in these kinds of venues in China, hospitality workers and patrons alike are exposed to high levels of SHS. A study conducted in Beijing in 2004 on SHS levels of 14 public places, including 5 restaurants, showed that airborne nicotine concentrations in the 5 restaurants ranged from 2.07 to 28.72 µg/m³, with a median of 4.91 µg/m³, more than 14 times the concentration in hospitals and over 7 times that in schools.¹⁰ A cross-sectional study of SHS in 92 restaurants and bars in Beijing China in 2006 showed that the average of the indoor PM_{2.5} levels in venues where smoking was allowed was 280 µg/m³, 200% higher than that in venues with smoking restrictions (93 µg/m³).¹¹

In China, objective assessments of SHS exposure are quite limited, especially in hospitality venues. As a party to the WHO FCTC, China is obligated to take effective measures to protect its public from SHS exposure as stated in Article 8. In recognition of its FCTC obligations, and as host of

the 2008 Olympic Games, China promised that the Games would be smoke-free. Mostly driven by these two factors, China initiated a series of tobacco control activities in public places including hospitality venues to reduce SHS exposure. This study aims to describe a convenient and practical method to assess indoor SHS exposure in China and to provide scientific evidence for the Chinese government to adopt effective measures to reduce or eliminate SHS hazards in hospitality venues.

METHODS

Sampling

The study was conducted from July to September in 2007 in five cities in China: Beijing, the capital of China, located in northern China; Xi'an, a city in the Central Western part of China; Wuhan, a city in the Central part of China; and Kunming and Guiyang, two cities in southwest China.

In each city, hospitality venues were sampled from two districts following three steps. First, all the hospitality venues were divided into five categories according to Standards of Industry Classification issued by the National Statistics Agency of China, which are Chinese restaurants, Chinese fast food restaurants, Western restaurants, Western fast food restaurants and bars.¹² Second, venues were sampled from each of the five restaurant types in the ratio 10:1:1:1:3 according to the number of restaurants and bars listed as hospitality venues on Yellow Pages websites; 50 Chinese restaurants, 5 Chinese fast food restaurants, 5 Western restaurants, 5 Western fast food restaurants and 15 bars were selected in each city. Third, restaurant size and average expenses per patron per visit according to the owners' reports were taken into account to keep a balance to some extent in these two aspects for the sampled venues. Via this procedure, a total of 405 hospitality venues were selected and surveyed in the 5 cities.

Instruments and measures

Fine respirable particles ($PM_{2.5}$) were used as the proxy measure for SHS. Data collectors in each city were trained directly to use a standard measurement protocol, which was consistent to the method detailed in the web-based training course (<http://www.tobaccofreeair.org>) developed by the Roswell Park Cancer Institute, New York, USA, and used in previous studies.⁵ Portable battery-operated aerosol monitors (TSI SidePak AM510 Personal Aerosol Monitors; TSI Incorporated, Shoreview, Minnesota, USA) fitted with 2.5 μm impactors were used to sample the outdoor and indoor $PM_{2.5}$ levels in each venue. The airflow rate was set at 1.7 litre/min using a Drycal DC Lite (BIOS, Butler, New Jersey, USA) flowmeter to ensure proper operation of the size-selective impactor. The calibration factor setting of 0.32, suitable for SHS,^{5, 13} was used and the monitor was set to a 1-min data log interval, which averages the 60 previous 1-s measurements. The portable device was calibrated to zero prior to each use by attaching a high efficiency particulate air filter according to the manufacturer's instructions.

To avoid disturbing people's normal behaviour during sampling, the monitor was placed in a bag with a short length of Tygon tubing (Saint-Gobain, Paris, France) attached to the inlet and left protruding on the outside. Logging of $PM_{2.5}$ levels began at least 5 min outside of a venue before entering to provide baseline measurements. Since the monitor was in a bag worn by a data collector, it sampled the air from the zone around the data collector's waist. After outdoor measurements, the monitor kept logging when collectors entered a venue as

patrons: they bought some food or drink and stayed for at least 30 min for indoor air sampling, and they tried to find a table as close as possible to the central position of the venue. The bag was placed on the table rather than on the floor or a chair, so that the air being sampled was at the level of occupants' normal breathing zone. The number of patrons and the number of burning cigarettes were recorded at the time of entry into the venue, at the time of exiting and every 15 min during the visit itself. The volume of each venue was calculated by using a sonic device (Zircon Corporation, Campbell, California, USA) to measure each of the linear dimensions of the room. If the room was irregular in shape, making it impossible to measure the volume using the sonic device, then the dimensions and volume were estimated by the trained data collectors. If a venue had a partial smoking ban, then the measurements were taken in the non-smoking area. Times of entry and exit, counts and occupants' smoking behaviours (eg, number of lit cigarettes) were recorded.

Data analysis

Data from each venue visit was downloaded to a computer using the TSI Trackpro V 3.4.1 software (TSI, Shoreview, Minnesota, USA). For each venue, the data logged during the minute of entry and exit was removed so that the remaining data points were either all from the indoor of a venue or all from its outdoor. These were averaged respectively to provide a mean $PM_{2.5}$ level inside or outside the venue. The $PM_{2.5}$ data from a bar in Wuhan was excluded from analysis due to its unexplainable extremely high indoor $PM_{2.5}$ level considering the smokers, patron numbers, outdoor $PM_{2.5}$ levels and other possible $PM_{2.5}$ sources; thus, data from 404 venues were finally used for analysis.

For the $PM_{2.5}$ data was log normally distributed, all statistical analyses used log-transformed $PM_{2.5}$ concentrations. Pearson χ^2 tests and Fisher exact tests were used to test proportion differences; geometric means of $PM_{2.5}$ levels were compared between different cities, different venue types, and outdoors versus indoors using analysis of variance (ANOVA) tests and Student t tests. Univariate analysis of variance (UNIANOVA) tests were used to compare the indoor $PM_{2.5}$ levels in different venues with or without smoking observed after controlling for outdoor $PM_{2.5}$ levels.

The occupant density (OD: the number of occupants per 100 m^3) and the active smoker density (ASD: the number of burning cigarettes per 100 m^3) were calculated for each establishment sampled. Spearman rho as well as partial correlation analyses were performed to determine the correlations between the OD, ASD, outdoor $PM_{2.5}$ levels and indoor $PM_{2.5}$ levels. Additionally, linear regression models were used to examine the relationship between indoor $PM_{2.5}$ levels with outdoor $PM_{2.5}$ levels, ASD, OD, different cities and different types of venues.

RESULTS

Table 1 presents the general characteristics of the hospitality venues where samples were taken in the 5 cities. The numbers of the five types of hospitality venues in each city were basically consistent with the proportion of 10:1:1:1:3 (as described in the Methods section), and the Pearson χ^2 test (χ^2 (16) = 1.98, p = 1.00) indicated no statistical differences among the proportions of different types of restaurants and bars in different cities. Maximum occupancy at 42.6% of the venues was ≤ 100 patrons, while 33.2% of venues had a capacity of 101 to 300

Table 1 Characteristics of hospitality venues surveyed in five cities during July to September 2007

	Beijing, n (%)	Wuhan, n (%)	Xi'an, n (%)	Kunming, n (%)	Guiyang, n (%)	Total, n (%)
Venue type:						
Chinese dinner	52 (61.2)	50 (63.3)	52 (64.2)	50 (63.3)	49 (61.3)	253 (62.6)
Chinese fast food	8 (9.4)	5 (6.3)	5 (6.2)	5 (6.3)	6 (7.5)	29 (7.2)
Western dinner	6 (7.1)	5 (6.3)	4 (4.9)	6 (7.6)	5 (6.3)	26 (6.4)
Western fast food	5 (5.9)	5 (6.3)	5 (6.2)	4 (5.1)	6 (7.5)	25 (6.2)
Bar	14 (16.5)	14 (17.7)	15 (18.5)	14 (17.7)	14 (17.5)	71 (17.6)
Holding capacity:						
≤ 100 seats	36 (42.4)	35 (44.3)	40 (49.4)	38 (48.1)	23 (28.8)	172 (42.6)
101–300 seats	27 (31.8)	28 (35.4)	26 (32.1)	19 (24.1)	34 (42.5)	134 (33.2)
≥ 301 seats	14 (16.5)	16 (20.3)	8 (9.9)	13 (16.5)	23 (28.8)	74 (18.3)
Missing	8 (9.4)	0 (0.0)	7 (8.6)	9 (11.4)	0 (0.0)	24 (5.9)
Average expense per patron:						
≤ 20 RMB	16 (18.8)	17 (21.5)	31 (38.3)	37 (46.8)	34 (42.5)	135 (33.4)
21–50 RMB	43 (50.6)	47 (59.5)	30 (37.0)	27 (34.2)	30 (37.5)	177 (43.8)
≥ 50 RMB	26 (30.6)	14 (17.7)	17 (21.0)	12 (15.2)	14 (17.5)	83 (20.5)
Missing	0 (0.0)	1 (1.3)	3 (3.7)	3 (3.8)	2 (2.5)	9 (2.2)
Smoking ban:						
Complete	7 (8.2)	2 (2.5)	8 (9.9)	3 (3.8)	3 (3.8)	23 (5.7)
Partial	2 (2.4)	4 (5.1)	1 (1.2)	2 (2.5)	0 (0.0)	9 (2.2)
No bans	76 (89.4)	73 (92.4)	72 (88.9)	73 (93.7)	77 (96.3)	372 (92.1)
Total	85 (21.0)	79 (19.8)	81 (20.0)	79 (19.5)	80 (19.8)	404 (100.0)

patrons. About 44% of the venues had an average expense per patron per visit of 21–50 RMB and a third of venues had an average expense per patron of 20 RMB or lower, which suggests that most of the venues surveyed were frequented by people with moderate incomes. Only 23 restaurants completely banned smoking, and 7 restaurants and 2 bars had non-smoking areas, 4 of which were not completely separated from the smoking areas. In 1 of the 23 venues with complete smoking bans and in 5 of the 9 venues with partial smoking bans, smoking occurred during sampling, and only in 1 venue was there an intervention to stop the smoking.

Although there were numerically more restaurants with smoking bans in Beijing and Xi'an than the other cities, a Fisher exact test showed that there were no statistically significant overall differences across the five cities in the proportions of venues with no smoking regulations ($\chi^2(8) = 10.12$, $p = 0.199$).

Table 2 presents the data collected from the 404 hospitality venues, which includes active smoking behaviours observed during sampling and geometric means of outdoor and indoor $PM_{2.5}$ levels. Smoking was observed in 77.5% (313) of the surveyed venues during sampling and the overall average active smoker density of these 313 venues was 1.0 burning cigarettes per 100 m^3 . Pairwise comparisons showed no statistically significant differences in average ASD among the five cities, while it was statistically higher in bars (1.9) than that in

restaurants (0.8) ($t(76.67) = 3.84$, $p < 0.001$, data not shown). The outdoor and indoor $PM_{2.5}$ levels were 79 $\mu g/m^3$ and 99 $\mu g/m^3$, respectively, in the 91 places without smoking observed, and they were 77 $\mu g/m^3$ and 208 $\mu g/m^3$, respectively, in the 313 smoking venues. Follow-up UNIANOVA tests showed that in each city, when the outdoor $PM_{2.5}$ levels were controlled for as a covariate, the indoor $PM_{2.5}$ levels of venues with active smoking observed were consistently significantly higher than that of venues without smoking observed ($F = 80.49$, $p < 0.001$).

Table 3 shows the $PM_{2.5}$ levels in venues stratified by smoking bans and cities. A paired sample Student t test indicated that there was a significant statistical difference between indoor and outdoor $PM_{2.5}$ levels ($t(403) = 19.95$, $p < 0.001$). When stratified by whether smoking was observed or not, outdoor $PM_{2.5}$ levels were all similar to or lower than corresponding indoor $PM_{2.5}$ levels even in venues without smoking observed (table 2), but for venues with complete smoking bans, outdoor $PM_{2.5}$ levels were all similar to or higher than corresponding indoor $PM_{2.5}$ levels (table 3). This indicated that though there was no observed smoking during sampling in some venues allowing smoking, smoking might have happened before sampling or may have been missed by surveyors during observation, thus some $PM_{2.5}$ may be produced and kept inside the venue, leading to higher indoor $PM_{2.5}$ levels than outdoors.

Table 2 Observation of cigarette smoking and $PM_{2.5}$ (fine particles 2.5 μm in diameter and smaller) levels ($\mu g/m^3$) in restaurants and bars in five cities in China, July to September 2007

	Smoking not observed								Smoking observed							
	n		Outdoor $PM_{2.5}$ level			Indoor $PM_{2.5}$ level			n		Outdoor $PM_{2.5}$ level			Indoor $PM_{2.5}$ level		
			GM	Min	Max	GM	Min	Max			GM	Min	Max	GM	Min	Max
Beijing	23	0	101	41	234	131	45	662	62	0.9	134	45	377	275	54	1087
Wuhan	11	0	36	21	73	47	21	113	69	0.9	50	15	168	188	32	1424
Xi'an	25	0	184	120	317	196	58	523	56	1.5	193	32	309	404	165	1459
Kunming	16	0	29	19	44	40	16	206	63	1.1	33	12	105	110	14	1007
Guiyang	16	0	71	34	118	94	36	197	63	0.8	76	14	294	183	76	815
Total	91	0	79	19	317	99	16	662	313	1.0	77	12	377	208	14	1459

ASD, active smoker density: number of smokers per 100 m^3 ; GM, geometric mean with unit of $\mu g/m^3$.

Table 3 Geometric mean outdoor and indoor PM_{2.5} (fine particles 2.5 µm in diameter and smaller) levels (µg/m³) in venues with different smoking policies

	Complete bans			Partial bans			No bans			Total		
	PM _{2.5} level			PM _{2.5} level			PM _{2.5} level			PM _{2.5} level		
	n	Outdoor	Indoor	n	Outdoor	Indoor	n	Outdoor	Indoor	n	Outdoor	Indoor
Beijing	7	120	102	2	89	93	76	126	248	85	124	225
Wuhan	2	64	54	4	46	55	73	47	169	79	48	155
Xi'an	8	163	130	1	146	159	72	194	361	81	190	323
Kunming	3	26	19	2	32	162	74	32	94	79	32	90
Guiyang	3	110	106	0	–	–	77	74	163	80	75	160
Total	23	103	85	9	56	89	372	77	187	404	78	176

Table 4 shows the Spearman and partial correlation analysis of PM_{2.5} levels, ASD and OD. Indoor PM_{2.5} levels were significantly positively correlated with the outdoor PM_{2.5} level (Spearman rho = 0.58, p<0.001), ASD (Spearman rho = 0.52, p<0.001) and OD (Spearman rho = 0.33, p<0.001) for bivariate Spearman correlation analysis. Partial correlation analysis also showed significant positive correlation between indoor PM_{2.5} levels and outdoor PM_{2.5} levels (partial rho = 0.37 p<0.001), and between indoor PM_{2.5} levels and ASD (partial rho = 0.34, p<0.001). There existed no significant correlation between indoor PM_{2.5} levels and OD when the outdoor level and ASD were controlled.

Linear regression analysis (table 5) also indicate that when other factors were adjusted, the occupant density and city were not significantly statistically related to the indoor PM_{2.5} level, while the outdoor PM_{2.5} level, the active smoker density and the type of the venues were all significantly statistically related to the indoor PM_{2.5} level. When the active smoker density was removed from the second model, the R² decreased 16% (0.08/0.49 = 0.16), that is, without the predictor of the active smoker density, the model's potentiality to explain the variability of the indoor PM_{2.5} level decreased 16%, and this confirms the significant correlation between smoking and indoor PM_{2.5} level.

DISCUSSION

The study showed indoor PM_{2.5} levels are highly related to active smoking density. Places with smoking observed had much higher indoor PM_{2.5} levels than where no smoking was observed, while in places completely banning smoking, indoor PM_{2.5} levels were similar with outdoor levels. Even for venues with really high outdoor PM_{2.5} levels such as those in Xi'an and Beijing, indoor PM_{2.5} levels in venues with active smoking observed were significantly higher than in venues without smoking observed, adjusting for the outdoor PM_{2.5} levels. These indicate that although tobacco smoke is not the sole source of indoor PM_{2.5} in these venues, it is a major source.

PM_{2.5} levels in smoking places are consistently higher than that in smoke-free places across different countries. Hyland *et al* assessed indoor PM_{2.5} levels in 1822 public places across 32

countries from September 2005 to November 2006,⁵ using a standard measurement protocol that was adopted by this study. Figures 1 and 2 compare the results of that study and the present study. PM_{2.5} levels were measured in 92 hospitality venues in Beijing, China in 2006, we can see from fig 1 that, indoor PM_{2.5} levels either in places with smoking observed or in those without smoking observed were lower than indoor levels assessed in the present study. For places without smoking observed, this might be caused by the correspondingly higher outdoor PM_{2.5} levels possibly due to different seasons when the two studies were conducted. Venues in Beijing in this study were sampled in July and August, 2007, while the other study was conducted from February to August, which included the spring season with relatively lower outdoor PM_{2.5} levels. For places with smoking observed, the increased indoor PM_{2.5} level may be attributed to the correspondingly increased outdoor PM_{2.5} levels and the higher active smoker density. Additionally, indoor PM_{2.5} levels in places with smoking observed in this study are higher than that in places with almost equal ASD in the USA, and it is also higher in places without smoking observed than that in the USA and Ireland, which has enacted national comprehensive smoke-free indoor air laws (fig 2). This probably resulted from the higher outdoor PM_{2.5} levels in the five cities in China.

The only effective way to protect people from SHS is creating 100% smoke-free environments by implementing smoke-free laws and legislations. As of 1 April 2008, 15 countries and 45 regions, including Hong Kong, have enacted national or local comprehensive smoke-free laws and regulations in restaurants and bars.^{14 15} However, in mainland China, smoking regulations have been limited to places such as museums, libraries and waiting rooms, and only Guangzhou and Shenzhen in Guangdong Province prohibit smoking in restaurants with air conditioning.¹⁶ So, at the time of this study, hospitality venues in mainland China had smoking policies dependent on their owners. This study shows that only 23 of the 404 (5.7%) surveyed venues have smoking bans, and the indoor PM_{2.5} levels are very high in restaurants and bars, indicating that in mainland China, hospitality workers as well as patrons of these venues were at high risk of SHS exposure.

Table 4 Correlation analysis of indoor PM_{2.5} (fine particles 2.5 µm in diameter and smaller) level with outdoor PM_{2.5} level, ASD and OD

	Spearman correlation		Partial correlation analysis		
	rho	p Value	rho	p Value	Control variables
Outdoor PM _{2.5} level	0.58	<0.001	0.37	<0.001	ASD, OD
ASD	0.52	<0.001	0.34	<0.001	Outdoor PM _{2.5} level, OD
OD	0.33	<0.001	−0.05	0.352	Outdoor PM _{2.5} level, ASD

ASD, active smoker density: number of smokers per 100 m³; OD, occupant density: number of occupants per 100 m³.

Table 5 Regression models on the log value of indoor PM_{2.5} (fine particles 2.5 µm in diameter and smaller) level and its related influential factors

	Model 1			Model 2			Model 3		
	Coefficient	t	p Value	Coefficient	t	p Value	Coefficient	t	p Value
log(outdoor PM _{2.5} level)	0.52	4.43	0.000	0.54	15.06	0.000	0.57	14.84	0.000
ASD	0.41	6.45	0.000	0.41	7.30	0.000	–	–	–
OD	–0.03	–0.57	0.568	–	–	–	–	–	–
Restaurants or bars*	0.29	6.67	0.000	0.29	6.68	0.000	0.30	7.91	0.000
Type_ASD†	–0.20	–3.05	0.002	–2.0	–3.13	0.002	–	–	–
Wuhan	–0.31	–0.90	0.371	–	–	–	–	–	–
Xi'an	0.13	0.24	0.814	–	–	–	–	–	–
Kunming	–0.25	–0.67	0.502	–	–	–	–	–	–
Guiyang	0.41	1.04	0.299	–	–	–	–	–	–
Wuhan_pmout‡	0.39	1.28	0.202	–	–	–	–	–	–
Xi'an_pmout	–0.11	–0.20	0.845	–	–	–	–	–	–
Kunming_pmout	0.20	0.63	0.531	–	–	–	–	–	–
Guiyang_pmout	–0.43	–1.13	0.258	–	–	–	–	–	–
R ²		0.51			0.49			0.41	

All coefficients were standardised.

*Restaurants were coded as “0” (reference group) and bars were code as “1”; †interaction item of type of venues (restaurants or bars) with ASD; ‡interaction items of city and outdoor PM_{2.5} (pmout) levels.

ASD, active smokers density: number of smokers per 100 m³; OD, occupant density: number of occupants per 100 m³.

According to a study on hospitality patronage's attitudes towards smoke-free regulations in public places, only 30.0% and 19.8% of the patrons support completely banning smoking in restaurants or bars, respectively,¹⁷ and according to China Tobacco Control Report 2007, 52.2% of restaurant owners worry that smoking bans would reduce their revenues,¹⁸ a common belief that has been demonstrated to be false in systematic reviews of the economic impact of smoke-free laws across many jurisdictions in North America, Australia and other Western countries.¹⁹ These public opinion data as well as the observed smoking during samplings in non-smoking areas of 5 of the 9 venues with partial smoking bans and in 1 of the 23 venues with complete smoking bans demonstrate that challenges exist in China to implement legislation to protect the public from SHS hazards, particularly in hospitality venues.

This study demonstrated high levels of outdoor particle air pollution in some big cities in China and also demonstrated that levels are substantially worse than outdoors in indoor environments with smoking. There is currently a great deal of discussion on reducing the very high air pollution levels in China, which lead to over 400 000 premature deaths each year, and result in total associated health costs estimated at 157 to 520 billion Yuan in 2003.²⁰ In fact, billions of dollars were spent

to improve outdoor air quality for the recent 2008 Beijing Olympic Games.²¹ For exposed individuals, indoor smoking represents a harmful air pollution exposure at least as bad as outdoor pollution. However, comprehensive smoke-free indoor air policies are a simple, virtually cost-free solution that will dramatically reduce this exposure.

The current study measured PM_{2.5} exclusively, whereas other investigators have relied on nicotine measures for greater specificity to tobacco smoke exposure. PM_{2.5} is still an effective marker for SHS and also provides a more general air pollution measure that is effective for comparisons to other sources of pollution, such as outdoor particle levels. The laser photometer used in this study also provides continuous measurements demonstrating immediate changes in particle levels as conditions change or the device is moved between different microenvironments (fig 3).

Although this study adopted a convenience sample of venues, the results of this study were able to reflect the general situation of tobacco control and SHS exposures in hospitality venues in the five cities in China, as we have taken into account different types of venues, their possible proportions, their holding capacity and average expense.

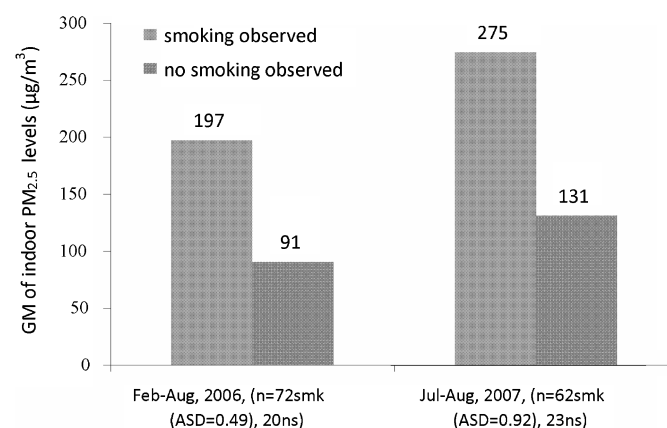


Figure 1 Geometric mean of PM_{2.5} levels of venues in Beijing by study (smk, smoking observed; ns, no smoking observed).

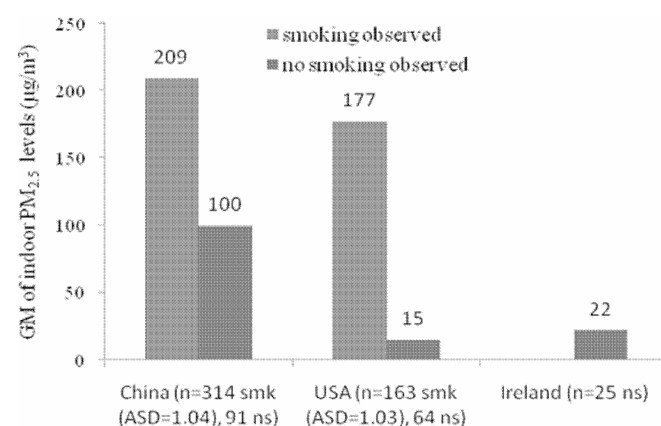


Figure 2 Geometric mean of indoor PM_{2.5} levels in China, USA and Ireland (smk, smoking observed; ns, no smoking observed).

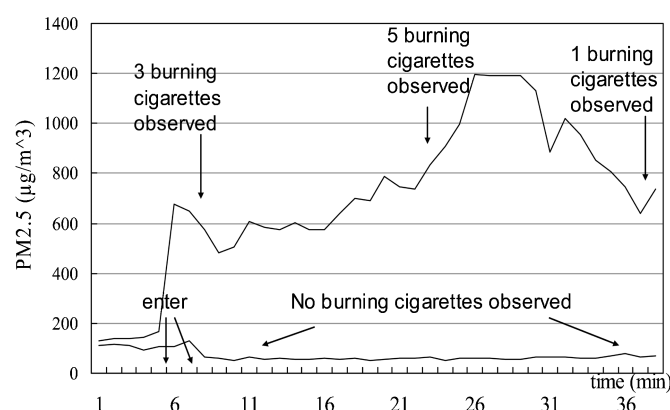


Figure 3 Real-time monitoring of PM_{2.5} levels in a restaurant with smoking observed and in another premises without smoking observed in Beijing.

What this paper adds

- The World Health Organization (WHO) Framework Convention on Tobacco Control (FCTC) calls for the expansion of smoke-free places in signatory countries to protect people from second-hand smoke (SH) hazards. However, up to the time when this study was conducted, smoking regulation was rare in hospitality venues in mainland China and quantitative assessments of SHS exposure in these venues were quite limited. This study is the largest study to assess indoor SHS exposure in hospitality venues in mainland China to date, and provides scientific evidence for the Chinese government to adopt effective measure to reduce or eliminate SHS hazards in hospitality venues.
- The results of this study show that, without smoking regulation, only a few (7.9%) of restaurants and bars had smoking regulations, and SHS exposure in these places was very high. The PM_{2.5} levels in venues with observed smoking was more than two times the level in venues without smoking, and only when smoking was completely banned could the indoor PM_{2.5} levels become similar to corresponding outdoor levels. These results underline the importance of a comprehensive smoke-free policy in accordance with the FCTC.
- For the purpose of the 2008 Olympic Games, China initiated a series of tobacco control activities in public places, including hospitality venues, to reduce SHS exposure; this study could provide baseline information for further studies aimed at evaluating the effectiveness of the tobacco control activities in hospitality venues.

Conclusions

PM_{2.5} levels in places with smoking are significantly higher than those in smoke-free places and are statistically associated with active smoker densities. SHS exposures are very serious in hospitality venues in the five cities in China and comprehensive

smoking regulations are commonly wanted to protect the public from SHS hazards.

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REFERENCES

1. Klepeis NE, et al. Determining size-specific emission factors for environmental tobacco smoke particles. *Aerosol Sci Tech* 2003;**37**:780–90.
2. Xiu GL, Zhao YN, Zhang DN, et al. Analysis on respirable particle matters pollutants in offices. *Shanghai Environ Sci* 1999;**18**:202–4.
3. Alpert H, Carpenter C, Travers MJ, et al. Environmental and economic evaluation of the Massachusetts smoke-free workplace law. *J Comm Health* 2007;**32**:269–81.
4. Vardavas CI, Kondilis B, Travers MJ, et al. Environmental tobacco smoke in hospitality venues in Greece. *BMC Pub Health* 2007;**7**:302.
5. Hyland A, Travers MJ, Dresler C, et al. A 32-country comparison of tobacco smoke derived particle levels in indoor public places. *Tob Control* 2008;**17**:159–65.
6. Semple S, Creely KS, Naji A, et al. Secondhand smoke levels in Scottish pubs: the effect of smoke-free legislation. *Tob Control* 2007;**16**:127–32.
7. US Department of Health and Human Services. *The health consequences of involuntary exposure to tobacco smoke: a report of the Surgeon General*. Atlanta, Georgia, USA: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, 2006.
8. Yang GH, Ma JM, Liu N, et al. Survey of smoking and passive smoking in Chinese population 2002. *Chinese J Epidemiol* 2005;**26**:77–83.
9. Yang GH. Smoking in China: findings of the 1996 National Prevalence Survey. *China Cancer* 1998;**7**:3–5.
10. Huang L, Yang G, Guo X, et al. Investigation of contamination level of environmental tobacco smoke in public places and workplaces. *J Environ Health* 2007;**24**:477–9.
11. Kang JM, Jiang Y, Lin XG, et al. Study on the level of environmental tobacco smoke in restaurants and bars in Beijing, China. *Chin J Epidemiol* 2007;**8**:738–41.
12. National Statistics Agency of China. Standards of Industry Classification [S/OL] [2008-4-15]. <http://www.stats.gov.cn/tjbz/hyflbz/> (accessed 15 April 2008).
13. Klepeis NE, Ott WR, Switzer P. Real-time measurement of outdoor tobacco smoke particles. *J Air Waste Man Assoc* 2007;**57**:522–34.
14. American Non-Smokers' Rights Foundation. Overview list - how many smokefree laws [EB/OL]. [2008-4-1] [2008-4-15]. <http://www.no-smoke.org/pdf/mediaordlist.pdf> (accessed 1 April 2008).
15. American non-smokers' rights foundation. Smokefree status of hospitality venues around the world [EB/OL]. [2008-4-1] [2008-4-15]. <http://www.no-smoke.org/pdf/internationalbarsandrestaurants.pdf> (accessed 1 April 2008).
16. Li YX, Jiang Y, Yang Y, et al. Analysis of laws and regulations on banning smoking in public places in China. *J Environ Health* 2007;**4**:221–3.
17. Ruiling L, Yan Y, Xurong L, et al. Knowledge and attitudes towards second hand smoking among hospitality patronage in five cities in China. *China J Epidemiol* 2008;**29**:421–5.
18. Office of Leading Group for FCTC Implementation, Ministry of Health, People's Republic of China. *China Tobacco Control Report 2007: create smoke-free environments, enjoy healthy life*. Beijing, China: Office of Leading Group for FCTC Implementation, Ministry of Health, People's Republic of China, 2007.
19. Hyland A, Vena C, Cummings MK. A review of the economic effect of smoke-free restaurant and bar policies on the hospitality economy. *Epidemiology* 2000;**11**:687.
20. The World Bank. *The cost of pollution in China: economic estimates of physical damages*. Washington, DC, USA: Rural Development, Natural Resources and Environment Management Unit, East Asia and Pacific Region, The World Bank, 2007.
21. Stewart E. IOC praises efforts to reduce air pollution in Beijing. <http://www.guardian.co.uk/world/2008/aug/07/china.olympics2008> (accessed 12 November 2008).

中国五城市餐厅和酒吧二手烟暴露水平的横断面研究

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摘要

目的: 通过检测PM_{2.5} (直径小于或等于2.5微米的细颗粒物) 水平来评估中国五城市餐厅和酒吧的室内二手烟暴露情况

方法: 本研究采用便携式气溶胶监测仪于2007年7至9月对北京、西安、武汉、昆明和贵阳五城市的404家餐厅和酒吧的PM_{2.5}浓度进行监测, 并通过观察估算每个场所监测期间的人员密度和吸烟者密度。

结果: 404家监测场所中有23家完全禁止吸烟, 9家部分禁止吸烟, 313家(77.5%) 在监测期间观察到吸烟。观察到吸烟的场所室内PM_{2.5}浓度的几何均值为208μg/m³, 未观察到吸烟的场所该值为99μg/m³。校正室外PM_{2.5}浓度后, 观察到吸烟的场所室内PM_{2.5}水平依然显著高于未观察到吸烟场所(F=80.49, p<0.001)。室内PM_{2.5}水平与室外PM_{2.5}水平呈正相关(偏相关系数=0.37, p<0.001), 与监测时吸烟者密度也呈正相关(偏相关系数=0.34, p<0.001)。

结论: 与其他国家的研究结果一致, 有人吸烟的场所室内PM_{2.5}浓度显著高于无人吸烟的场所, 并且与监测期间吸烟的人数和密度都显著相关。本研究结果显示中国餐饮场所二手烟暴露水平很高。正如2005年中国通过的《烟草控制框架公约》第8条所要求的, 中国亟需制定和实施全面禁止吸烟的法律法规, 以保护公众不受二手烟危害。

二手烟是由卷烟或其它烟草产品燃烧时释放的烟雾和吸烟者呼出的烟雾组成的混合物。二手烟成分复杂, 包含很多气体和颗粒成分, 其中的超细颗粒和细颗粒物直径为0.02μm至2μm¹, 可以轻易地被吸入肺部深处, 造成人体多系统和多器官的疾病。卷烟燃烧时会释放大量的可吸入颗粒物(RSP), 虽然其不只是来源于二手烟, 但修关利等人发现, 有人吸烟的办公室室内RSP水平是无人吸烟办公室的三倍²; 此外, Alpert等人也发现, 93%的室内可吸入颗粒都来自于二手烟³。二手烟中的可吸入颗粒物主要由平均空气动力学直径小于或等于2.5μm的细颗粒物(PM_{2.5})组成。PM_{2.5}是公认的公共卫生的一大威胁, 因此, 监测室内PM_{2.5}浓度是评估室内空气污染水平的一种重要手段⁴⁻⁶。

二手烟暴露是一种完全可以预防的健康危险因素, 对于二手烟暴露不存在所谓的“安全水平”⁷。2003年5月, 世界卫生组织(WHO)各成员国通过了一份历史性的烟草控制条约——《烟草控制框架公约》(以下简称《公约》)。《公约》第8条号召各缔约国在国家级和其它各级层面上扩大无烟场所覆盖面, 保护人们免遭二手烟暴露危害。2007年7月4日, WHO FCTC第二次缔约方会议通过了《防止暴露烟草烟雾指南》, 以帮助各缔约国履行WHO FCTC第8条规定的义务, 确定立法过程中的关键因素, 从而有效地保护人们免遭二手烟暴露危害。

中国有3亿5千万吸烟者, 总吸烟率高达35.8% (男性为66.0%, 女性为3.1%)⁸, 这也就意味着非吸烟者暴露于二手烟的风险非常高。中国几项关于吸烟率的全国性研究显示, 1996年, 53.0%的非吸烟者经常暴露于二手烟⁹, 2002年这一比例是51.9%⁸。二手烟暴露可以发生在各种场所, 2002年的全国吸烟流行病学调查显示, 有82%的非吸烟者在家中暴露于二手烟, 67%发生在公共场所, 35%发生在工作场所⁸。

餐饮场所(例如餐厅、酒吧、夜总会等)既是餐饮行业从业人员的工作场所, 又是公众可能停留很长时间的公共场所。在中国, 由于缺乏针对这些场所的禁烟规定, 餐饮行业工作人员和顾客都存在很高的暴露于二手烟的风险。2004年对北京14家公共场所(包括5家餐厅)的二手烟浓度监测表明, 5家餐厅空气尼古丁浓度从2.07到28.72μg/m³不等(中位数为4.91μg/m³), 是医院空气尼古丁浓度的14倍多, 学校的7倍多¹⁰。2006年对北京92家餐厅和酒吧的二手烟监测显示, 允许吸烟的场所的室内PM_{2.5}的平均水平高达280μg/m³, 比限制吸烟场所的高出200% (93μg/m³)¹¹。

在中国, 对于二手烟暴露, 特别是餐饮场所暴露的客观评估数据十分有限。作为WHO FCTC的缔约国之一, 中国有义务按照公约第8条规定, 采取有效的措施保护其公众免受二手烟暴露危害; 同时作为2008年奥运会的主办国, 中国承诺将本届奥运会办成无烟奥运。在这两个因素的推动下, 中国启动了一系列公共场所控烟活动, 包括降低餐饮场所的二手烟暴露。本研究的目的是介绍一种方便实用的评估二手烟暴露的方法, 为中国政府采取有效措施, 降低和消除餐饮场所二手烟暴露提供科学依据。

6 解锁

本篇论文按照BMJ杂志解锁办法可在网上免费下载, 详见: <http://tobaccocontrol.bmj.com/site/about/unlocked.xhtml>

方法

抽样

本研究于2007年7月至9月在以下五座城市开展：首都北京（北方）、西安（中西部）、武汉（中部）、昆明和贵阳（西南部）。

所调查场所从每个城市的两个区按以下三个步骤进行抽取：第一步，按照中国国家统计局的《行业分类标准》将所有餐饮场所分为五类，包括中式正餐厅、中式快餐厅、西式正餐厅、西式快餐厅和酒吧¹²；第二步，根据网络餐饮业黄页上所列出的不同类型餐厅和酒吧的数量，将五类场所按照10:1:1:1:3的比例进行抽样，即每个城市抽取50家中式正餐厅，5家中式快餐厅，5家西式正餐厅，5家西式快餐厅和15家酒吧；第三步，抽样时适当考虑餐厅规模和人均消费金额（根据经营者报告）。按以上的抽样方法，在五个城市共抽取405家餐饮场所。

仪器与检测指标

本研究采用可吸入细颗粒物（ $PM_{2.5}$ ）作为二手烟的标志物，并对每个城市的调查员直接使用如何进行标准监测方案的培训。该方案与美国纽约罗斯威尔帕克癌症研究所的在线培训课程（<http://www.tobaccofreeair.org>）所详尽描述的监测方法一致，并为以前的研究所采用过⁵。本研究使用TSI SidePak AM510个人型气溶胶监测仪对每个场所的室内外 $PM_{2.5}$ 进行实时采样。该监测仪由美国明尼苏达TSI公司出产，在用于测量二手烟中的颗粒物组分空气浓度时，需要使用2.5 μm 选择性撞击采样器，并将流速设为1.7升/分钟，校正系数设置为0.32^{5,13}，数据存取间隔设为每分钟一次，即存取每60秒测量数据的平均数。按照使用说明，每次开始采样前使用高效空气颗粒过滤器对监测仪进行调零。

为了避免采样过程对周围人产生干扰，监测仪被置于调查员所携带包内，其采样口与一短T软管相接，管另一头露出包外。开始监测后，先在餐馆或酒吧外测量至少5分钟作为室外基底值；由于监测仪是放在调查员所携带的包里，其主要是测量调查员腰部水平的 $PM_{2.5}$ 浓度。完成室外监测后，仪器继续采样的同时，调查员以顾客身份进入场所，进行一定的消费，并在场所内停留至少30分钟以监测室内 $PM_{2.5}$ 浓度。调查员尽量将装监测仪的包放在离场所中央最近的桌子上，并尽量避免将包放在地上或者椅子上，以监测顾客呼吸带水平的 $PM_{2.5}$ 浓度。调查员在监测室内 $PM_{2.5}$ 浓度的同时，分别于进入场所时、离开场所时和停留期间每隔15分钟记录顾客人数和吸烟人数；并通过声波测距仪（Zircon Corporation, Campbell, California, USA）测量场所的长宽高，以估计所监测场所的体积。如果场所形状不规则，无法使用声波设备测量其维度，则由调查员对其进行估计。如果场所部分禁止吸烟，则空气监测在其非吸烟区域进行。记录进入和离开时间，室内人数及燃着卷烟数。

数据分析

每次监测的数据通过TSI TrackproV3.4.1软件（TSI, Shoreview, Minnesota, USA）导入到电脑上。去掉进入和离开每个场所时1分钟的数据，以保证剩余数据全部是室内或室外数据；再分别计算室内和室外的 $PM_{2.5}$ 平均值。武汉一家酒吧的 $PM_{2.5}$ 监测数据被剔除，因为在考虑了其吸烟者人数、顾客数、室外 $PM_{2.5}$ 水平和其它可能的 $PM_{2.5}$ 来源后，依然无法解释其异常高的室内 $PM_{2.5}$ 测量值。因此，最终有404个场所的数据被用于分析。

由于 $PM_{2.5}$ 数据呈对数正态分布，所有统计分析采用经对数转换后的 $PM_{2.5}$ 浓度值。采用Pearson χ^2 检验和Fisher精确检验方法比较频数差别；采用方差分析（ANOVA）和Student t 检验比较不同城市、不同类型场所以及室内、室外 $PM_{2.5}$ 水平的几何均数；采用协方差分析（UNIANOVA），将室外 $PM_{2.5}$ 浓度作为协变量进行校正，比较观察到吸烟和未观察到吸烟的场所的室内 $PM_{2.5}$ 浓度。

计算每个场所监测时的人员密度（occupant density, OD：每100m³的人员人数）和吸烟者密度（active smoker density, ASD 每100m³内观察到的吸烟人数）。使用Spearman 相关和偏相关分析研究OD、ASD和室外 $PM_{2.5}$ 与室内 $PM_{2.5}$ 水平之间的相关性。此外，采用线性回归模型分析室内 $PM_{2.5}$ 水平同室外 $PM_{2.5}$ 水平、ASD、OD、不同城市 and 不同场所类型之间的关系。

结果

表1是五城市所监测餐饮场所的一般特征。每个城市所监测的五种类型餐饮场所的数目基本符合10:1:1:1:3的比例（如“方法”一节所述），同时Pearson χ^2 检验（ $\chi^2(16)=1.98$, $P=1.00$ ）显示，不同城市不同类型的餐厅和酒吧比例之间的差异不具有统计学意义。有42.6%的场所可容纳100名以下顾客，33.2%的场所可容纳101到300名顾客。约44%的场所人均消费金额为21-50元，1/3的场所人均消费金额不超过20元，表明所大部分监测场所的顾客为中等收入人群。只有23家餐厅完全禁烟，7家餐厅和2家酒吧设置了无烟区，其中4个场所的非吸烟区与吸烟区并未完全隔开。23家完全禁烟的场所中有1家，9家部分禁烟场所的非吸烟区中有5家在监测过程中观察到有人吸烟，其中仅有1家场所对吸烟者进行了劝阻。

虽然北京和西安禁烟的餐厅在数量上多于其它城市，但Fisher精确检验显示，各城市无烟场所所占的比例没有统计学差异（ $\chi^2(8)=10.12$, $P=0.199$ ）。

404家餐饮场所在监测时的观察吸烟情况和室内外 $PM_{2.5}$ 浓度见表2。77.5%（313个）的场所在监测时观察到有人吸烟，这313家场所的总体平均吸烟者密度为1.0，即每100m³有1.0 人在吸烟。两两比较发现五城市在平均吸烟者密度方面没有统计学差异，但酒吧的平均平均吸烟者密度（ASD=1.9）显著高于餐馆的（ASD=0.8）（ $t(76.67)=3.84$, $P<0.001$ ）。对91个没有观察到吸烟的场所，其室外和室内 $PM_{2.5}$ 几何均值分别是79 $\mu g/m^3$ 和99 $\mu g/m^3$ ，而对313个观察到吸烟的场所这两个值分别是77 $\mu g/m^3$ 和208 $\mu g/m^3$ 。进一步的协方差检验表明，将室外 $PM_{2.5}$ 水平作为一个协变量进行控制后，观察到吸烟的场所室内 $PM_{2.5}$ 水平普遍显著高于没有观察到吸烟的场所的水平（ $F=80.49$, $P<0.001$ ）。

表3显示的是按禁烟规定和城市分层后监测场所的 $PM_{2.5}$ 水平。配对Student t 检验显示，室内和室外的 $PM_{2.5}$ 水平具有统计学差异（ $t(403)=19.95$, $P<0.001$ ）。当按是否观察到吸烟进行分层时，未观察到吸烟的场所室外 $PM_{2.5}$ 水平都接近于或低于相应的室内 $PM_{2.5}$ 水平（见表2），但是对于完全禁烟的场所，室外 $PM_{2.5}$ 水平则都接近于或高于相应场所的室内 $PM_{2.5}$ 水平（见表3）。这表明，虽然在有些允许吸烟的场所在监测过程中没有观察到有人吸烟，但在监测前可能有人吸烟，因此吸烟产生的 $PM_{2.5}$ 可能在监测时仍然滞留在场所内，或者调查者在观察中没有注意到有人吸烟；这些都可以导致室内的 $PM_{2.5}$ 水平高于室外。

表 1 2007年7-9月五城市所调查餐饮场所的基本情况

	北京 n (%)	武汉 n (%)	西安 n(%)	昆明 n(%)	贵阳 n(%)	合计 n(%)
餐馆类型						
中式正餐	52 (61.2)	50 (63.3)	52 (64.2)	50 (63.3)	49 (61.3)	253 (62.6)
中式快餐	8 (9.4)	5 (6.3)	5 (6.2)	5 (6.3)	6 (7.5)	29 (7.2)
西式正餐	6 (7.1)	5 (6.3)	4 (4.9)	6 (7.6)	5 (6.3)	26 (6.4)
西式快餐	5 (5.9)	5 (6.3)	5 (6.2)	4 (5.1)	6 (7.5)	25 (6.2)
酒吧	14 (16.5)	14 (17.7)	15 (18.5)	14 (17.7)	14 (17.5)	71 (17.6)
可容纳顾客数						
≤100人	36 (42.4)	35 (44.3)	40 (49.4)	38 (48.1)	23 (28.8)	172 (42.6)
101-300人	27 (31.8)	28 (35.4)	26 (32.1)	19 (24.1)	34 (42.5)	134 (33.2)
≥301人	14 (16.5)	16 (20.3)	8 (9.9)	13 (16.5)	23 (28.8)	74 (18.3)
缺失	8 (9.4)	0 (0.0)	7 (8.6)	9 (11.4)	0 (0.0)	24 (5.9)
平均个人消费						
≤20元	16 (18.8)	17 (21.5)	31 (38.3)	37 (46.8)	34 (42.5)	135 (33.4)
21-50元	43 (50.6)	47 (59.5)	30 (37.0)	27 (34.2)	30 (37.5)	177 (43.8)
≥50元	26 (30.6)	14 (17.7)	17 (21.0)	12 (15.2)	14 (17.5)	83 (20.5)
缺失	0 (0.0)	1 (1.3)	3 (3.7)	3 (3.8)	2 (2.5)	9 (2.2)
禁烟规定						
完全禁烟	7 (8.2)	2 (2.5)	8 (9.9)	3 (3.8)	3 (3.8)	23 (5.7)
部分禁烟	2 (2.4)	4 (5.1)	1 (1.2)	2 (2.5)	0 (0.0)	9 (2.2)
不禁烟	76 (89.4)	73 (92.4)	72 (88.9)	73 (93.7)	77 (96.3)	372 (92.1)
合计	85 (21.0)	79 (19.8)	81 (20.0)	79 (19.5)	80 (19.8)	404 (100.0)

表2 2007年7-9月五城市所调查餐饮场所的观察吸烟情况和PM_{2.5} 浓度 (μg/m₃)

未观察到吸烟									观察到吸烟								
		室外浓度PM _{2.5} 浓度				室内浓度PM _{2.5} 浓度					室外浓度PM _{2.5} 浓度				室内浓度PM _{2.5} 浓度		
	n	ASD	GM	Min	Max	GM	Min	Max	n	ASD	GM	Min	Max	GM	Min	Max	
北京	23	0	101	41	234	131	45	662	62	0.9	134	45	377	275	54	1087	
武汉	11	0	36	21	73	47	21	113	69	0.9	50	15	168	188	32	1424	
西安	25	0	184	120	317	196	58	523	56	1.5	193	32	309	404	165	1459	
昆明	16	0	29	19	44	40	16	206	63	1.1	33	12	105	110	14	1007	
贵阳	16	0	71	34	118	94	36	197	63	0.8	76	14	294	183	76	815	
合计	91	0	79	19	317	99	16	662	313	1.0	77	12	377	208	14	1459	

ASD, active smoker density, 吸烟者密度, 即监测时平均每100 m³ 内观察到吸烟的人数 GM: 几何均值, 单位为 μg/m³; Min: 最小值; Max: 最大值

表3 不同禁烟规定的餐饮场所室内外 PM_{2.5} 浓度几何均值 (μg/m³)

完全禁烟				部分禁烟			不禁烟			合计			
		PM _{2.5} 浓度				PM _{2.5} 浓度				PM _{2.5} 浓度			
	n	室外	室内	n	室外	室内	n	室外	室内	n	室外	室内	
北京	7	120	102	2	89	93	76	126	248	85	124	225	
武汉	2	64	54	4	46	55	73	47	169	79	48	155	
西安	8	163	130	1	146	159	72	194	361	81	190	323	
昆明	3	26	19	2	32	162	74	32	94	79	32	90	
贵阳	3	110	106	0	--	--	77	74	163	80	75	160	
合计	23	103	85	9	56	89	372	77	187	404	78	176	

表4是对PM_{2.5}水平、吸烟者密度(ASD)和人员密度(OD)的Spearman相关和偏相关分析的结果。两因素Spearman相关性分析结果显示,室内PM_{2.5}水平同室外PM_{2.5}水平(Spearman相关系数=0.58, P<0.001)、ASD(Spearman相关系数=0.52, P<0.001)和OD(Spearman相关系数=0.33, P<0.001)之间存在显著正相关。偏相关分析结果也表明室内PM_{2.5}水平和室外PM_{2.5}水平之间(偏相关系数=0.37, P<0.001)以及室内PM_{2.5}水平和ASD之间(偏相关系数=0.34, P<0.001)存在显著正相关。而当控制室外PM_{2.5}水平和ASD之后,室内PM_{2.5}水平和OD之间不存在显著的相关性。

线性回归分析(表5)结果也表明,当对其它因素进行调整之后,人员密度和城市同室内PM_{2.5}水平之间的相关性不具有统计学意义,而室外PM_{2.5}水平、吸烟者密度和场所类别与室内PM_{2.5}水平显著相关。当把吸烟者密度被从第二个模型中去掉后,R²下降了16%(0.08/0.49=0.16),也就是说,去掉吸烟者密度这一影响因素后,这个模型解释室内PM_{2.5}水平差异的能力降低了16%,这也证实了吸烟和室内PM_{2.5}水平之间的显著相关性。

讨论

本研究表明,室内PM_{2.5}水平与实际吸烟者密度之间存在强相关性。观察到吸烟的场所室内PM_{2.5}水平远高于没有观察到吸烟的场所,而完全禁烟场所的室内PM_{2.5}水平同室外的基本一样。即便是西安和北京那些室外PM_{2.5}水平也很高的场所,在对室外PM_{2.5}水平进行调整之后,观察到吸烟的场所室内PM_{2.5}水平也显著高于没有观察到吸烟的场所的室内水平。这些结果显示,烟草烟雾虽然不是这些场所室内PM_{2.5}的唯一来源,但却是主要来源。

各国吸烟场所的PM_{2.5}水平都普遍高于无烟场所。Hyland等从2005年9月到2006年11月采用同本研究相同的标准监测方案对32个国家1822个公共场所的室内PM_{2.5}水平进行了评估⁵。图1和图2对Hyland等的研究结果和本研究结果进行了比较。从图1可以看到,2006年北京的92个餐饮场所的室内PM_{2.5}水平,无论是否在场所内观察到了吸烟都比本研究的室内PM_{2.5}水平低。对于没有观察到吸烟的场所,这可能是由于两个研究进行现场监测的季节不同,从而导致本研究的室外PM_{2.5}水平比2006年的高。本研究的现场监测时间是2007年的7月和8月,而2006年的则是从2月到8月,其中包括春季这个室外PM_{2.5}水平相对较低的季节。对于观察到吸烟的场所,2007年室内PM_{2.5}水平较高可能是由于相应的室外PM_{2.5}水平较高,同时吸烟者密度也较高。另外,本研究中观察到吸烟的场所室内PM_{2.5}水平比美国吸烟者密度相当的场所的室内水平要高些,同时没有观察到吸烟的场所室内PM_{2.5}水平也比美国和爱尔兰相应场所的要高些(爱尔兰早已实施了全国性的全面室内无烟法律),见图2。造成这差异的原因可能是中国这五个城市的室外PM_{2.5}水平较高。

通过实施无烟法律法规创造全面无烟环境是唯一的可以有效保护人们免遭二手烟危害的方法。到2008年4月1日为止,全世界共有15国家和45个地区(包括香港在内)实施了全国或地方性的餐厅和酒吧全面无烟法^{14,15}。但在中国大陆,禁烟法规仅限于博物馆、图书馆和候车厅等场所,只有广东省的广州和深圳两个城市禁止在有空调的餐厅吸烟¹⁶。因此,在本研究进行期间,中国大陆餐饮场所禁烟与否依然取决于经营者的意愿。本研究显示,在404个调查场所中,仅有23个(5.7%)禁止吸烟,并且所调查餐厅和酒吧的室内PM_{2.5}水平都非常高,这也就意味着,中国大陆的餐饮行业工作人员和顾客都还面临着很高的二手烟暴露风险。

表4 室内PM_{2.5}浓度与室外PM_{2.5}浓度,监测时吸烟者密度和人员密度的相关性分析

	Spearman 相关分析		偏相关分析		
	相关系数	p 值	相关系数	p 值	控制变量
室外PM _{2.5} 浓度	0.58	<0.001	0.37	<0.001	ASD, OD
ASD	0.52	<0.001	0.34	<0.001	室外PM _{2.5} 浓度
OD	0.33	<0.001	-0.05	0.352	室外PM _{2.5} 浓度ASD

ASD: active smoker density, 吸烟者密度, 即监测时平均每100 m³内观察到吸烟的人数
OD: occupant density, 人员密度, 即监测时平均每100 m³内观察到的人数

根据一项关于餐饮行业顾客对公共场所无烟法规的态度, 分别只有30.0%和19.8%的顾客支持在餐厅和酒吧完全禁止吸烟¹⁷; 根据《2007年中国控烟报告》, 52.2%的餐厅经营者担心禁止吸烟会减少其营业收入¹⁸, 而根据北美、澳洲和其他很多西方国家对无烟法律法规对经济影响的系统综述, 这一观点被证实是错误的¹⁹。公众对餐厅和酒吧禁烟的态度以及9个部分禁烟场所的无烟区有5个观察到有人吸烟和23个完全禁烟场所中有1个观察到吸烟的事实表明, 在中国实施无烟立法保护公众不在公共场所, 尤其是餐饮场所, 暴露于二手烟面临着很大挑战。

本研究显示中国一些大城市的室外空气颗粒物污染还很严重, 而吸烟场所的室内空气颗粒物污染的情况比室外还

要糟糕。中国的高空气污染每年可导致40万例早死, 据估计, 2003年与空气污染相关的总卫生成本高达1570到5200亿人民币, 因此, 当前有很多关于如何降低中国的空气污染水平的讨论²⁰。实际上, 近期举行的北京2008年奥运会花费了数十亿美元改善室外空气质量²¹。对于遭受暴露的个人而言, 室内二手烟雾与室外空气污染的有害有过之而无不及。室内全面无烟政策可以极大地降低暴露水平, 是一个简单并极符合成本效益的解决办法。

本次研究采用PM_{2.5}作为二手烟的标志物, 也有研究者采用对二手烟具有更高特异性的尼古丁作为标志物。作为二手烟的一种有效的标志物, PM_{2.5}可以同时作为一种更通用的空气污染指标, 其可以用于同其它来源的颗粒污染物进行

表5 对室内 $PM_{2.5}$ 浓度对数值及其影响因素的回归分析模型

	模型 1			模型 2			模型 3		
	回归系数	t	p 值	回归系数	t	p 值	回归系数	t	p 值
室外 $PM_{2.5}$ 浓度对数值	0.52	4.43	0.000	0.54	15.06	0.000	0.57	14.84	0.000
ASD	0.41	6.45	0.000	0.41	7.30	0.000	---	---	---
OD	-0.03	-0.57	0.568	---	---	---	---	---	---
餐厅或酒吧*	0.29	6.67	0.000	0.29	6.68	0.000	0.30	7.91	0.000
场所类型与ASD的交互效应	-0.20	-3.05	0.002	-2.0	-3.13	0.002	---	---	---
武汉	-0.31	-0.90	0.371	---	---	---	---	---	---
西安	0.13	0.24	0.814	---	---	---	---	---	---
昆明	-0.25	-0.67	0.502	---	---	---	---	---	---
贵阳	0.41	1.04	0.299	---	---	---	---	---	---
武汉与室外 $PM_{2.5}$ 浓度的交互效应	0.39	1.28	0.202	---	---	---	---	---	---
西安与室外 $PM_{2.5}$ 浓度的交互效应	-0.11	-0.20	0.845	---	---	---	---	---	---
昆明与室外 $PM_{2.5}$ 浓度的交互效应	0.20	0.63	0.531	---	---	---	---	---	---
贵阳与室外 $PM_{2.5}$ 浓度的交互效应	-0.43	-1.13	0.258	---	---	---	---	---	---
R^2		0.51			0.49			0.41	

表格中的回归系数都是标准化后的回归系数

* 餐厅编码为“0”（对照组），酒吧编码为“1”；

ASD: active smoker density, 吸烟者密度, 即监测时平均每100 m³内观察到吸烟的人数

OD: occupant density, 人员密度, 即监测时平均每100 m³内观察到的人数

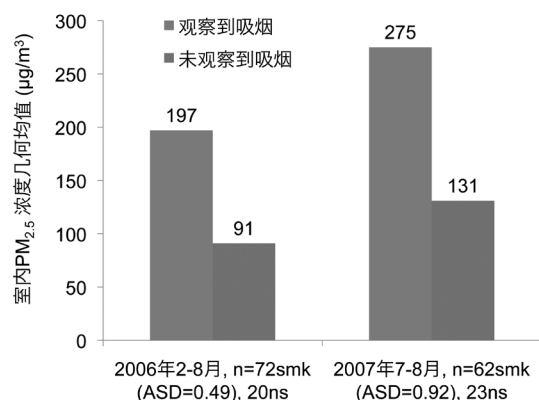


图1 北京不同研究所监测的室内 $PM_{2.5}$ 浓度几何均值(smk:允许吸烟的场所; ns:禁止吸烟的场所; ASD:平均每100m³内观察到的吸烟人数)

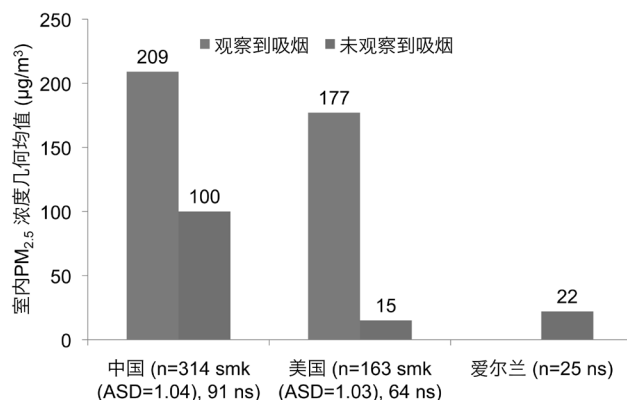


图2 中国、美国和爱尔兰所监测的室内 $PM_{2.5}$ 浓度几何均值(smk:允许吸烟的场所; ns:禁止吸烟的场所; ASD:平均每100m³内观察到的吸烟人数)

比较, 譬如室外颗粒污染。本研究使用的监测仪是一种激光光度仪, 其可以提供连续的监测数据, 从而可用于即时反映随周围条件变化或者不同的微环境的变化而不断改变的颗粒物水平(图3)。

虽然本研究的调查场所是通过方便抽样选取的, 但本研究结果却仍然能够反映五个城市餐饮场所的总体控烟状况和二手烟暴露状况, 因为我们对场所类型、不同类型可能的比例、场所的容客量和平均消费水平等因素都进行了考虑。

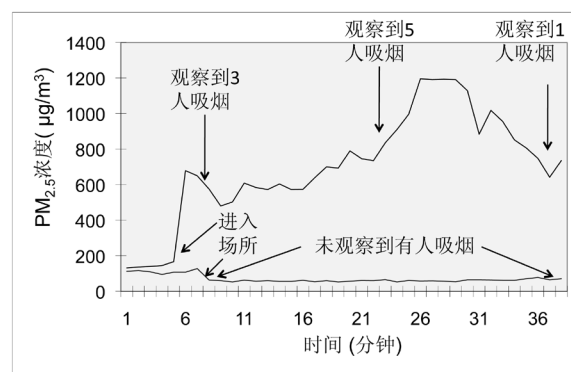


图3 在北京一家观察到吸烟的餐馆和一家未观察到吸烟的餐馆实时监测的室内 $PM_{2.5}$ 浓度变化

研究贡献

- ▶ 世界卫生组织（WHO）《烟草控制框架公约》（FCTC）号召各缔约国扩大无烟场所范围，保护人们免遭二手烟危害。然而，到本次研究开展时为止，中国大陆地区仍然很少有关于餐饮场所禁烟的法律法规，而且对于这些场所内的二手烟暴露状况的定量评估也非常有限。到目前为止，本研究是评估中国大陆地区餐饮场所室内二手烟暴露的最大规模研究，为中国政府采取有效措施，减少和消除餐饮场所二手烟危害提供了科学证据。
- ▶ 本次研究的结果显示，仅有少数（7.9%）的餐厅和酒吧有禁止吸烟的规定，这些场所的二手烟暴露水平非常高。在观察到有人吸烟的场所， $PM_{2.5}$ 水平是没有人吸烟场所的两倍以上，只有完全禁止吸烟的情况下，室内 $PM_{2.5}$ 水平才能接近相应的室外水平。这些结果都突出显示了根据《公约》制定和实施全面无烟政策的重要性。
- ▶ 为了2008年奥运会，中国开展了一系列公共场所烟草控制活动，其中就包括餐饮场所，以期达到降低二手烟暴露的目的。本研究可以为进一步评估这些餐饮场所控烟活动有效性提供基线信息。

结论

吸烟场所的 $PM_{2.5}$ 水平显著高于无烟场所，同时 $PM_{2.5}$ 水平与吸烟者密度显著相关。中国五城市餐饮场所的二手烟暴露问题十分严峻，需要制定和实施全面的禁烟法规，以保护公众免遭二手烟暴露危害。

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利益冲突：无。

参考文献

1. Klepeis NE, et al. Determining size-specific emission factors for environmental tobacco smoke particles. *Aerosol Sci Tech* 2003;**37**: 780-90.
2. Xiu GL, Zhao YN, Zhang DN, et al. Analysis on respirable particle matters pollutants in offices. *Shanghai Environ Sci* 1999;**18**:202-4.
3. Alpert H, Carpenter C, Travers MJ, et al. Environmental and economic evaluation of the Massachusetts smoke-free workplace law. *J Comm Health* 2007;**32**:269-81.
4. Vardavas CI, Kondilis B, Travers MJ, et al. Environmental tobacco smoke in hospitality venues in Greece. *BMC Pub Health* 2007;**7**:302.
5. Hyland A, Travers MJ, Dresler C, et al. A 32-country comparison of tobacco smoke derived particle levels in indoor public places. *Tob Control* 2008;**17**:159-65.
6. Semple S, Creely KS, Naji A, et al. Secondhand smoke levels in Scottish pubs: the effect of smoke-free legislation. *Tob Control* 2007;**16**:127-32.
7. US Department of Health and Human Services. *The health consequences of involuntary exposure to tobacco smoke: a report of the Surgeon General*. Atlanta, Georgia, USA: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, 2006.
8. Yang GH, Ma JM, Liu N, et al. Survey of smoking and passive smoking in Chinese population 2002. *Chinese J Epidemiol* 2005;**26**:77-83.
9. Yang GH. Smoking in China: findings of the 1996 National Prevalence Survey. *China Cancer* 1998;**7**:3-5.
10. Huang L, Yang G, Guo X, et al. Investigation of contamination level of environmental tobacco smoke in public places and workplaces. *J Environ Health* 2007;**24**:477-9.
11. Kang JM, Jiang Y, Lin XG, et al. Study on the level of environmental tobacco smoke in restaurants and bars in Beijing, China. *Chin J Epidemiol* 2007;**8**:738-41.
12. National Statistics Agency of China. Standards of Industry Classification [S/OL] [2008-4-15]. <http://www.stats.gov.cn/tjbz/hyflbz/> (accessed 15 April 2008).
13. Klepeis NE, Ott WR, Switzer P. Real-time measurement of outdoor tobacco smoke particles. *J Air Waste Man Assoc* 2007;**57**:522-34.
14. American Non-Smokers' Rights Foundation. Overview list - how many smokefree laws [EB/OL]. (2008-4-1) [2008-4-15]. <http://www.no-smoke.org/pdf/mediaordlist.pdf> (accessed 1 April 2008).
15. American non-smokers' rights foundation. Smokefree status of hospitality venues around the world [EB/OL]. (2008-4-1) [2008-4-15]. <http://www.no-smoke.org/pdf/internationalbarsandrestaurants.pdf> (accessed 1 April 2008).
16. Li YX, Jiang Y, Yang Y, et al. Analysis of laws and regulations on banning smoking in public places in China. *J Environ Health* 2007;**4**:221-3.
17. Ruiling L, Yan Y, Xiurong L, et al. Knowledge and attitudes towards second hand smoking among hospitality patronage in five cities in China. *China J Epidemiol* 2008;**29**:421-5.
18. Office of Leading Group for FCTC Implementation, Ministry of Health, People's Republic of China. *China Tobacco Control Report 2007: create smoke-free environments, enjoy healthy life*. Beijing, China: Office of Leading Group for FCTC Implementation, Ministry of Health, People's Republic of China, 2007.
19. Hyland A, Vena C, Cummings MK. A review of the economic effect of smoke-free restaurant and bar policies on the hospitality economy. *Epidemiology* 2000;**11**:687.
20. The World Bank. *The cost of pollution in China: economic estimates of physical damages*. Washington, DC, USA: Rural Development, Natural Resources and Environment Management Unit, East Asia and Pacific Region, The World Bank, 2007.
21. Stewart E. IOC praises efforts to reduce air pollution in Beijing. <http://www.guardian.co.uk/world/2008/aug/07/china.olympics2008> (accessed 12 November 2008).