Assessing exposure to secondhand smoke in restaurants and bars 2 years after the smoking regulations in Beijing, China

Abstract  Field observation of patron smoking behaviors and multiple sampling approaches were conducted in 79 restaurants and bars in Beijing, 2010, 2 years after implementing the governmental smoking regulations. Smoking was observed in 30 visits to 22 of the 37 nominal non-smoking venues during peak patronage times and six visits to four of the 14 nominal non-smoking sections. The median area secondhand smoke (SHS) concentrations during peak patronage time were 27, 15, 43, and 40 $\mu g/m^3$ in nominal non-smoking venues, non-smoking sections, smoking sections, and smoking venues, respectively, as indicated by the difference between indoor and outdoor PM$_{2.5}$ levels; and 1.4, 0.6, 1.7, and 2.7 $\mu g/m^3$, respectively, as indicated by airborne nicotine. In the 27 venues with sampling of different approaches and over different time periods, the median nicotine concentration was 1.8 $\mu g/m^3$ by one-hour peak patronage-time sampling, 1.1 $\mu g/m^3$ by 1-day active area sampling, 2.5 $\mu g/m^3$ by 1-day personal sampling, and 2.3 $\mu g/m^3$ by week-long passive sampling. No significant differences in nicotine levels were observed among venues/sections with different nominal smoking policies by all sampling approaches except during peak patronage time. This study showed that the 2008 Beijing governmental smoking restriction has been poorly implemented, and SHS exposures in Beijing restaurants and bars remain high.

Background  Secondhand smoke (SHS) is a well-known health hazard (USDHHS, 2006; WHO IARC, 2004). However, smoking was not restricted in public places like restaurants and bars in China until 2008. On May 1, 2008, the Beijing government implemented a regulation requiring large restaurants (dimensions were not specified) to designate at least 50% of their dining areas as non-smoking. Later, several other big cities, including Shanghai, Guangzhou, Hangzhou, and Yinchuan, followed Beijing in regulating smoking in public places. All these local smoking regulations followed the so-called Spanish Model, which allows owners of small hospitality venues to choose whether smoking should be allowed in their venues or not (Schneider et al., 2011). On May 1, 2011, the Chinese government revised the implementation guidelines of the Health Regulations in Public Places issued in 1987 to tighten its rules of restricting smoking in all indoor public places national wide including restaurants and bars.

Monitoring SHS exposure is important in the estimation of the disease burden attributable to SHS and therefore providing guidance for public health policy (Woodward and Al-Delaimy, 1999). It is also...
essential to evaluate the efficacy of a smoking policy. However, only a few studies have monitored SHS exposure in different types of environments in China. Hammond et al. (1999) measured airborne nicotine in some Chinese homes in 1998. Stillman et al. (2007) measured airborne nicotine concentrations in public places in four cities and three rural towns in 2005, and Gan et al. (2008) monitored airborne nicotine levels in 14 Chinese office buildings in 10 provinces from 2005 to 2006; all these studies used week-long passive area nicotine sampling method. Another three studies measured SHS for half an hour during peak patronage times via the tracer of fine particulate matter (PM$_{2.5}$) in Chinese restaurants and bars in 2006 and 2007 (Kang et al., 2007; Lee et al., 2010; Liu et al., 2010).

In 2007, as part of a study on SHS exposure in five Chinese cities, a convenience sample of 85 restaurants and bars were selected from two districts in Beijing (Liu et al., 2010). This paper reports a follow-up study of the 2007 study to assess SHS exposure in restaurants and bars 2 years after the implementation of the Beijing governmental smoking restriction. The study was designed to examine profiles of SHS exposure of servers and patrons in restaurants and bars, that is, SHS concentrations in restaurants and bars during typical peak patronage times, during servers’ full working shifts, and in one typical week. Evaluation of the smoking regulations is published in another paper (Liu et al., 2013). The monitor protocol was approved by the Committee for Protection of Human Subjects at University of California, Berkeley.

**Methods**

Overview of sampling approaches used in this study

Five sampling approaches were used in this study: week-long passive area nicotine sampling, 1-day active area nicotine sampling, 1-day active personal nicotine sampling, and one-hour area nicotine sampling and area PM$_{2.5}$ sampling during peak patronage. Field observations were also conducted during peak patronage sampling periods.

Passive monitors developed by Hammond and Leader (1987) were affixed to items on walls or ceilings where monitors could rest undisturbed and sample airborne nicotine for one or two continuous weeks. Active nicotine monitors used were quite similar to the passive monitors, except that a top polystyrene cassette replaced the windscreen, and a pump was used to draw air through the cassettes. Active monitors were used to sample airborne nicotine for a whole working day, starting around the time when the venue was opened to the public and ending around the time when it was closed to the public. To prevent possible loss of the sampling pumps and to keep them charged during sampling, active monitors were placed on cashier bars or near outlets where they could remain undisturbed.

For personal sampling, an active nicotine monitor with a battery-charged mini pump was worn by a voluntary non-smoking server who worked for a full daytime shift. Some venues were closed for a break between lunch and dinner, and servers were instructed to place the monitor on the cashier bar without turning the pump off during the break to avoid SHS exposure in other places. The sampling rate for both 1-day active area sampling and 1-day personal sampling was set at 150 ml/min and was checked both before and after the sampling. The average flow rate was used for the concentration calculation.

Sampling was also conducted during peak patronage time on the same day as the active area sampling and personal sampling. Peak patronage time was defined as lunch (11:30 AM to 2:00 PM) or dinner time (5:00–8:30 PM) for restaurants, and evening (8:00 PM to 2:00 AM) for bars; for cafés, peak time was more flexible, usually in the afternoon. Two investigators visited each venue during a peak patronage time as patrons and discreetly conducted monitoring and observations so that occupants were not disturbed. Investigators carried an active nicotine monitor and a real-time PM$_{2.5}$ monitor in a bag. The cassette of the nicotine monitor and the sampling tube of the PM$_{2.5}$ monitor were placed side-by-side outside of the bag and the pumps inside the bag. They seated themselves at a table as close to the central dining area as possible, put the bag with the monitors on a chair, and conducted sampling for about 1 h. The flow rate of the nicotine monitor was set to around 2 l/min. Area PM$_{2.5}$ concentrations were measured with TSI SidePak AM510 Aerosol Monitors (TSI Inc. St. Paul, MN, USA), using the methods described by Hyland et al. (2008). Outdoor PM$_{2.5}$ levels were monitored for at least 10 min before or after entering the venue. SHS-derived PM$_{2.5}$ concentrations (SHS PM) were calculated as the difference between the average indoor and outdoor PM$_{2.5}$ concentrations multiplied with a calibration factor of 0.32, suitable for SHS (Hyland et al., 2008).

During each peak-time sampling, investigators counted the number of patrons, the number of employees, and the number of lit cigarettes every 15 min. They also observed whether any non-smoking signs were obvious to patrons, the availability of ashtrays, and compliance to smoking restrictions. Venue dimensions were measured via Straint-line® Sonic laser tapes (Huntersville, NC, USA) or by estimates when the space was irregular. In addition, a TSI 8854 Q-Trak Plus IAQ Monitor Model (TSI Inc., St. Paul, MN, USA), a Fluke 975 AirMeterTM Test Tool (Fluke Co., Everett, WA, USA), or a Hobo U12/Telaire7001 was used to monitor CO$_2$, temperature, and relative humidity (RH) for at least 10-min outdoor and for about one-hour indoor, simultaneously with airborne nicotine and PM$_{2.5}$ sampling.
Venue selection

This study was part of a larger project evaluating the efficacy of smoking regulations in Beijing restaurants and bars in 2008, and thus, venues monitored in the study conducted in 2007 (Liu et al., 2010) were included in this study whenever possible. All the 85 venues in Beijing monitored in the 2007 study were physically re-visited to check their current smoking policies by inquiring of their workers or by observing non-smoking signs in venues. A total of 66 venues were re-identified (Figure 1), and their smoking policies were examined by inquiries. Forty-three venues allowed smoking everywhere or in designated sections; their owners or managers were contacted by phone or in person for permission for 1-week passive area nicotine sampling, 1-day active area nicotine sampling, and 1-day active personal air nicotine sampling. Permission for at least one sampling approach was obtained from 27 venues. To increase the sample size for comparisons between different smoking policies and sampling approaches, permission was sought from another 14 venues located in the same districts and allowing or restricting smoking. One of the 66 venues from the 2007 study was not accessible due to requirement of security check upon entry, resulting in a total of 79 venues included in the 2010 study.

Data collection

Field work was conducted from July to August 2010. In each of the 41 venues where sampling permission was obtained, at least two passive area nicotine monitors were placed at different locations in the main dining area for 1 or 2 weeks. Monitors were lost from two venues. On 1 day of this time period, one active area nicotine monitor and one to three active personal nicotine monitors were set up for sampling. Also, area nicotine and PM$_{2.5}$ sampling and observations were conducted for one hour during both lunch and dinner times for restaurants and once for cafés and bars on the same day. In venues with well-defined smoking and non-smoking sections (according to locations of non-smoking signs), all the sampling approaches were applied in both sections unless sampling devices or field investigators were not available for simultaneous sampling during peak time. In the other 38 venues, field sampling and observations were conducted in one of the peak patronage times only. In all, one-hour peak-time sampling and observation were conducted during

85 venues included in the 2007 study

- Excluded: 4 under remodeling; 15 not found or changed business

23 smoking not permitted

16 smoking permitted; permission not obtained

27 smoking permitted; permission obtained

One not accessible

38 concealed peak-time monitoring

14 newly recruited in 2010

- Passive area nicotine sampling;
- One-day active area nicotine sampling;
- One-day active personal nicotine sampling;
- Concealed peak-time monitoring, lunch and dinner

Fig. 1 Venue selection procedure and sampling approaches applied for the follow-up study on assessing secondhand smoke exposure in restaurants and bars, Beijing, 2010
121 visits to all the 79 venues, with 25 venues measured during both lunch and dinner times. Eleven of the 14 venues nominally restricting smoking were visited simultaneously during peak times in both smoking and non-smoking sections. In 27 venues, all five sampling approaches were implemented. Figure 2 presents the final sampling approaches applied and number of samplers collected in all selected venues.

For all nicotine sampling, one blank sampler was carried by each team on each day of sampling. Five TSI SidePaks were used to monitor PM$_{2.5}$ levels, and another five CO$_2$ monitors were used in this study. Two side-by-side tests were conducted to examine the consistency between different devices. One test was conducted in a hotel room with PM$_{2.5}$ levels averaged 24 $\mu$g/m$^3$ and the other in a restaurant with relatively higher concentrations (mean: 196 $\mu$g/m$^3$). The differences between the average of measurements by any individual device and the average of all measurements by the five devices for PM$_{2.5}$ and the five devices for CO$_2$, respectively, were within 5% for the hotel room sampling and within 10% for the restaurant sampling.

Nicotine sampling filters were analyzed in Dr. Hammond’s laboratory. The laboratory limit of detection (LOD) was 0.001 $\mu$g per filter, the coefficient of variability for replicate analysis was less than 5%, and the efficiency of extracting nicotine from filters was all higher than 90%. In this study, all 39 field blank samples and three laboratory blanks were below the LOD, and all the other samples were above LOD. The LOD for airborne nicotine concentrations varied depending on air sampling volume.

**Data analysis**

Descriptive analyses were conducted for both observed patron smoking behaviors and measured SHS concentrations by different sampling approaches. Patron smoking behavior was indicated by active smoker density (ASD, average number of active smokers observed per 100 m$^3$) and active smoking rate (ASR, percentage of counted adult patrons that were observed smoking during sampling time). Results were contrasted among different nominal smoking policies adopted by restaurants and bars. The nominal smoking policy in a venue was defined according to investigators’ observations during peak patronage times. If only no-smoking signs were observed in a venue, the venue was referred as a nominal non-smoking venue; if both no-smoking signs and smoking signs or labels pointing to designated smoking areas or non-smoking areas were observed, the designated non-smoking areas were defined as nominal non-smoking sections. If a venue or section was sampled during both lunch and dinner times, the average of these two periods was used to represent peak-time SHS concentration in the venue or section. The quantitative relationships between SHS concentrations, as indicated by SHS PM and airborne nicotine and observed ASD during peak patronage times, and the quantitative relationships between measurements by any two nicotine sampling approaches conducted in the same venues or sections were examined. All the data analyses were conducted with Stata IC11 (College Station, TX, USA).

Air change rates per hour (ACH) during peak time were estimated using the following equation, as recommended by ASHRAE 6.21.

\[
ACH = \frac{CO_2 \text{ generation rate}}{(C_{avg} - C_{out})}
\]

where the CO$_2$ generation rate was estimated by counts of workers and patrons during peak time, and by assuming a worker generates $8.6 \times 10^{-4}$ l CO$_2$ per second and a seated patron generates $5.16 \times 10^{-4}$ l CO$_2$ per second, according to Appendix C of ASHRAE 6.21. $C_{avg}$ is the average indoor concentration of CO$_2$ during peak time, and $C_{out}$ is the outdoor CO$_2$ concentration.

**Fig. 2** Secondhand smoke sampling approaches applied in restaurants and bars, Beijing, 2010
Results

General features of venues included in the study are described in Table 1. Most restaurants included prohibited or restricted smoking, while most bars allowed smoking. Some venues with large areas (>100 m²) or large capacity (>100 seats) still allowed smoking. Of the 14 venues restricting smoking, five restricted smoking to separate rooms or different floors, three had half walls between smoking and non-smoking sections, and the remaining six venues had no physical separations between the two sections.

Peak-time field monitoring and observation

For sampling visits during peak patronage times, the medians of outdoor and indoor temperatures/relative humidity were 29°C/56% and 27°C/53%, respectively. Doors were open in 88 of the 121 visits during peak times and windows were open during 5 visits; air conditioners were used during 64 visits, and mechanical ventilation methods, such as center ventilation system and floor fans, were used during 60 visits. The median air exchange rates were estimated to be 4.5/h (range: 0–14/h). The median reading of the outdoor PM$_{2.5}$ measurements was 95 µg/m$^3$ (range: 9–581 µg/m$^3$, no calibrating factors applied).

Ashtrays were observed on tables in three of the 37 venues nominally prohibiting smoking, and they would be provided if requested by patrons in 20 venues and two sections which nominally did not allow smoking. Smoking was observed in 77 of the 121 visits, including 30 visits to 22 of the 37 (59%) nominal non-smoking venues and six visits to four of the 14 (29%) nominal non-smoking sections. Tables 2 and 3 present observed ASR and ASD and measured SHS PM and airborne nicotine during peak-time visits. Both observed ASR

and ASD were higher in nominal non-smoking venues than in nominal non-smoking sections. Similar trends were observed for SHS PM and nicotine. Nonparametric tests showed significant differences in ASD, SHS PM, and nicotine among venues or sections with different nominal smoking policies, and non-significant differences during visits on different days of a week (data not shown) or in different peak time periods. Both SHS PM and nicotine levels were significantly higher during visits with smoking observed than during visits without smoking observed ($P < 0.0001$), and air nicotine levels (but not SHS PM) were significantly higher in bars than in restaurants ($P = 0.02$).

Simultaneous observation and airborne nicotine sampling were conducted in nominal smoking sections and non-smoking sections during 15 peak times in 11 venues. PM$_{2.5}$ was monitored simultaneously in two sections during only 13 of the 15 peak times because of the availability of instruments. ASD in smoking sections was significantly higher than in non-smoking sections; the medians of SHS concentrations in non-smoking sections were much lower than those of smoking sections. All ASD, SHS PM, and nicotine were significantly different in smoking and non-smoking sections ($P < 0.01$).

One-day or week-long field monitoring

Table 4 presents all the nicotine sampling results aggregated to the venue level. One personal sampler from a nominal non-smoking restaurant had nicotine concentration of 60 µg/m$^3$, while for all other samplers in the same venue, nicotine concentration was less than 2.0 µg/m$^3$; the nicotine concentration of another personal sampler from a restaurant nominally restricting smoking was 284 µg/m$^3$, while nicotine was <13 µg/m$^3$ for all other samplers in the same venue. Therefore, these two personal samples were suspected to be contaminated by other sources of tobacco smoke rather than SHS in the sampling venues and were excluded for this data analysis. Four passive samplers were lost, resulting in 87 passive samples included in the final analysis.

For day- or week-long samples, no significant differences in nicotine levels were observed in venues or sections with different nominal smoking policy or in restaurants or bars (Table 4). Paired $t$-test or Wilcoxon matched pairs signed rank test showed non-significant difference for both 1-day active and week-long passive area nicotine sampling conducted simultaneously in smoking and non-smoking sections.

Relationships between different approaches to estimate SHS exposure

Both SHS PM and airborne nicotine levels measured during peak patronage times were significantly related to observed ASD. Simple linear regression analyses
showed a $R^2$ of 0.29 between observed ASD and SHS PM concentrations, of 0.46 between observed ASD and airborne nicotine levels, and of 0.54 between SHS PM and airborne nicotine levels ($P < 0.0001$). There were 27 venues with four different nicotine sampling approaches applied. The median nicotine concentration was 1.8 g/m³ during times of peak patronage, 1.1 g/m³ by active area sampling, 2.5 g/m³ by 1-day personal sampling, and 2.3 g/m³ by week-long passive sampling. Simple regression analyses showed that airborne nicotine levels by peak-time area, 1-day active area, and week-long passive area sampling were significantly related to each other ($P$ values $< 0.005$, data not shown), and SHS levels by peak-time area sampling and 1-day active area sampling were all significantly related to servers’ personal exposure to air nicotine during their full shifts ($P < 0.005$, data not shown). Paired $t$-tests showed that mean nicotine concentration by peak-time sampling was significantly higher than that by 1-day active area sampling and week-long passive sampling ($P < 0.01$), but similar to that by 1-day personal sampling ($P = 0.36$). Mean nicotine levels by both 1-day active area sampling and week-long passive sampling were significantly lower than that by 1-day personal sampling ($P < 0.01$).

**Discussion**

Implementation of the 2008 Beijing governmental smoking restriction in 2010

The 2008 Beijing governmental smoking restriction requires large restaurants to designate $\geq 50\%$ of their dining area as non-smoking. However, it does not define ‘large’ and does not include bars. There are no specifications on how the designated smoking sections and non-smoking sections should be separated: About 70% of the venues restricting smoking in this study did not have full walls between the two sections. In addition, the restriction implementation guidelines do not specify how violation of the policy will be fined. These factors alone indicate that the smoking
restriction is not enforceable, and the exemption of small venues or bars means that it does not provide universal protection to servers and patrons.

The implementation of the governmental restriction was poor. Thirty-seven of the 79 venues were observed to nominally prohibit smoking, while only 23 venues were reported to be smoke-free by staff. That is, in many venues nominally prohibiting smoking, the staff did not know about the smoke-free policy. Ashtrays were either observed or provided upon request in many nominal non-smoking venues/sections. Smoking was commonly observed during field visits to nominal non-smoking venues/sections, while interventions to stop smoking were rarely observed. Larger percentages of patrons were observed smoking in nominal non-smoking venues than in non-smoking sections. The possible reason may be that smokers were more likely to select the designated smoking section when they visited a venue with both sections, while they tended to ignore the non-smoking signs in non-smoking venues when they were not offered a designated smoking section. This may also explain why higher SHS PM and airborne nicotine concentrations were measured in non-smoking venues than in non-smoking sections of venues with smoking sections. A complete evaluation of the Beijing smoking policy is presented elsewhere (Liu et al., 2013).

### SHS exposure in restaurants and bars in Beijing compared to other countries/regions

Consistent with other studies, PM$_{2.5}$ levels in venues with smoking observed were significantly higher than in venues without smoking observed (Agbenyikey

#### Table 4 Nicotine levels (µg/m$^3$) in restaurants and bars by different sampling approaches, Beijing, 2010

<table>
<thead>
<tr>
<th>Sampling Approach</th>
<th>N</th>
<th>Mean</th>
<th>s.d.</th>
<th>Median</th>
<th>IQR</th>
<th>Min</th>
<th>Max</th>
<th>Stat test</th>
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<tr>
<td>Smoking venue</td>
<td>28</td>
<td>3.22</td>
<td>2.50</td>
<td>2.52</td>
<td>1.33–4.59</td>
<td>0.13</td>
<td>9.93</td>
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<td>4.60</td>
<td>5.75</td>
<td>1.81</td>
<td>1.15–7.47</td>
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<td>19.42</td>
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<td>1.65</td>
<td>0.77</td>
<td>0.48–1.22</td>
<td>0.14</td>
<td>6.09</td>
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<td>1.90</td>
<td>1.37</td>
<td>0.65–2.26</td>
<td>0.02</td>
<td>7.49</td>
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<tr>
<td>Restaurants</td>
<td>62</td>
<td>2.08</td>
<td>2.12</td>
<td>1.38</td>
<td>0.75–2.62</td>
<td>0.02</td>
<td>9.93</td>
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<td>3.30</td>
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<td>Smoking venue</td>
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<td>1.83</td>
<td>1.99</td>
<td>1.08</td>
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<td>Allow</td>
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<td>2.92</td>
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<td>3.09</td>
<td>2.40</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking venue</td>
<td>12</td>
<td>2.68</td>
<td>1.74</td>
<td>2.12</td>
<td>1.38–3.45</td>
<td>0.71</td>
<td>6.56</td>
<td>$\chi^2 = 3.6$</td>
</tr>
<tr>
<td>Smoking section</td>
<td>10</td>
<td>2.39</td>
<td>1.60</td>
<td>2.32</td>
<td>0.83–3.03</td>
<td>0.52</td>
<td>5.13</td>
<td>df = 3</td>
</tr>
<tr>
<td>Non-smoking section</td>
<td>6</td>
<td>1.60</td>
<td>1.12</td>
<td>1.53</td>
<td>0.64–2.69</td>
<td>0.29</td>
<td>2.92</td>
<td>$P = 0.30$</td>
</tr>
<tr>
<td>Non-smoking venue</td>
<td>17</td>
<td>1.71</td>
<td>1.22</td>
<td>1.38</td>
<td>0.85–2.18</td>
<td>0.13</td>
<td>4.14</td>
<td></td>
</tr>
<tr>
<td>Type of establishments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restaurants</td>
<td>28</td>
<td>1.84</td>
<td>1.18</td>
<td>1.62</td>
<td>0.84–2.68</td>
<td>0.13</td>
<td>4.14</td>
<td>$P = 0.23$</td>
</tr>
<tr>
<td>Bars/cafes</td>
<td>11</td>
<td>2.79</td>
<td>1.81</td>
<td>2.46</td>
<td>1.31–3.81</td>
<td>0.71</td>
<td>6.56</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>2.11</td>
<td>1.43</td>
<td>1.83</td>
<td>0.92–3.21</td>
<td>0.13</td>
<td>6.56</td>
<td></td>
</tr>
</tbody>
</table>

N indicates number of venues; because some venues have both non-smoking sections and smoking sections, the sum of $n$ under ‘Nominal smoking policy’ may not equal the number ‘Total’; Kruskal–Wallis rank tests were used to compare the distribution of nicotine concentrations among different groups defined by nominal smoking policy, and two-sample Kolmogorov–Smirnov tests were used for comparison between restaurants and bars.

SHS exposure in restaurants and bars in Beijing compared to other countries/regions

Consistent with other studies, PM$_{2.5}$ levels in venues with smoking observed were significantly higher than in venues without smoking observed (Agbenyikey...
Liu et al.

e et al., 2011; Hyland et al., 2008), indicating that SHS is a major source of indoor PM$_{2.5}$ contaminant. Peak-time SHS PM concentrations in smoking restaurants and bars or in designated smoking sections reported in this study were lower than concentrations reported in some other studies, which reported median (or geometric mean, GM) PM$_{2.5}$ concentrations ranging from 50 to 663 $\mu$g/m$^3$ in smoking restaurants (Akbar-Khanzadeh, 2003; Alfaro, 1997; Branis et al., 2002; Brauer and Mannetje, 1998; Carrington et al., 2003; Gleich et al., 2011; Huss et al., 2010; Lai et al., 2011; Lambert et al., 1993; Proescholdbell et al., 2009; Travers, 2008) and 40–465 $\mu$g/m$^3$ in smoking bars (Bolte et al., 2008; Daly et al., 2010; Ellingsen et al., 2006; Gleich et al., 2011; Goodman et al., 2007; Lee et al., 2008; Maskarinec et al., 2000; Repace et al., 2006; Rosen et al., 2011; Semple et al., 2010; Siegel, 1993; Travers, 2008; Valente et al., 2007; Vardavas et al., 2007; Waring and Siegel, 2007). However, for non-smoking venues, SHS PM concentrations were higher in this study than in some other studies, which reported median PM$_{2.5}$ concentrations below 20 $\mu$g/m$^3$ (Lopez et al., 2011; Proescholdbell et al., 2009; Travers, 2008; Wilson et al., 2007). Similarly for airborne nicotine, the median of week-long time-weighted average levels was lower in smoking venues in this study than those reported in most of other countries (median or GM ranging from 0.58 to 35.5 $\mu$g/m$^3$) (Barnoya et al., 2011; Gorini et al., 2008; Jane et al., 2002; Jones et al., 2012; Lopez et al., 2008; Mulcahy et al., 2005; Navas-Acien et al., 2004; Nebot et al., 2009; Ochir et al., 2011), but they were higher in non-smoking venues in this study than in other countries (median or GM ranging from 0.03 to 0.90 $\mu$g/m$^3$) (Barnoya et al., 2011; Gorini et al., 2008; Jones et al., 2012; Lopez et al., 2008, 2011; Nebot et al., 2009). SHS concentrations in smoking restaurants and bars are lower in Beijing than in other countries, which might be attributed to the different sampling seasons and/or different physical features of the venues, such as window/door opening and ventilation applications. The finding in this study that SHS concentrations in non-smoking restaurants and bars are higher in Beijing than in other countries is not surprising, given that the Beijing governmental smoking restriction was poorly enforced.

Simultaneous monitoring in nominal smoking sections and non-smoking sections

Elevated SHS concentrations measured in nominal non-smoking sections where smoking was not observed during sampling could be due to smoking occurred before the sampling, or diffusion of SHS from the smoking section; however, in nominal non-smoking sections where smoking was observed, the main reason should be smoking. The median of non-smoking-section SHS concentration/smoking-section SHS concentration ratios by simultaneous sampling was 0.69 for SHS PM and 0.31 for airborne nicotine, comparable to those reported in the literature (Akbar-Khanzadeh, 2003; Bohanan et al., 2003; Cains et al., 2004; Carrington et al., 2003; Jane et al., 2002; Kuusimaki et al., 2007; Lambert et al., 1993; Moshhammer et al., 2004; Navas-Acien et al., 2004; Schneider et al., 2008). The difference between the ratios for airborne nicotine and for SHS PM may be attributed to other sources of indoor PM, and different diffusion activities of SHS PM and airborne nicotine from smoking sections to non-smoking sections.

For airborne nicotine concentration based on longer time sampling, for example 1-day area sampling and week-long passive area sampling, non-significant differences existed between nominal smoking sections and non-smoking sections, which may be due to the diffusion of SHS from designated smoking sections to non-smoking sections over the sampling time. There is no safe level of SHS exposure, and the most effective way to protect people from SHS exposure is 100% comprehensive smoking bans (USDHHS, 2006; WHO, 2009). Results from this study strongly support the point that the use of designated smoking areas is ineffective in eliminating SHS exposure (WHO, 2007).

Comparison of different sampling approaches

Indoor SHS concentration depends on the volume of the space where SHS is dispersed, and the generation and removal rate of this contaminant. Observed number of active smokers density (ASD) gives information on both the space volume and SHS generation rate. Regression analysis showed that observed ASD could explain 29% of the variance of the difference in indoor and outdoor PM$_{2.5}$ concentrations and 40% of the variance of nicotine concentrations, indicating that both PM$_{2.5}$ and nicotine are sensitive to SHS, while nicotine is more specific than PM$_{2.5}$. The remaining variance may be attributed to the variance of removal rates and/or other sources, such as cooking for PM$_{2.5}$ and surface adsorption for airborne nicotine. Air nicotine and PM concentrations in hospitality venues are closely related to each other. Fu, et al. reported a Spearman’s rank correlation coefficient of 0.74 based on 185 pair of simultaneous measurements in bars (Fu et al., 2013), and Ellingsen et al. (2006) reported a Pearson’s correlation coefficient of 0.86 based on 48 paired measurements in restaurants, pubs, and nightclubs. This study found a similarly high Pearson’s correlation coefficient of 0.73 ($R^2 = 0.54$) based on 111 pair of measurements in Beijing restaurants and bars.

Although the sampling time periods were quite different for the three area nicotine sampling approaches, their results were significantly related to each other. Airborne nicotine concentrations estimated by 1-day personal air nicotine sampling and 1-day area active
sampling, conducted almost simultaneously, were significantly related, consistent with findings from other studies (Ellingsen et al., 2006; Jenkins and Counts, 1999). Because servers have frequent near-field exposure to SHS when they serve tables with active smoking patrons and they may be exposed SHS from other workers’ smoking in the kitchens or other locations beyond the dining areas, it is not surprising that personal samples are typically higher than 1-day area samples. One-day personal air nicotine sampling results were similar to one-hour peak-time area sampling results in the same venue, probably because most of servers’ exposure to SHS at work occurs during peak patronage time.

Strengths and limitations of the study

This study was the first to combine personal sampling and different area sampling approaches with different time periods to characterize SHS concentrations in restaurants and bars. The limitations of this study included that: (i) the venues were not a random sample of restaurants and bars in Beijing; however, they were selected to include a diversity of venues with different smoking policies, different sizes, and service types; (ii) some owners might worry that the presence of sampling devices would interrupt their business or that sampling results might be used to evaluate their enforcement of smoking policies, and thus refused to have sampling conducted in their venues. However, permission was required for personal sampling and 1-day or week-long area sampling only, and owners were assured that all sampling results would be used for research purpose only; peak-time sampling was conducted in a concealed manner in all the venues, and comparison of peak-time nicotine concentrations showed no significant difference in venues with owners’ permission obtained and in venues with owners’ permission sought but not obtained when stratified by observed nominal smoking policy (data not shown). Thus, the probability that venue selections based on owners’ permission would bias SHS concentrations measured in restaurants and bars is small; (iii) the study was conducted in a summer only, and there might be seasonal variations due to different ventilation and door and/or window opening; (iv) most of the area samplings during peak times, operating hours, and 1 or 2 weeks were not conducted at the same location; thus, the differences among sampling results of different time periods might reflect spatial as well as temporal differences; (v) the calibrating factor of 0.32 suitable for SHS was from other studies, and it was not confirmed in this study; it is possible that this factor was different in Beijing restaurants and bars. However, previous studies have reported factors of 0.295–0.328 (Bohac et al., 2010; Jenkins et al., 2004; Klepeis et al., 2007; Travers, 2008); thus, it is not likely that the calibrating factor for SHS in Beijing restaurants and bars (if measured) would be significantly different from the one used in this study.

Conclusions

The 2008 Beijing governmental smoking restriction in restaurants and bars is not enforceable because of its vague language; it cannot provide universal protection of servers and patrons from SHS exposure because of the exemption of small restaurants and bars; and it has been poorly implemented. SHS concentrations in Beijing restaurants and bars indicated either by airborne nicotine or PM2.5 concentrations, or by different sampling approaches over different time periods, are very high. Setting designated smoking and non-smoking sections is ineffective in preventing patrons and servers from SHS exposure, while comprehensive smoking bans and effective enforcement is necessary to eliminate SHS exposure in restaurants and bars.

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SHS exposure in restaurants and bars after the smoking ban

Before and after a smoking ban, *BMC Public Health*, 6:266.


