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Research Article

Attached Smoking Room Is a Source of $PM_{2.5}$ in Adjacent Nonsmoking Areas

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The smoking ban is not working in some entertainment venues in China. $PM_{2.5}$ pollution induced by cigarette smoking in these places is still unknown. In this study, we took mahjong clubs as target places, monitored the real-time $PM_{2.5}$ concentration, and recorded on-site inspection information to investigate the $PM_{2.5}$ pollution characteristics induced by cigarette smoking. In occupied and smoking rooms, the geomean and median values of $PM_{2.5}$ concentration were 276 and 347 μg/m^3. The number of smoking persons in room is the dominant factor to enhance $PM_{2.5}$ levels. For each additional person smoking in the room, $PM_{2.5}$ increased by 32% (95% CI: 31%, 33%). Regarding adjacent nonsmoking rooms, $PM_{2.5}$ increased due to the air penetration from smoking rooms and the increase trend usually had a lag time of 20 minutes. The geomean values of $PM_{2.5}$ concentrations were 109 μg/m^3 in the nonsmoking and occupied rooms and 148 μg/m^3 in the vacant rooms. To close the door of the room is the most effective measure to alleviate the $PM_{2.5}$ penetration. The geomean values of 24-hour and annual average excess exposure concentration if spending 5 hours/day and 2 days/week in mahjong club were 32.1 and 9.2 μg/m^3, respectively; both exceeded the World Health Organization's air quality guidelines, 15 and 5 μg/m^3, respectively. Our results revealed severe $PM_{2.5}$ pollution and exposure risk by cigarette smoking in entertainment venues, as well as the penetration effect on adjacent nonsmoking areas. The smoking bans should be strictly enforced in entertainment venues, and the setting of smoking areas in indoor public places should be scientific to avoid diffusion into nonsmoking areas.

1. Introduction

Fine particulate matters could cause adverse health outcomes on human beings. It was estimated that millions of premature deaths were attributable to air pollution globally [1]. Apart from ambient air pollution, indoor air pollution (IAP) is catching raising concern since people spent most time indoor. A bulk of publications focused on IAP resulting from strong internal emissions, e.g., IAP in rural homes associated with residential fuel combustion [2–4] and smoking [5, 6], calling for more attention on IAP due to its negative impact on human health [7, 8].

Smoking is well recognized as a contributor to IAP to threaten health of both passive and active smokers [9]. In a field study in rural Chinese homes, smoking is found as a significant influence factor to the exposure to $PM_{2.5}$ and PAHs [10]. Thus, it is crucial to pay attention to the IAP related to smoking. In China, some developed megacities such as Beijing and Shanghai have implemented strict smoking ban [11]. This ban prohibited smoking in indoor environments including offices and restaurants, which no doubt protected nonsmokers from exposure to high air pollutants from cigarette smoke. Unfortunately, in some entertainment venues, there is still a long way to avoid smoking. As a recreational activity, playing mahjong is popular in countries in eastern Asia, especially in China due to its positive impact on psychological health [12]. Many mahjong clubs in China provided space for mahjong likers. During the entertainment, four or more people stayed in a relatively enclosed room for several hours, with unprohibited smoking. It is reasonable to expect highly polluted air pollution in mahjong clubs, which unfortunately has been ignored for a long time. It is essential to evaluate the IAP in non-smoke-free mahjong clubs for making future control policies.

In this study, typical mahjong clubs were selected to investigate the impact of smoking on indoor $PM_{2.5}$ pollution and human exposure using real-time $PM_{2.5}$ monitors. The influence of cigarette combustion on indoor $PM_{2.5}$ was discussed based on the high time resolution data. The result is expected to provide new insight of air pollution in relatively enclosed rooms with strong internal sources and also help policymakers to protect human health by enacting a stricter ban.

2. Methods

2.1. Sampling Sites and Population Recruitment. The field sampling was conducted in Nanchong, Sichuan province, where mahjong is a popular entertainment [13]. Three typical mahjong clubs were selected for the investigation. All three clubs were usually open for six hours from 13 to 19 o'clock, sometimes lasted until 20 or 21 o'clock. Club 1 has 13 rooms, each of which contains only one table for four people playing mahjong, and two more mahjong tables are in the hall (Figure S1). It is in a suburban location, just on a busy road. Both Clubs 2 and 3 have two rooms, no extra table in hall, and are located in residential communities, 20–50 meters away from the nearest traffic road (Figure S1). All spaces in three clubs, including each room and hall, were equipped with separate windows and air conditioners (AC), which were all open or operating when there were people in the space. The door of the room was closed when it was occupied and open when vacant. The room size ranged 22.5–90 m^3, averaging $45.1 \pm 18.2\,m^3$. Temperature and relative humidity (RH) were quite stable due to the use of AC, with the mean of $29.7 \pm 4.0^{\circ}C$ and $51.6 \pm 8.2\%$. Smoking is not forbidden in these clubs. 51% of the rooms had cigarette butts at the end of sampling day (Table 1).

382 person-times visited the clubs during our sampling campaign and stayed for 4.9 ± 1.1 hours averagely (Table 1). 179 females and 203 males were included, aging from 15 to 80, with the mean and median values of 44 ± 11 and 46, respectively. 35% of visitors were active smokers.

2.2. PM Measurement. The optical real-time $PM_{2.5}$ monitors (Zefan Technol., China) were used in this filed campaign, of which the operation details could be found elsewhere [14, 15]. The $PM_{2.5}$ data was recorded with a 5-second interval for 24 hours. Prior to the field campaign, all the $PM_{2.5}$ monitors were calibrated for at least 15 days against a particulate matter monitor (model 5030 synchronized hybrid ambient real-time particulate monitor, Thermo Scientific). The monitors were placed in each separate room at the height of 1.5 m and about 1.0 m away from the walls. The ambient (outdoor) $PM_{2.5}$ was measured at the roof of a 3-floor building.

2.3. Excess Exposure Concentration Assessment. Excess $PM_{2.5}$ exposure concentrations were averaged in 24 hours and a year (annual), according to the World Health Organization global air quality guidelines (WHO AQG). The recommendation of a short-term (24-hour) AQG level of 15 $\mu g/m^3$ and an annual AQG level of 5 $\mu g/m^3$ was used herein for comparison [16].

We assumed five hours per day and two days per week staying in club based on our survey. Therefore, the average excess $PM_{2.5}$ exposure concentrations of 24-hour and annual averaging time are shown in Equations (1) and (2), where C_{E-24h} and C_{E-ann} are the average excess exposure concentrations ($\mu g/m^3$) of 24-hour and annual averaging time, respectively, C is the mean concentration ($\mu g/m^3$) indoors from 13 to 19 o'clock, and $C_{outdoor}$ is the mean concentration ($\mu g/m^3$) outdoors from 13 to 19 o'clock.

$$C_{E-24h} = \frac{(C - C_{outdoor}) \times 5\,(\text{hours})}{24\,(\text{hours})}, \tag{1}$$

$$C_{E-ann} = \frac{(C - C_{outdoor}) \times 5\,(\text{hours}) \times 2\,(\text{days})}{24\,(\text{hours}) \times 7\,(\text{days})}. \tag{2}$$

2.4. Data Analysis. Due to the skewed distribution of $PM_{2.5}$, the geometric mean values were presented, together with medians and ranges. Indoor to outdoor ratio (I/O) of $PM_{2.5}$ concentration was calculated to evaluate the relationship between indoor and outdoor concentrations. The Mann–Whitney U test was conducted for comparison between two groups, e.g., indoor and outdoor $PM_{2.5}$. Pearson's correlation test was used for identifying the correlation of $PM_{2.5}$ in different groups. General linear regression model (GLM) was used to identify the influence factors. Both indoor $PM_{2.5}$ and outdoor $PM_{2.5}$ were log-transformed in GLM. The change and 95% confidence interval (95% CI) of $PM_{2.5}$ concentration were calculated at each unit increment of influencing factors except for doubling values of outdoor $PM_{2.5}$ in GLM.

All statistical tests were two-sided with a type-I error rate of 0.05. Data were analyzed using SPSS (SPSS, Inc.) and R version 4.0.1 (R Core Team, 2021).

3. Results and Discussion

3.1. Indoor and Outdoor $PM_{2.5}$ Levels. During open hours (13–19 o'clock), the geometric mean value of indoor $PM_{2.5}$ levels was 174 $\mu g/m^3$ (range: 10–2174 $\mu g/m^3$), and the median value was 178 $\mu g/m^3$. The geomean and median $PM_{2.5}$ levels were 276 and 347 $\mu g/m^3$ in the occupied and smoking rooms, 109 and 109 $\mu g/m^3$ in the occupied but nonsmoking rooms, and 148 and 169 $\mu g/m^3$ in the vacant rooms. The geomean of outdoor $PM_{2.5}$ was 22.8 $\mu g/m^3$ (ranging 10.0–94.0 $\mu g/m^3$), and the median was 20.0 $\mu g/m^3$. The outdoor $PM_{2.5}$ was significantly much lower than

Table 1: Detailed information of sampling site and population in the mahjong clubs of this study.

Characteristic	Value[a]	Indoor $PM_{2.5}$	p[b]
Site			
Number (site-time)	105	/	
Opening hours	13 : 00-19 : 00	/	
Room size (m^3)			
Mean ± standard deviation	45.1 ± 18.2	288 ± 294	<0.001
Median	37.5	178	
Ventilation			
Opening window number			
1	98 (93%)	304 ± 301	<0.001
2	7 (7%)	133 ± 83.8	
Working air conditioner number			
0	18 (17%)	180 ± 109	<0.001
1	17 (16%)	404 ± 412	
2	60 (58%)	309 ± 296	
4	10 (9%)	228 ± 204	
Temperature (°C)			
Mean ± standard deviation	29.7 ± 4.0	288 ± 294	<0.001
Median	29.3	178	
Relative humidity (RH, %)			
Mean ± standard deviation	51.6 ± 8.2	288 ± 294	<0.001
Median	51.5	178	
Cigarette butts found in room			
Yes	54 (51%)		<0.001
Number (mean ± standard deviation)	28 ± 25	410 ± 342	
Number (median)	20		
No	49 (47%)	149 ± 122	
Population			
Number (person-time)	382	/	
Gender			
Female	179 (47%)	/	
Male	203 (53%)	/	
Age (year)			
Mean ± standard deviation	44.3 ± 11.5	/	
Median	46.0	/	
Active smoker			
Yes	112 (35%)	/	
No	211 (65%)	/	
Staying duration (hours)			
Mean ± standard deviation	4.9 ± 1.1	/	
Median	5.0	/	

[a]Values are expressed as means ± standard deviations for room size, temperature, relative humidity, cigarette, age and staying hours, and as numbers and percentages for ventilation, cigarette, gender, and active smoker. [b]Spearman's correlation analysis was used to assess the correlations between room size/temperature/relative humidity, and indoor $PM_{2.5}$. The Mann–Whitney U test or Kruskal-Wallis H test was used to assess indoor $PM_{2.5}$ differences among other categories.

indoor $PM_{2.5}$. As presented in Figure 1, the ratio of indoor to outdoor $PM_{2.5}$ (I/O) began to rise at 13 o'clock, peaked (~20) one hour later at around 14 o'clock, and maintained the level (I/O > 10) until club closed at 19 o'clock. Indoor sources in clubs were the overwhelming contributors to indoor $PM_{2.5}$, and the time of occurrence was completely

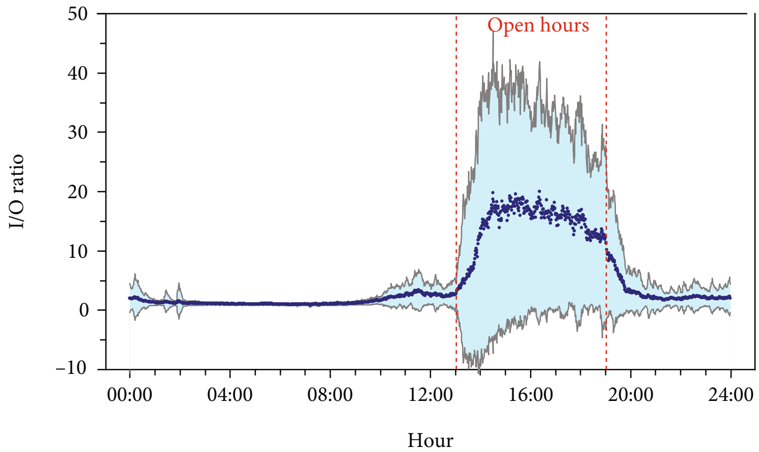


Figure 1: Diurnal ratio of indoor and outdoor $PM_{2.5}$ from the studied mahjong clubs during the sampling period. The dark blue dots are the means, and the light blue areas are the standard deviations.

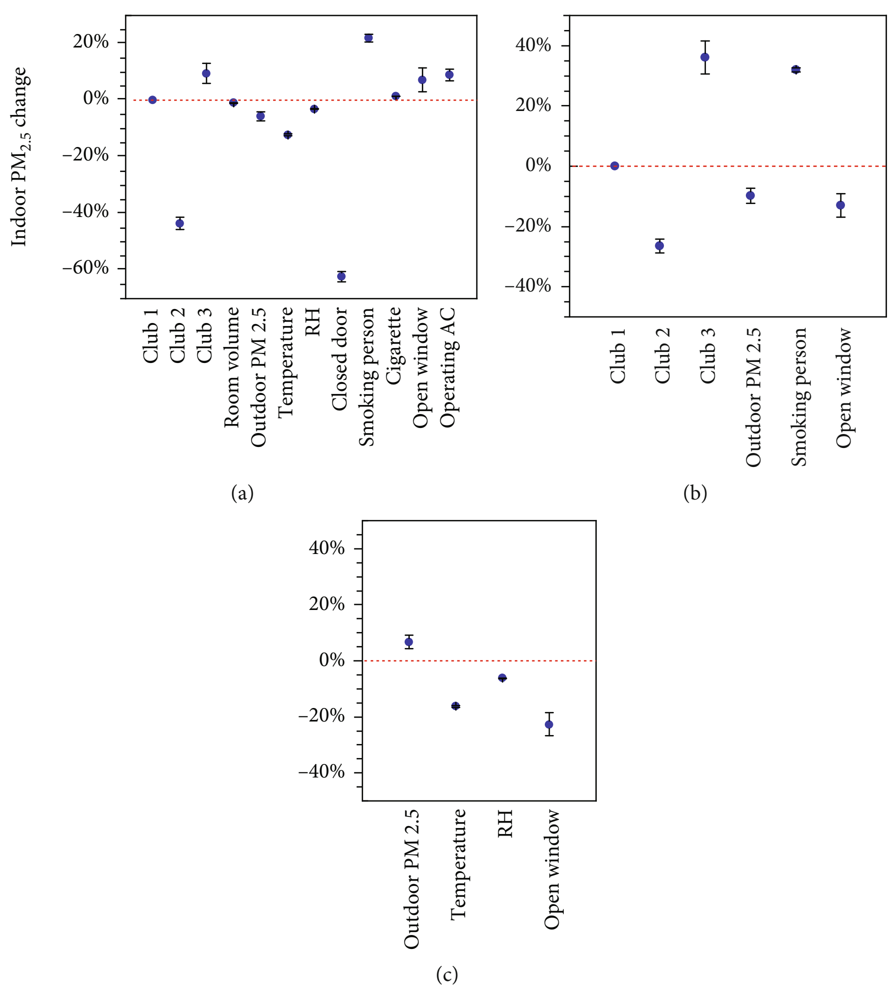
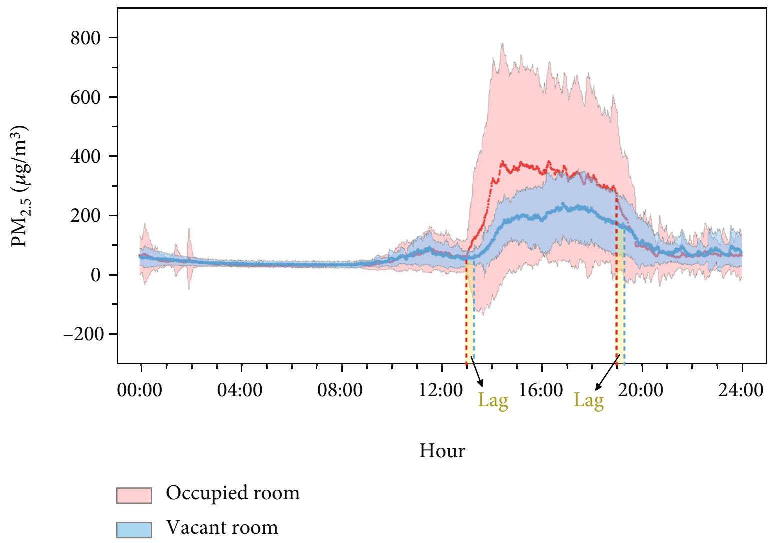


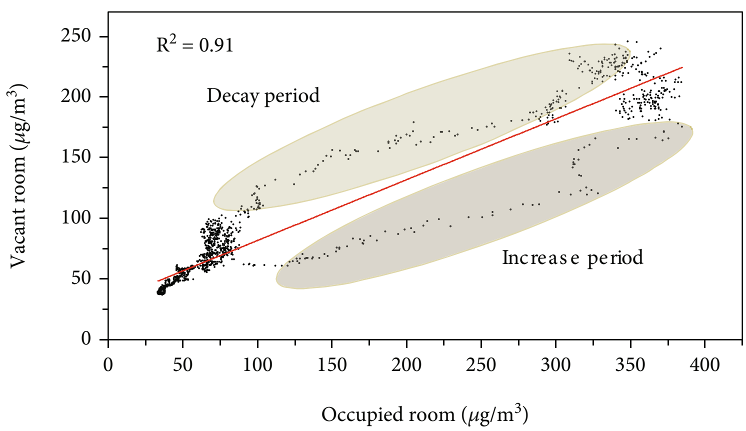
Figure 2: The change (estimation and 95% CI) of indoor $PM_{2.5}$ associated with each unit increment of influencing factors except for doubling outdoor $PM_{2.5}$ in all rooms (a), occupied rooms (b), and vacant rooms (c).

synchronized with open hours, corroborating the contribution of human activity, i.e., smoking.

A study conducted in other entertainment venues (game rooms, pubs, and billiards halls) in South Korea reported lower $PM_{2.5}$ levels (averaging 29–134 $\mu g/m^3$, Table S1) [17], while in other public places, including restaurants, bars, cafes, and smoking rooms in airport, several reports found close $PM_{2.5}$ levels to this study. For example,



(a)



(b)

FIGURE 3: (a) Diurnal characteristics (means and standard deviations) of indoor $PM_{2.5}$ from occupied and vacant rooms and (b) correlation of indoor $PM_{2.5}$ between occupied rooms and vacant rooms.

designed smoking rooms in restaurants, cafes, and bars in Kazakhstan had a mean level of 648 $\mu g/m^3$; in the separate smoking zones, still connected with the nonsmoking areas, the mean $PM_{2.5}$ levels were close with the nonsmoking rooms in our study, which was 182 $\mu g/m^3$; diffusion of particulate matters made the nonsmoking zones have a level of 56 $\mu g/m^3$ [18]. The independent smoking rooms in various airports all around the world reported mean $PM_{2.5}$ levels from 152 to 532 $\mu g/m^3$ [19, 20].

3.2. Influencing Factors. The distributions of indoor and outdoor $PM_{2.5}$ using different time resolutions and periods are shown in Figure S2. When using 15 min resolution, indoor $PM_{2.5}$ during open hours performed bimodal distribution. Prominently, the higher one (~452 $\mu g/m^3$) was from occupied and smoking rooms. General linear models identified that the rooms with closed doors had -62% reduction (95% CI: -64%, -60%) of $PM_{2.5}$ (Figure 2(a)), which was the most effective factor. According to the on-site inspection, only occupied rooms had closed doors, and all vacant rooms had opened doors. For example, Room 1 in Club 1 had the lowest level of $PM_{2.5}$ when door was closed without cigarette consumption but higher level when it was vacant with open doors (Figure S3). Therefore, we speculated that the lower peak of bimodal distribution was from the vacant rooms.

Figure 3(a) presents the diurnal characteristics of indoor $PM_{2.5}$ in occupied rooms and vacant rooms, respectively, portraying a synchronous trend. They also presented a significantly positive correlation ($R^2 = 0.91$, Figure 3(b)). A lag time about 20 minutes during both increase and decay periods substantiated that $PM_{2.5}$ diffusion from smoking rooms is the largest contributor to vacant rooms. Therefore, the lower peak of the bimodal distribution reflects the penetration of smoking air pollution into adjacent rooms. Both peaks were actually induced by smoking, of which one was mainly from the emission and the other was from penetration.

Among occupied rooms, we found significant effects of different clubs, room size, outdoor $PM_{2.5}$, temperature, RH,

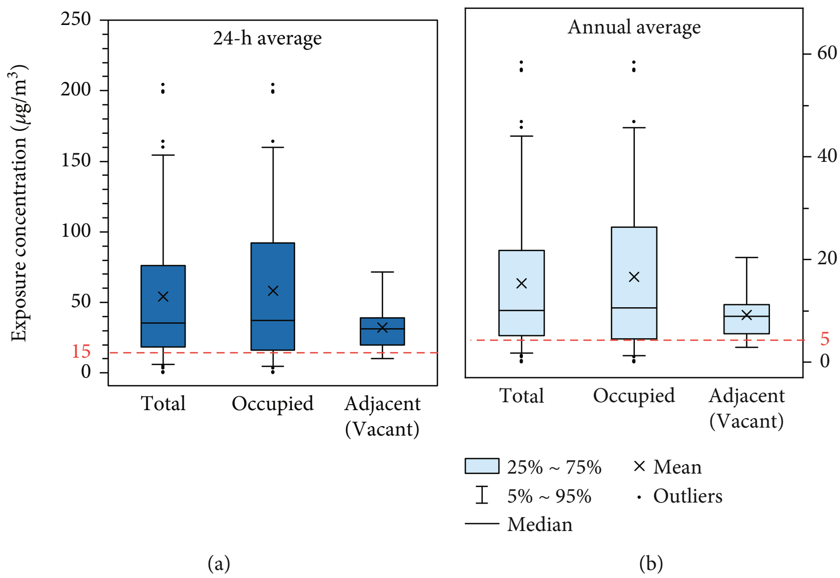


Figure 4: Boxplots of average excess $PM_{2.5}$ exposure concentrations in (a) 24-hour and (b) annual averaging time in mahjong club. The WHO AQG for 24-hour and annual averaging time are 15 and 5 $\mu g/m^3$, also shown in the figure.

smoking people number in room, cigarette number, open window number, and operating AC number on indoor $PM_{2.5}$ levels (Table S2), while several factors play a very limited role in $PM_{2.5}$, e.g., room size, RH, and cigarette number. Different clubs, outdoor $PM_{2.5}$, smoking people number in room, and open window number affected indoor $PM_{2.5}$ of occupied rooms mostly (Figure 2(b)). For each additional person smoking in the room, $PM_{2.5}$ increased by 32% (95% CI: 31%, 33%). Since mahjong is usually played by four people, $PM_{2.5}$ levels will not rise indefinitely. A -10% reduction of indoor $PM_{2.5}$ was associated with doubling outdoor $PM_{2.5}$. Higher outdoor temperatures might make people close the window, which lowered the ventilation rates and enhanced indoor $PM_{2.5}$ levels; meanwhile, outdoor temperature was negatively associated with outdoor $PM_{2.5}$ levels ($p < 0.05$), which resulted in the negative association between outdoor and indoor $PM_{2.5}$ levels. Each open window was associated with -13% less of $PM_{2.5}$, suggesting the effectiveness of open windows and higher air change rates on indoor air pollution alleviation [21].

With respect to vacant rooms, all were in Club 1 and had opened doors. Room size, outdoor $PM_{2.5}$, temperature, RH, and open window number had significant effects on indoor $PM_{2.5}$ (Table S3). After excluding room size, temperature and open window numbers affected mostly (Figure 2(c)). For each incremental degree of temperature, indoor $PM_{2.5}$ reduced -16% (95% CI: -17%, -16%). All occupied rooms turned on ACs to maintain a cool environment during sampling period. Cold air could diffuse from occupied rooms to the vacant rooms, together with smoking $PM_{2.5}$, resulting in an inverse association between indoor temperature and indoor $PM_{2.5}$. Each open window was associated with -23% (95% CI: -27%, -18%) reduction of $PM_{2.5}$, playing a more effective role in vacant rooms. Meanwhile, doubling outdoor $PM_{2.5}$ enhanced indoor $PM_{2.5}$ by 6.7% (95% CI: 4.3%, 9.1%), informing the external penetration of outdoor $PM_{2.5}$ [14].

3.3. Average Excess Exposure Concentrations. The 24-hour and annual average excess $PM_{2.5}$ exposure concentrations were assessed based on the assumption of 5 hours/day and 2 days/week staying in mahjong club (Figure 4). The geomean and median values of 24-hour average excess exposure concentration were 32.1 and 35.4 $\mu g/m^3$ (range: 0.01–204 $\mu g/m^3$). 79% of the 24-hour average excess exposure concentrations exceeded 15 $\mu g/m^3$, the WHO AQG for 24-hour averaging time [16]. The geomean and median values of annual average excess exposure concentration were 9.2 and 10.1 $\mu g/m^3$ (range: 0.003–58.4 $\mu g/m^3$). 75% of the annual average excess exposure concentrations exceeded 5 $\mu g/m^3$, the WHO AQG for annual averaging time [16]. Although the highest average excess exposure concentrations appeared in occupied rooms, more average excess exposure concentrations in vacant rooms exceeded the corresponding WHO AQG.

Both 24-hour and annual average results indicated a very serious air quality problem in non-smoke-free mahjong club, and it is also substantiated that $PM_{2.5}$ diffusion from smoking area would significantly enhance the exposure in adjacent nonsmoking area. We need to note that these are excess concentrations, which should be added to the outdoor concentrations, implying a median 10 $\mu g/m^3$ increase of $PM_{2.5}$ annually if spending 5 hours/day and 2 days/week in mahjong club. Numerous studies have verified that a 10 $\mu g/m^3$ increment of $PM_{2.5}$ will induce significant increase of lower respiratory infection incidence [22, 23], mortality of cerebrovascular disease [24, 25], chronic obstructive pulmonary disease [26, 27], ischemic heart disease [25, 28], and lung cancer [29, 30]. The WHO AQG defined the 24-hour average concentration as the 99th percentile of the annual distribution of 24-hour average concentrations (equivalent to 3–4 exceedance days per year) [16], while based on the assumption of two days per week in mahjong, there were over 100 exceedance days per year. Actually, we found many mahjong players visited the club even every day, which tripled the annual average exposure concentrations and resulted in almost 100% exceedance days per year. That demonstrates a very severe health risk for the mahjong club visitors and needs immediate forbidden of smoking in mahjong clubs and similar entertainment venues.

3.4. Study Strengths and Limitations. There are several strengths in the present study. Continuous real-time measurements for a week in several venues ensured the quality of data. In conjunction with the simultaneous monitoring of multiple locations in the same venue, temporal and spatial variability is more prominent. Detailed inspections and records facilitated the recovery of the influencing factors on indoor air quality. We recognize several limitations in the study. Given the sampling in limited venues and cities, our results may not reflect the comprehensive situation of entertainment venues in China. This campaign was conducted only in summer and may not characterize winter situations. Some information was not recorded in real time, e.g., cigarette numbers, which limited the influence assessment of these factors. More follow-up studies are warranted.

4. Conclusions

By taking mahjong clubs as target examples, this study investigated the $PM_{2.5}$ pollution characteristics induced by cigarette smoking in entertainment venues. The $PM_{2.5}$ concentrations usually peaked one hour later since the clubs were open and maintained the levels until closed. The number of smoking persons in the room is the dominant factor to enhance $PM_{2.5}$ levels. Regarding adjacent nonsmoking rooms, $PM_{2.5}$ also increased due to the air penetration from smoking rooms and the increase trend usually had a lag time of around 20 minutes. To close the door of the room is the most effective measure to alleviate the $PM_{2.5}$ penetration. The derived average excess exposure concentrations were tens of times higher than the WHO air quality guidelines, even in adjacent nonsmoking areas. The results suggested that the smoking ban performs no function in several entertainment venues in China. It also implied that attached smoking space in indoor public places could jeopardize the air quality and endanger people in nonsmoking areas. Our study warns of the need to facilitate smoking bans in several entertainment venues and also suggests that the setting of smoking areas should be scientific and effective.

Data Availability

The data used to support the findings of this study are available from the corresponding authors upon request.

Additional Points

Highlights. (i) $PM_{2.5}$ pollution induced by cigarette smoking in entertainment venues is severe. (ii) The number of smoking persons is the dominant factor to enhance $PM_{2.5}$ levels. (iii) $PM_{2.5}$ in smoking rooms could penetrate into adjacent nonsmoking areas. (iv) To close the door is the most effective measure to alleviate the $PM_{2.5}$ penetration.

Conflicts of Interest

The authors declare no competing financial interest.

Authors' Contributions

Wei Du was responsible for conceptualization, methodology, funding acquisition, resources, project administration, and writing the original draft. Jinze Wang was responsible for the investigation, software, writing the original draft, and visualization. Nan Lin and Bo Pan were responsible for data curation, formal analysis, funding acquisition, validation, supervision, visualization, project administration, writing the original draft, reviewing, and editing. Yuanchen Chen and Guofeng Shen were responsible for reviewing and editing.

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Supplementary Materials

Supporting Materials include: Table S1: $PM_{2.5}$ concentrations in smoking rooms and nonsmoking rooms in previous studies and present study; Table S2: general linear regression model results of log-transformed indoor $PM_{2.5}$ in occupied rooms; Table S3: general linear regression model results of log-transformed indoor $PM_{2.5}$ in vacant rooms; Figure S1: locations and layout of three mahjong clubs; Figure S2: distributions of indoor and outdoor log-transformed $PM_{2.5}$ concentrations during different periods by using 1 min and 15 min time resolution; Figure S3: $PM_{2.5}$ concentrations during open hours (13 to 19 o'clock) in Room 1 and outdoor, with date, people, ventilation conditions, and smoking conditions as shown. *(Supplementary Materials)*

References

[1] WHO, "Air pollution," July 2022, https://www.who.int/health-topics/air-pollution#tab=tab_1.

[2] G. F. Shen, Y. C. Chen, C. Y. Xue et al., "Pollutant emissions from improved coal- and wood-fuelled cookstoves in rural households," *Environmental Science & Technology*, vol. 49, no. 11, pp. 6590–6598, 2015.

[3] N. Lin, X. Mu, G. Wang et al., "Accumulative effects of indoor air pollution exposure on leukocyte telomere length among non-smokers," *Environmental Pollution*, vol. 227, pp. 1–7, 2017.

[4] K. K. Lee, R. Bing, J. Kiang et al., "Adverse health effects associated with household air pollution: a systematic review, meta-

analysis, and burden estimation study," *The Lancet Global Health*, vol. 8, no. 11, pp. E1427–E1434, 2020.

[5] Y. Hu and B. Zhao, "Indoor sources strongly contribute to exposure of Chinese urban residents to $PM_{2.5}$ and NO_2," *Journal of Hazardous Materials*, vol. 426, p. 127829, 2022.

[6] Y. Hu, J. S. Ji, and B. Zhao, "Deaths attributable to indoor PM2.5in urban China when outdoor air meets 2021 WHO Air Quality Guidelines," *Environmental Science & Technology*, vol. 56, no. 22, pp. 15882–15891, 2022.

[7] WHO, "Household air pollution and health," July 2022, https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health.

[8] W. Du, J. Z. Wang, S. S. Zhang et al., "Impacts of Chinese spring festival on household $PM_{2.5}$ pollution and blood pressure of rural residents," *Indoor Air*, vol. 31, no. 4, pp. 1072–1083, 2021.

[9] J. F. Zhang and K. R. Smith, "Indoor air pollution: a global health concern," *British Medical Bulletin*, vol. 68, no. 1, pp. 209–225, 2003.

[10] Y. Huang, W. Du, Y. C. Chen et al., "Household air pollution and personal inhalation exposure to particles ($TSP/PM_{2.5}/PM_{1.0}/PM_{0.25}$) in rural Shanxi, North China," *Environmental Pollution*, vol. 231, Part 1, pp. 635–643, 2017.

[11] Y. Jiang and Tobacco Control Office, Chinese Center for Disease Control and Prevention, Beijing, China, "Urgent need to ratify national legislation banning smoking in public places," *China Cdc Weekly*, vol. 2, no. 23, pp. 426-427, 2020.

[12] C. E. Ross and W. Zhang, "Education and psychological distress among older Chinese," *Journal of Aging and Health*, vol. 20, no. 3, pp. 273–289, 2008.

[13] Z.-H. Zhu, S.-T. Wu, W.-Z. Wang, Z.-B. Shi, and J.-X. Zhang, "Mahjong play and cigarette/alcohol use affect mental health of people in Sichuan earthquake area," *Advances in Psychological Science*, vol. 17, no. 3, pp. 551–555, 2009.

[14] H. Z. Shen, W. Y. Hou, Y. Q. Zhu et al., "Temporal and spatial variation of $PM_{2.5}$ in indoor air monitored by low-cost sensors," *Science of The Total Environment*, vol. 770, article 145304, 2021.

[15] N. Lin, W. Du, J. Z. Wang, X. Yun, and L. Chen, "The effect of COVID-19 restrictions on particulate matter on different modes of transport in China," *Environmental Research*, vol. 207, p. 112205, 2022.

[16] World Health, O, *WHO Global Air Quality Guidelines: Particulate Matter (PM2.5 and PM10), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide*, World Health Organization, Geneva, 2021.

[17] J. H. Lee, D.-U. Park, and W. Ha, "Evaluation of indoor ETS exposure levels in pubs, PC game rooms, and billiards halls around a university campus using $PM_{2.5}$ concentrations," *Journal of Korean Society of Occupational and Environmental Hygiene*, vol. 26, no. 4, pp. 411–417, 2016.

[18] J. Sadykova, A. Baizhaxynova, and B. Crape, "Air quality at venues of mixed smoking policies in Kazakhstan," *Tobacco Induced Diseases*, vol. 18, pp. 1–9, 2020.

[19] J. Peesing, N. Charoenca, A. Tipayarom, N. Kungskulniti, S. L. Hamann, and S. Pitayarangsarit, "Tobacco smoke pollution from designated smoking rooms in Bangkok's major international airport," *Environment and Natural Resources Journal*, vol. 13, no. 2, pp. 26–32, 2015.

[20] N. Kungskulniti, N. Charoenca, J. Peesing et al., "Assessment of secondhand smoke in international airports in Thailand, 2013," *Tobacco Control*, vol. 24, no. 6, pp. 532–535, 2015.

[21] N. Lin, M. A. Rosemberg, W. Li, E. Meza-Wilson, C. Godwin, and S. Batterman, "Occupational exposure and health risks of volatile organic compounds of hotel housekeepers: field measurements of exposure and health risks," *Indoor Air*, vol. 31, no. 1, pp. 26–39, 2021.

[22] I. Hertz-Picciotto, R. J. Baker, P. S. Yaw et al., "Early childhood lower respiratory illness and air pollution," *Environmental Health Perspectives*, vol. 115, no. 10, pp. 1510–1518, 2007.

[23] C. Karr, T. Lumley, A. Schreuder et al., "Effects of subchronic and chronic exposure to ambient air pollutants on infant bronchiolitis," *American Journal of Epidemiology*, vol. 165, no. 5, pp. 553–560, 2007.

[24] G. Cesaroni, C. Badaloni, C. Gariazzo et al., "Long-term exposure to urban air pollution and mortality in a cohort of more than a million adults in Rome," *Environmental Health Perspectives*, vol. 121, no. 3, pp. 324–331, 2013.

[25] K. A. Miller, D. S. Siscovick, L. Sheppard et al., "Long-term exposure to air pollution and incidence of cardiovascular events in women," *The New England Journal of Medicine*, vol. 356, no. 5, pp. 447–458, 2007.

[26] I. M. Carey, R. W. Atkinson, A. J. Kent, T. van Staa, D. G. Cook, and H. R. Anderson, "Mortality associations with long-term exposure to outdoor air pollution in a national English cohort," *American Journal of Respiratory and Critical Care Medicine*, vol. 187, no. 11, pp. 1226–1233, 2013.

[27] O. Naess, P. Nafstad, G. Aamodt, B. Claussen, and P. Rosland, "Relation between concentration of air pollution and cause-specific mortality: four-year exposures to nitrogen dioxide and particulate matter pollutants in 470 neighborhoods in Oslo, Norway," *American journal of epidemiology*, vol. 165, no. 4, pp. 435–443, 2007.

[28] S. Weichenthal, J. A. Hoppin, and F. Reeves, "Obesity and the cardiovascular health effects of fine particulate air pollution," *Obesity*, vol. 22, no. 7, pp. 1580–1589, 2014.

[29] K. Katanoda, T. Sobue, H. Satoh et al., "An association between long-term exposure to ambient air pollution and mortality from lung cancer and respiratory diseases in Japan," *Journal of Epidemiology*, vol. 21, no. 2, pp. 132–143, 2011.

[30] M. C. Turner, M. Jerrett, C. A. Pope et al., "Long-term ozone exposure and mortality in a large prospective study," *American Journal of Respiratory and Critical Care Medicine*, vol. 193, no. 10, pp. 1134–1142, 2016.