Title
Assessing the Exposure and Health Risks of Secondhand Smoke in Restaurants and Bars by Workers and Patrons & Evaluating the Efficacy of Different Smoking Policies in Beijing Restaurants and Bars

Author
Liu, Ruiling

Publication Date
2012

Peer reviewed|Thesis/dissertation

Assessing the Exposure and Health Risks of Secondhand Smoke in Restaurants and Bars by Workers and Patrons
&
Evaluating the Efficacy of Different Smoking Policies in Beijing Restaurants and Bars

By

Ruiling Liu

A dissertation submitted in partial satisfaction of the

Requirements for the degree of

Doctor of Philosophy

in

Environmental Health Sciences

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor S. Katharine Hammond, Chair

Professor Michael Bates

Professor Mark Nicas

Professor Alan Hubbard

Fall 2012

Abstract

Assessing the Exposure and Health Risks of Secondhand Smoke
in Restaurants and Bars by Workers and Patrons & Evaluating the Efficacy
of Different Smoking Policies in Beijing Restaurants and Bars

By
Ruiling Liu
Doctor of Philosophy in Environmental Health Sciences
Professor S. Katharine Hammond, Chair

Exposure to secondhand smoke (SHS) is harmful and hazardous to the health of the general public. A large body of research has been conducted in this topic, and great efforts have been made to prevent people from being exposed to SHS. Legislation on restricting smoking in workplaces and many public places has also been increasing. However, tobacco industries have been fighting against smoking bans in restaurants and bars with multiple strategies, which has led to the current situation that smoking bans in restaurants and bars usually lag behind other environments in many countries. As of January 2012, a total of 66 nations worldwide have enacted a 100% smoke-free law in workplaces and hospitality venues, while only 46 of the 66 include both restaurants and bars, and more than 90% of the world population can't enjoy smoke-free restaurants and bars. In addition, tobacco industries have made continuing efforts to remove existing smoking bans, and such efforts are sometimes successful. For example, as of October 2011, 15 U.S. municipalities that had adopted effective smoke-free laws subsequently repealed, weakened, or postponed them due to such efforts.

This dissertation aims to quantify SHS exposure and the attendant health risks, morbidity and mortality, among restaurant and bar servers and patrons, to provide scientific evidence on whether SHS exposure in restaurants and bars can be ignored and whether restaurants and bars should be exempted from smoking bans. The dissertation consists of seven chapters. Chapter 1 presents the general background, Chapters 2 and 3 focus on quantifying SHS exposure in restaurants and bars by workers and patrons; Chapter 4 evaluates the efficacy of different smoking policies adopted to reduce SHS exposure in restaurants and bars in Beijing China; and Chapters 5 and 6 assess the excess heath risks, morbidity and mortality, due to SHS exposure in restaurants and bars, and the last chapter summarizes the findings and conclusions from the previous five chapters.

The study in Chapter 2 applies multiple approaches to assess restaurant and bar servers' and patrons' exposure to SHS two years after the implementation of the governmental smoking restriction in Beijing, 2010. Of the 79 restaurants and bars monitored in the study, 37 (47%) nominally prohibited smoking, and 14 (18%) restricted smoking to designated sections. A total of 121 visits were made during peak-patronage times, and smoking was observed in 26 (51%) of these nominal nonsmoking venues or sections. Patrons were exposed to a median (interquartile range IQR) of 27 (4-93) $\mu g/m^3$ of fine particulates derived from SHS (SHS PM) and a median (IQR) of 1.53 (0.69-3.10) $\mu g/m^3$ of airborne nicotine during their visits. For servers, continuous real-time sampling of SHS PM and sequential area sampling of airborne nicotine, for more than 24 hours in two restaurants, showed obvious spikes of SHS concentrations during peak-patronage times, and SHS concentrations remained high during intervals between peak-

patronage times or in evenings due to staff smoking. Servers were exposed to a median (IQR) of 2.62 (1.22-5.40) μg/m^3 of airborne nicotine during their day-time working hours by one-day active personal sampling, and 1.83 (0.92-3.21) μg/m^3 of airborne nicotine during a whole week by week-long passive sampling. Nonparametric Kruskal-Wallis rank tests of SHS concentrations by different nominal smoking policies showed statistically significant difference of peak-patronage-time SHS PM and airborne nicotine concentrations, while no statistically significant differences of one-day average nicotine concentration by active area or personal sampling, or of week-long average nicotine concentration by passive sampling. Comparison of results by different sampling approaches showed that both measured SHS PM and airborne nicotine concentrations were significantly related to observed active smoker activities. A slope of 17 μg/m^3 of SHS PM per one μg/m^3 of nicotine was observed. Time-weighted nicotine concentrations by one-hour peak-patronage time area sampling were higher than those by one-day area sampling and by week-long area sampling; and results of peak-patronage-time sampling could explain about half of the variance of the results by the latter two sampling approaches. One-hour peak-patronage-time area nicotine sampling results were very close to one-day personal nicotine sampling results. Thus, peak-time area sampling is a feasible and also a reasonably accurate way to access patrons' exposure to SHS during their short-term visits and servers' exposure during their full shifts.

Chapter 3 develops and evaluates a mass balance model to predict SHS concentrations in restaurants and bars in China during peak-patronage times. The model is based on field data from an intensive study, with field monitoring of SHS concentrations in a representative sample of Minnesota restaurants and bars during representative peak-patronage times, and field data from existing studies of Chinese restaurants and bars. The model could predict SHS PM concentrations reasonably well, but not so well for airborne nicotine concentrations. Using the model and Monte Carlo simulation, the mean (SD) of simulated SHS PM concentrations was predicted to be 135 (182) μg/m^3, 90 (129) μg/m^3, and 49 (79) μg/m^3 in restaurants with smoking allowed everywhere, designated smoking sections of restaurants, and designated nonsmoking restaurants, respectively. Predicted SHS concentrations in bars were about two times as in restaurants with the same smoking policy. These predicted concentrations were used to assess the health risks for both servers and patrons in Chapter 6.

Chapter 4 uses field data collected in three previous studies from 2006 to 2008 and the study conducted in 2010, which is presented in Chapter 2, to evaluate the efficacy of different smoking policies adopted in Beijing restaurants and bars during this time period. There were significant overlaps of sampling venues included in each year. In 2006, all voluntary smoking bans in restaurants and bars were completely self-motivated by owners, and in 2007, they were encouraged by the government. Less than 20% of restaurants and bars prohibited or restricted smoking in 2006 or 2007. This indicates that both the self-motivated and governmental encouraged voluntary smoking bans are rarely adopted; thus, voluntary smoking bans cannot protect people from SHS exposure in restaurants and bars. When the Beijing government started to require smoking restrictions in restaurants and bars in 2008, more than 80% of venues did so as required; in these venues, the active smoking rate of patrons decreased, while no significant changes were observed in venues without any policy changes. However, some venues stopped prohibiting or restricting smoking two years later in 2010, resulting in less than 60% restaurants and bars nominally prohibited or restricted smoking, showing non-continuous enforcement by the government and decreasing compliance by venue owners. Though SHS PM concentrations in Beijing restaurants and bars decreased after the governmental smoking restriction in both 2008 and 2010, compared to those in 2006 and 2007, this happened in all the venues followed up with, regardless of the policy changes. In 2010, two years after the smoking restrictions, both SHS PM concentrations and active smoking rates in restaurants and bars were higher than in 2008, regardless of the changes in smoking policy. The similarity of SHS levels experienced by servers of restaurants and bars with different nominal smoking policies during their full shifts in 2010 also showed poor enforcement and compliance of the restrictions two years after the implementation.

Chapters 5 and 6 estimate the health risks and excess morbidity and mortality caused by SHS exposure in restaurants and bars in Minnesota, in the U.S., and in China. Intensive field monitoring of SHS exposure in a representative sample of 65 Minnesota restaurants and bars, for multiple times in each venue, showed that more than 80% of patrons were exposed to SHS concentrations above the threshold of eye and nasal irritation during more than 80% of their visits. Patrons' and servers' lifetime excess risk (LER) of lung cancer death (LCD) due to SHS exposure in restaurants and bars in both Minnesota and in China was well above the acceptable level of 1×10^{-6}. And this was true even for patrons who visited designated nonsmoking sections only for about 1.5 hours a week in their lifetime. The LER can be much higher for patrons who visit restaurants and bars more often, or for patrons who also visit smoking sections or venues allowing smoking everywhere. As for servers, their LER of LCD or asthma initiation (estimated for Minnesota and U.S. restaurant and bar servers only) could be higher than the significant risk of 1×10^{-3}, considered an unsafe level by the U.S. Occupational Safety and Health Administration (OSHA). In the population level, SHS exposure in restaurants and bars was estimated to cause three LCDs and 32 ischaemic heart disease (IHD) deaths per year among the general nonsmoking population, and 53 new asthma cases per year among nonsmoking servers in Minnesota, 214 LCDs and 3001 IHD deaths per year among the general nonsmoking population, and 1420 new asthma cases per year among nonsmoking servers in the U.S. This death toll was predicted to be 1325 LCDs and 1525 IHD deaths a year in China.

In all, restaurants and bars are major employers, and they are also important public places for the general population. This dissertation shows that both servers and patrons are exposed to high concentrations of SHS in restaurants and bars, and the attendant health risks, morbidity, and mortality are too significant to be ignored. Thus, to protect people from the health hazards of SHS exposure, restaurants and bars should not be exempted from any smoking bans. The only effective way is to create 100% smoke-free environments by comprehensive smoking bans, and just passing a smoking ban is not enough, while full enforcement and compliance is extremely important.

Dedication

To Zhijun Liu, for his love, support, patience and encouragements.

To Yuan Jiang, for her wisdom, and her continuous enthusiasm and support for my work.

Acknowledgements

First, I would like to express my deepest appreciation and gratitude to my advisor, Professor S. Katharine Hammond. Over the years of working together, I learned from her valuable knowledge and practical approaches to conduct scientific research, critical ways to think about existing knowledge, and the importance of having a big picture in mind. Her enthusiastic and committed supervision has made this a thoughtful and rewarding journey; her intellectual curiosity and her passion with both her research and her life beyond work is something I hope to emulate in my career. I especially appreciate her flexibility and her continuous support in both my academic work and my personal life along the journey. I am truly fortunate to have had the opportunity to work with Professor Hammond, and I attribute my academic achievements to her great mentorship.

I own special thanks to Dr. Yuan Jiang. Her wisdom and tremendous support since seven years ago provided me the opportunity to start this journey to explore a brand new life. Furthermore, her deep interest in tobacco control in China, and her help in recruiting student assistants and study subjects in Beijing two years ago enabled me to successfully finish the field data collection.

I would like to thank Michael G. Apte, for his allowing me the opportunity to develop more practical skills for risk assessment. His meticulous supervision, encouragements and trust in me helped me to grow more independent and confident in research. I also feel particularly thankful to him for his continuous support of my career development after his retirement. I would also like to thank Martha J. Hewett, for her critical comments on my work of risk assessment related to secondhand smoke exposure in Minnesota restaurants and bars.

My thanks go to Professors Robert C. Spear and John Balmes, who provided critical comments on my research proposal in my graduate group examination and my qualification examination; to Marion Gillen, whose detailed and critical comments on the protocol for IRB review on human subjects made the process much less painful; to Dr. Mark J. Travers and Dr. Dongxun Xu, who lended their instruments for my field sampling; and to Charles Perrino, who was patient in training me for the nicotine laboratory analysis, and provided valuable technical support for all my laboratory analysis. My thanks also go to Professors Mark Nicas, Michael Bates and Alan Hubbard, for their comments on my research proposal development, advice on data analysis and reviews of my dissertation drafts.

I greatly appreciate the National Tobacco Control Office of the Chinese CDC for all the support essential for the completion of the field work in Beijing. Thanks to Zhijun Liu, Jijiang Wang, Yiting Gu, Yangna Yang, Jingjing Zhang, Yang (Sophia) Song, and Lili Wang for their hard work of conducting the field data collection, and to all the participating restaurant and bar owners/managers and servers of the Beijing evaluation study.

I thank Sa Liu and Bethy Noth for sharing their experiences and giving practical advice to deal with various issues along the journey. Also, I thank David Dauphine for the fun we had on the Davis-Berkeley shuttle, and for his help editing the English in my presentations and one of my papers.

I would like to thank my mom and dad, who raised me as a person valuing dreams, strong will and hard work, who have always respected and supported whatever I decided to do, despite their unwillingness to be too far away from me, and who flew all the way here to help take care of my daughter so that I could focus on my dissertation. Thanks to my two sisters, Ruifen and Ruihua, and my brother, Bin, for taking care of mom and dad for more than their fair share, which made me feel much less guilty to start this journey. A special thank you to Zhijun Liu, for being a supportive husband and great friend. Thanks to my lovely daughter, Claire, who fills my heart with more-than-ever love of life, and who gives me complete breaks from academic work.

I am grateful to all the funding sources of my program, which include Dr. William Cahan Distinguished Professor Award to S. K. Hammond from the Flight Attendants Medical Research Institute, the Suzanne Llewellyn COEH Student Project Award and the CC Chen Fellowship from University of California, Berkeley, and ClearWay Minnesota (Grant Number RC 2006-0050).

Table of Contents

List of Tables

List of Figures

Chapter 1 Introduction

1.1 Health Effects and Disease Burden from Exposure to Secondhand Smoke

Secondhand smoke (SHS) is comprised of a complex dynamic of over 4,000 chemicals. There has been extensive research on the associations between exposure to SHS and adverse health effects, which have been reviewed by several major reports, including those published by the Surgeon General, the California Environmental Protection Agency (EPA), World Health Organization (WHO), International Agency for Research on Cancer (IARC) (WHO 1999; WHO IARC 2004; Cal/EPA 2005; USDHHS 2006) (Table 1.1).

Extensive epidemiological evidence shows that SHS exposure can cause respiratory and non-respiratory disease and other adverse effects in children, including low birth weight, sudden infant death syndrome (SIDS), lower respiratory illnesses, acute and recurrent otitis media, wheeze, cough and asthma exacerbation (Table 1.1). It may also increase the risk of childhood cancer, including childhood acute lymphoblastic leukemia (Liu, Zhang et al. 2011).

SHS contains numerous irritants, which can cause irritation of the eyes and upper and lower airways. Early surveys of nonsmokers showed that 50% of respondents complained about SHS at work, and a majority were disturbed by tobacco smoke in restaurants (USDHHS 1986). Junker et al suggested that there might be increasing sensitivity to SHS as the general level of exposure declines (Junker, Danuser et al. 2001). The odor and irritation associated with SHS merit special consideration, because a high proportion of nonsmokers are annoyed by exposure to SHS, and control of concentrations in indoor air poses difficult problems in the management of heating, ventilating, and air-conditioning systems (IARC 2009). The 2006 Surgeon General's report on The Health Consequences of Involuntary Exposure to Tobacco Smoke concluded that the evidence is suggestive but not sufficient to infer a causal relationship between SHS exposure and adult asthma onset or exacerbation (USDHHS 2006). However, based on more recent evidence published, California EPA found causal associations between SHS exposure and the two health conditions (Cal/EPA 2005).

The association between SHS and coronary heart disease (CHD) was first reviewed in 1986. Results of a number of meta-analyses of epidemiological studies since then have consistently shown increases of 25-30% in the risk of CHD from various exposures. Though there is no direct evidence that a relatively brief exposure (under one hour) to SHS can precipitate an acute coronary event, it is biologically possible (Institute of Medicine 2009).

Different reviews by major agencies consistently show that SHS exposure is associated with lung cancer among nonsmoking adults, regardless of exposure location. Pooled evidence shows increases of 20 to 30% in the risk of lung cancer from SHS exposure associated with living with a smoker (USDHHS 2006). However, studies on SHS exposure and breast cancer reached inconsistent conclusions. None of the 2006 Surgeon General's report, the 2004 WHO IARC monograph and the 2009 WHO IARC report found a causal relationship based on their reviews of this topic (IARC 2004; USDHHS 2006; IARC 2009), while the 2005 California EPA and the Ontario Tobacco Research Unit reviewed studies with "exposure assessment of best quality" and concluded that SHS is casually related to breast cancer in "younger, primarily pre-menopausal women" (Cal/EPA 2005; Collishaw NE, Boyd NF et al. 2009).

SHS exposure was estimated to have caused about 600,000 premature deaths worldwide in 2004, 28% of which were among children and 47% among women (Oberg, Jaakkola et al. 2011). Among adults, 87% of the estimated deaths were from ischemic heart disease, 8% from asthma and the remaining 5% from lung cancer (Figure 1.1). The U.S. Centers for Disease Control and

Prevention (CDC) estimated that SHS caused annual deaths of 49,000 between 2000 and 2004 (CDC 2008). In China, where there are more than 301 million current smokers (Li, Hsia et al. 2011) and 740 million nonsmoking adults potentially exposed to SHS (Chinese CDC 2011), about 56,000 deaths among adults from lung cancer and ischemic heart disease in 2002 were attributed to exposure to SHS (Gan, Smith et al. 2007).

Table 1.1 Health effects from exposure to secondhand smoke

	SGR 2006	Cal EPA 2005	WHO IARC 2004	WHO 1999
Reproductive and Developmental Effects				
Female Fertility	*	**		
Male reproductive toxicity	*	*		
Spontaneous abortion	*	**		
Perinatal death	*	*		
Infant deaths	*			
Sudden infant death syndrome	***	***		**
Preterm delivery	**	***		
Low birth weight	***	***		***
Congenital malformations	*	*		
Cognitive development	*	**		
Behavioral development	*	**		
neuropsychological development		**		**
Height/Growth	*	*		
Allergic sensitization		**		
Respiratory Effects in Children				
Lower respiratory illnesses	***	***		***
Acute and recurrent otitis media	***	***		***
Adenotonsillectomy	*			
Wheeze	***	***		***
Cough	***	***		***
Childhood asthma onset	**	***		
Childhood asthma exacerbation	***	***		***
Atopy (immunoglobulin e-mediated allergy)	*	**		
Lung growth and pulmonary function	***	**		***
Childhood Cancer	**	**		**
Respiratory Effects in Adults				
Acute irritant symptoms and effects	***	***		
Cough, wheeze, chest tightness and difficulty breathing	**			
Chronic respiratory symptoms	**	**		
Decrement in pulmonary function	**	**		
Adult-onset of asthma	**	***		

	SGR 2006	Cal EPA 2005	WHO IARC 2004	WHO 1999
Asthma exacerbation	**	***		
Chronic obstructive pulmonary disease (COPD)	**	*		
Morbidity in persons with COPD	*			
Exacerbation of cystic fibrosis		**		
Cardiovascular Diseases in Adults				
Coronary heart disease morbidity and mortality	***	***		
Stroke	**	**		
Atherosclerosis	**			
Altered vascular properties		***		
Cancer in Adults				
Lung cancer	***	***	***	
Breast cancer	**	***	*	
Nasal sinus cancer	**	***	*	
Nasopharyngeal carcinoma	*	**	*	
Cervical cancer	*	**	*	
Urinary tract/bladder cancer		*	*	
Stomach cancer		*	*	
Brain cancer		*	*	
Leukaemia		*		
Lymphoma		*		

Note: SGR 2006: The Health Consequences of Smoking: A Report of the Surgeon General 2006; Cal EPA 2005: Proposed Identification of Environmental Tobacco Smoke as a Toxic Air Contaminant by California Environmental Protection, 2005; WHO IARC: Monographs on the Evaluation of Carcinogenic Risks to Humans by WHO IARC, 2004; WHO 1999: International Consultation on Environmental Tobacco Smoke (ETS) and Child Health by WHO, 1999; * the evidence is inadequate to infer a causal relationship; ** the evidence is suggestive of a causal relationship; *** the evidence is sufficient to infer a causal relationship.

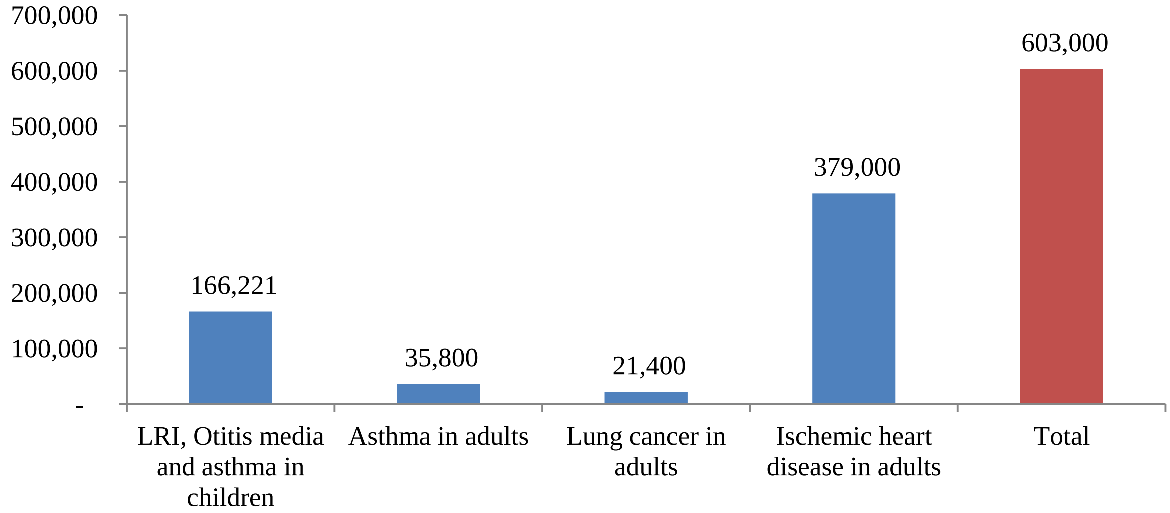


Figure 1.1 Number of deaths from exposure to secondhand smoke in 2004 (Oberg, Jaakkola et al. 2011)

1.2 Prevalence of SHS Exposure

SHS exposure is widespread worldwide. About 40% of children under age 15 years and one third of nonsmoking adults were estimated to be regularly exposed to SHS in 2004 (Oberg, Jaakkola et al. 2011). The proportion of children and nonsmoking adults with regular SHS exposure is lowest in the Africa (E) subregion, 12% for children and below 10% for nonsmoking adults, and highest in the Europe (C), above 60% for both children and nonsmoking adults, followed by the western Pacific region (B). See Figure 1.2 for details.

SHS exposure can occur in many microenvironments. The Global Youth Tobacco Surveys (GYTS) conducted in 132 countries between 1999 and 2005 indicated that 44% of students aged 13 to 15 in every World Health Organization Region were exposed to SHS at home and 56% in public places (The GTSS Collaborative Group 2006). A study including 32 countries, conducted from 2005 to 2007, found that smoking was observed in 79% of bars, 68% of restaurants, 55% of transportations and 53% of other indoor public places (Hyland, Travers et al. 2008). In China, the prevalence of SHS exposure among nonsmoking adults was 54% in 1996 (Yang, Fan et al. 1999), 52% in 2002 and 74% in 2010 (Chinese CDC 2011). The prevalence increased significantly in 2010, which may be due to a different definition of SHS exposure and increased awareness of SHS exposure among respondents. In both of the 1996 and 2002 studies, SHS exposure was defined as exposure for at least one day per week with at least 15 minutes' exposure per day, while in the 2010 study, it was defined as any exposure for at least 15 minutes in the last 30 days. The proportion of passive smokers who were exposed in homes, public places and workplaces all increased from 1996 to 2002, with exposure at home dominating in both years; in 2010, the proportions of exposure in the three environments were similar (Figure 1.3) (Yang and Hu 2010).

The National Human Activity Pattern Survey (NHAPS), which collected 24-hour diary data from 9,386 respondents between October 1992 and September 1994 in the United States, showed that 58% of the respondents had exposure from residential indoor, with an average of 305 minutes of exposure during 24 hours, 33% had exposure from vehicle, and 23% from restaurants and bars, with an average of 79 minutes and 143 minutes of exposure during 24 hours, respectively. Of those respondents who were exposed to SHS for at least one minute on the diary day, the location with the largest overall percentage of time spent being exposed was residential-indoors (48%), followed by office/factory (9.7%), bar/restaurant (8.8%) and in vehicle (7%) (Klepeis, Tsang et al. 1996). For restaurant servers and bar attendants, their time spent being exposed to SHS in restaurants and bars can be much longer if they work full time in a venue without smoking bans. As more public places other than restaurants and bars are covered by smoke-free legislation, the public is expected to have an increased percentage of time being exposed to SHS in restaurants and bars; for people living in nonsmoking homes, especially those who work in smoke-free environments, restaurants and bars can be the main source of SHS exposure.

Restaurants and bars are major employers. There were 11 million workers employed by this industry in 2010 in the United States, more than 2.7 million of whom were servers and bartenders (U.S. BLS 2011); About 11.4 million workers were employed by restaurants and bars in 2004 (National Bureau of Statistics of China 2008) in China, with a 36% increase in 2008 (Oberg, Jaakkola et al. 2011). They are also important public places for the general population. According to a telephone interview with a nationally representative sample of 2250 adults conducted by the Pew Research Center, 66% of adults, including 75% of those aged 18 to 29 in the United States eat out at least weekly and one third eat out twice a week or more (Pew Research Cener 2006). The NHAPS showed that patrons spent an average of 86 minutes each time in restaurants and bars (Tsang and Klepeis 1996). In China, 15 % of people aged 15 years and older ate out every day in 2002 (Ma, Hu et al. 2005) (Figure 1.4); and each person spend an average of 13 minutes each day in restaurants and/or bars (National Bureau of Statistics and Ministry of Labour and Social Security of China 2005). Therefore, exempting restaurants and bars from smoke-free bans can lead to a large population being exposed to SHS.

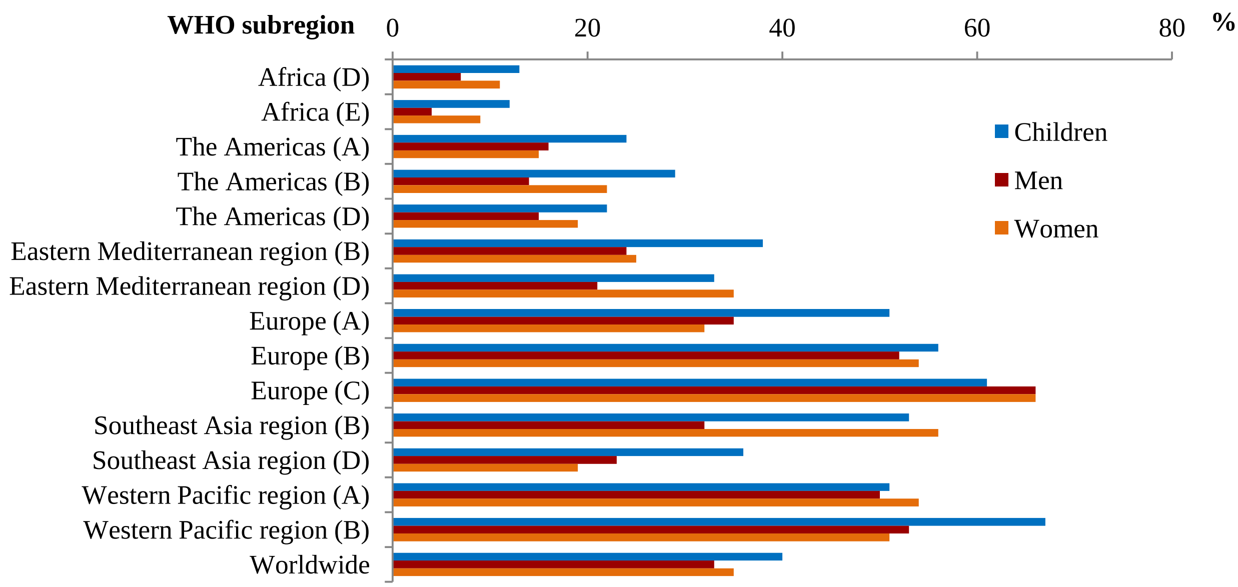


Figure 1.2 Proportion of children (younger than 15 years) and adult non-smokers exposed regularly to second-hand smoke estimated for the year 2004 based on survey data and modeling by WHO subregion
Note: this figure was adopted from Oberg et al (Oberg, Jaakkola et al. 2011);
Children's exposure is approximated based on having one or more parents who smoke.

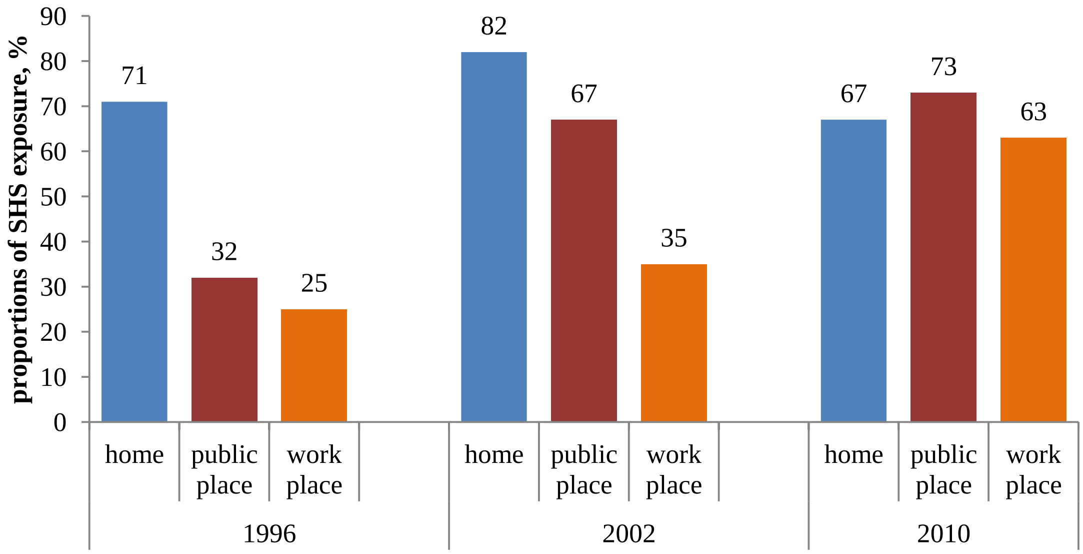


Figure 1.3 Proportions of SHS exposure happened in different places in China in 1996, 2002 and 2010
Note: In both of the 1996 and 2002 studies, SHS exposure was defined as with exposure for at least one day per week with at least 15 minutes' exposure per day, while in the 2010 study, it was defined as any exposure for at least 15 minutes in the last 30 days. Reproduce from Table 7-3, Yang and Hu (2010)

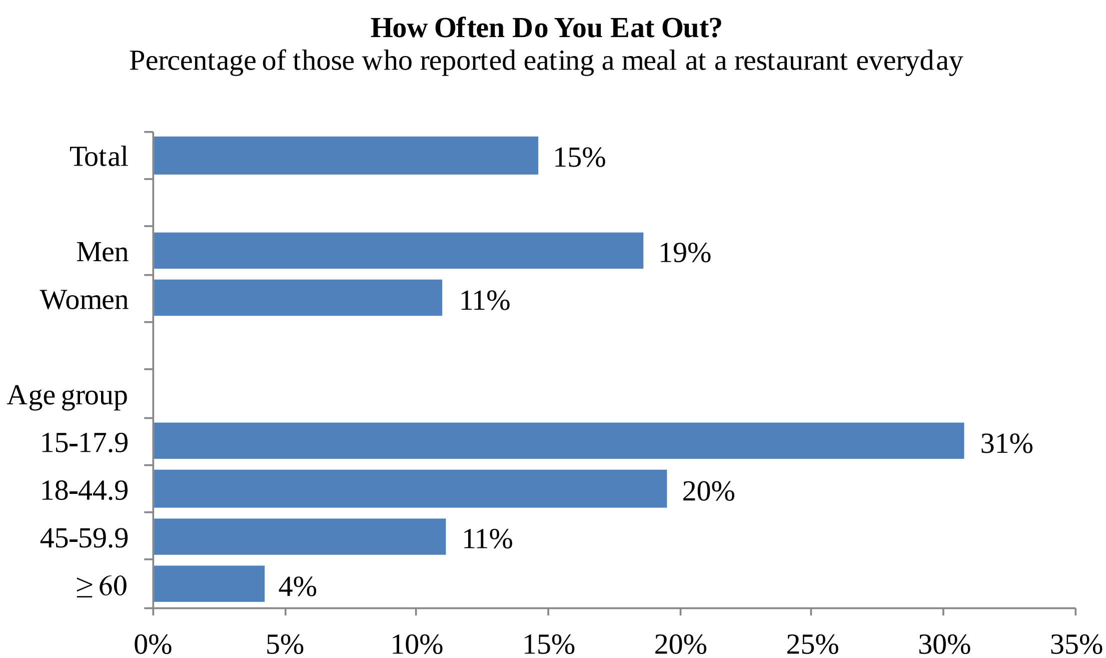


Figure 1.4 Percent of people who eat out at least every day, China, 2002
Note: this figure was adopted from Ma et al (Ma, Hu et al. 2005)

1.3 Measurement of Secondhand Smoke

The exposure-disease biological pathway is shown in Figure 1.5. People are exposed to SHS in multiple microenvironments. The total human exposure to an atmospheric contaminant like SHS represents the time-integrated sum of the exposures in multiple microenvironments where time is spent. The concentration of SHS in a microenvironment depends on intensity of smoking in that space, the volume of the space where SHS is dispersed, dilution by ventilation, and other processes that remove smoke from the air. The consequent exposures lead ultimately to doses of SHS components that may reach and harm target organs and manifest as adverse health effects.

Exposure to SHS can be directly or indirectly measured at one or more points on the pathway. Cigarette smoke is a complex aerosol consisting of thousands of gases and volatile chemicals in which particulate matter (PM) is suspended. The gas phase consists of air, carbon dioxide, carbon monoxide and many other chemicals, including nicotine, carbonyls (such as acetaldehyde, formaldehyde and acrolein), hydrocarbons (such as benzene, toluene, some polycyclic aromatic hydrocarbons [PAHs]), nitrogen oxides, pyridine, ammonia, nitrosamines and hydrogen cyanide (Cal/EPA 2005). The particulate phase, "tar", consists of thousands more chemicals, including alkaloids, larger PAHs, tobacco-specific nitrosamines, polonium-210, nickel, cadmium, arsenic and lead; some compounds, such as cresols and PAHs, are partitioned between vapor and particulate phases (Cal/EPA 2005). Because of the many potentially toxic agents in SHS, the measurement of all components in SHS is not practical or even desirable, due to limitations in knowledge of the mixture of components related to the effects of interest, as well as the feasibility and cost of sampling. Thus, using an indicator for SHS that will, when measured, accurately represent the frequency, duration, and magnitude of the exposure is necessary. These indicators can be questionnaires, chemicals measured in the air (airborne tracers), biomarkers or models (U.S. EPA 1992). Advantages and disadvantages of these indicators are listed in Table 1.2.

Questionnaire survey is the most commonly used indicator to assess SHS exposure in both retrospective and prospective studies of acute and chronic effects. They can be used to provide a simple categorization of SHS exposure, to determine time-activity patterns of individuals, and to acquire information on the factors or properties of the environment affecting SHS concentrations. The time-activity pattern information may be combined with measured or estimated concentrations of SHS in each environment to provide an estimate of total exposure. Information on the factors affecting SHS concentrations can be used to model or predict SHS levels in those environments (Woodward and Al-Delaimy 1999).

When using airborne tracers as the indicator of SHS, the National Research Council (NRC 1986) recommended that the tracer should (1) be unique to the source, (2) be easily detected in air at low concentrations, (3) be similar in emission rates for a variety of tobacco products, and (4) occur in a consistent ratio in air to other SHS components in the complex mix. A number of airborne tracers have been used to represent SHS concentrations in both field and chamber studies. Nicotine, carbon monoxide, 3-ethenylpyridine (3-EP), pyridine, aldehydes, nitrous acid, acrolein, benzene, toluene, myosmine, respirable suspended particulate matter (RSP), solanesol and several other compounds have been used or suggested for use as tracers for SHS (U.S. EPA 1992; Jenkins, Maskarinec et al. 2001). Vapor phase nicotine and RSP are most commonly used as tracers of the presence and concentration of SHS for a variety of reasons associated with their ease of measurement, existing knowledge of their emission rates from tobacco combustion, and their relationship to other SHS contaminants (U.S. EPA 1992). Some researchers have investigated the relationship of RSP and air nicotine in field studies with parallel measurements. Regression models showed that for various environments like residential venues, offices or other working places, the slopes of RSP measurements against parallel air nicotine measurements were approximately 10 (Leaderer and Hammond 1991; Daisey 1999; USDHHS 2006), though the intercepts (assumed to be background RSP levels) varied.

Both stationary area monitoring and mobile personal air monitoring can be used to measure concentrations of airborne tracers of SHS. SHS concentrations measured by stationary monitoring are combined with time-activity patterns (time budgets) to determine the average exposure of an individual as the sum of the concentrations in each microenvironment weighted by the time spent in that microenvironment. Personal air monitoring allows for a direct integrated measure of an individual's exposure. It employs samplers (worn by individuals) that record the integrated concentration of a contaminant to which individuals are exposed in the course of their normal activity for some time periods. The monitors can be active (employing pumps to collect and concentrate the air contaminant) or passive (working on the principle of diffusion). Because it incorporates human activity patterns and collects samples from immediate and continually changing environments to which subjects are exposed, personal sampling is usually preferred to area sampling in measuring individual exposure to airborne constituents (White, Armstrong et al. 2008). However, personal sampling has been used less frequently than area sampling, because it requires human participants to use sampling equipments.

Jenkins, et al (2000) reviewed four studies comparing results from area sampling with results from personal sampling of nicotine, and they found that results on the quantitative relationship were mixed: one study reported that nicotine levels were somewhat higher from area sampling than from personal sampling in restaurants, one reported no statistical difference between results of area sampling and personal sampling, another found large differences between individual samples; and the last one reported good agreement between statistical groupings of area-sampling and personal-sampling data for subjects employed in the hospitality industry and that on an individual basis, area samples are useful for estimating individual exposures to SHS within a factor of 5 to 10. A more recent paper found a significant linear relationship between area sampling (x) and personal sampling (y) of nicotine in restaurants and bars ($y=1.07x+1.59$ $R^2=0.65$) (Ellingsen, Fladseth et al. 2006) The relationship between results from area sampling and personal air sampling in venues with designated smoking areas can be more complex because the variation of exposure time in smoking areas and nonsmoking areas.

Based on different objectives of studies, area sampling durations of SHS range from one hour to multiple days via measuring nicotine, and from less than 10 minutes to multiple days via measuring RSP (Jenkins R.A., Guerin M.R. et al. 2000). To estimate the acute health risk like respiratory irritation or vascular function changes (Cal/EPA 2005), short-term sampling during peak patronage hours may be useful. And for risk assessment of long-term exposure to SHS, estimating the average daily exposure levels is often necessary. However, in microenvironments like restaurants and bars, SHS concentrations in the ambient air can be quite different during patronage peak times and non-peak times and during day time and nights.

Biomarkers, within the context of assessing exposure to air contaminants, refer to cellular, biochemical, or molecular measures obtained from biological media, such as human tissues, cells, or fluids that are indicative of human exposure to air contaminants (U.S. EPA 1992). Biomarkers of exposure are actually measures of dose or uptake and hence indicators that an exposure has taken place. The National Research Council presented similar criteria of selecting a biomarker as of selecting an airborne tracer for SHS exposure assessment. The criteria include the sensitivity of the assay for the biomarker, the specificity of the biomarker for SHS, the relevance of the biomarker to the exposure and disease outcome of interest, the practicality of biomarker collection and analysis and the pharmacokinetics of the biomarkers, especially in terms of its half-life of the compound measured (NRC 2006). Nicotine in body fluids, hair or nails, cotinine in body fluids and 4-(methynitrosamino)-1-(3-pyridyl)-1-butanone (NNK) metabolites have been used as biomarkers of SHS exposure (Institute of Medicine 2009). Monitoring of biomarkers provides an integrated measure of exposure to air contaminants across a number of environments where an individual spends time but does not provide direct information on concentrations of the air contaminant of interest in individual environments or on the level of exposure in each environment unless the exposure occurs in only one environment (U.S. EPA 1992).

When resources are limited to collect representative field data, models become useful in predicting SHS concentrations. Considerable progress has been made over decades in developing, testing, and validating mathematical models to predict the pollutant concentrations present in indoor settings due to smoking activity. Many of these models were summarized by Repace in 1989 (Repace 1987) and by Ott in 1999 (Ott 1999), showing that all the models have a similar mathematical structure, which all use the mass balance equation. Experimental results show that these models can predict indoor pollutant concentrations from smoking activity in indoor settings with high accuracy (Ott, Langan et al. 1992; Klepeis, Ott et al. 1996; Klepeis 1999).

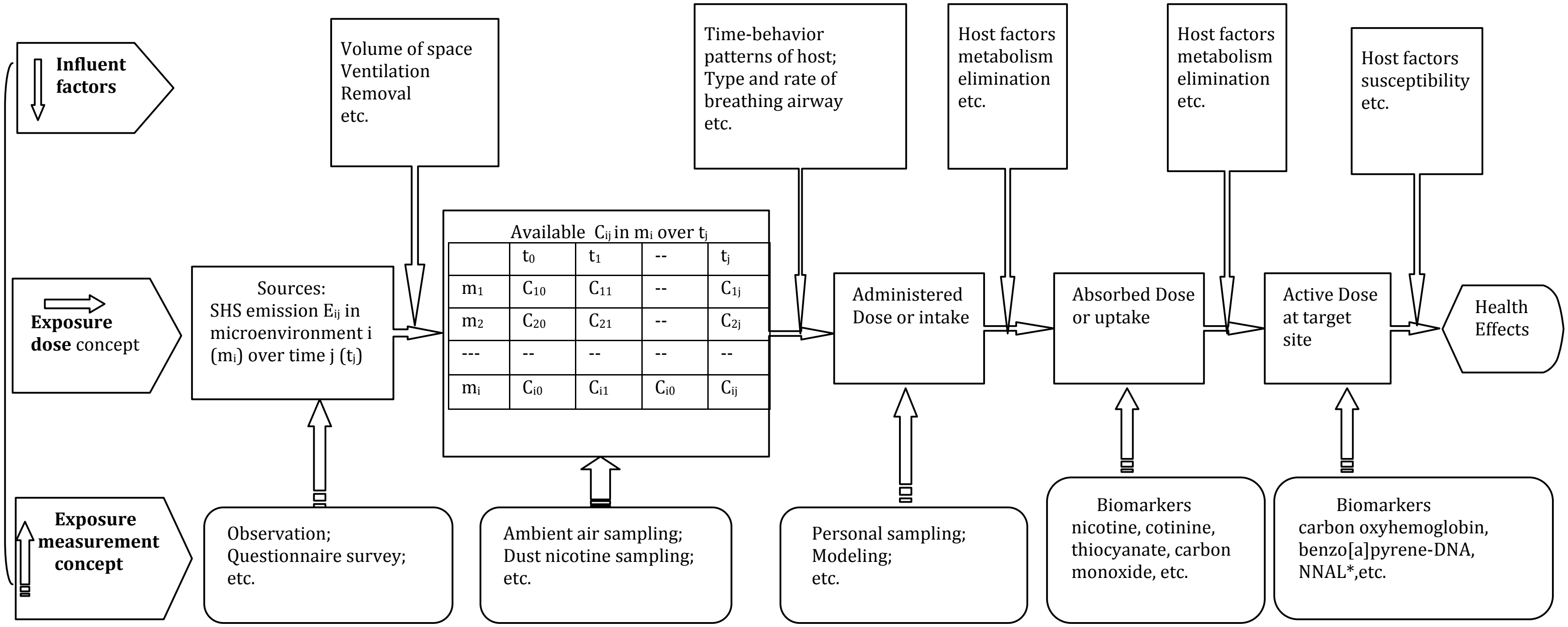


Figure 1.5 Influent factors, exposure-dose concept and exposure measurement concept in the SHS exposure-disease biological pathway

Adopted from White E, Armstrong B, Saracci R., 2008 (White, Armstrong et al. 2008), Jaakkola MS, Samet JM. , 1999 (Jaakkola and Samet 1999) and Jaakkola MS, Jaakkola JJK, 1997 (Jaakkola and Jaakkola 1997).

Available dose: the amount of the exposure measured in the subject's external environment;

Administered dose or intake: the actual amount of the agent coming into contact with the human body, which depends on the subject's behavior in all the microenvironments with available dose;

Absorbed dose or uptake: the dose actually enters various compartments of the body;

Active dose at target site: the biologically effective dose at the site(s) in the body which are the specific target of action of the agent on the disease of interest.

* NNAL: 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL), a metabolite of the tobacco-specific carcinogen

4-methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK)

Table 1.2 Advantages and disadvantages of using different indicators to measure SHS exposure

	advantages	**disadvantages**
Questionnaires	Can collect information on past exposure, time-activities, possible confounders, etc.; relatively inexpensive; most commonly used in large studies and retrospective studies	Exposure information collected is subjective; more likely to suffer to misclassification error; lack of standardized questionnaires to assess SHS exposure
Airborne tracers	Can measure and compare exposures from different microenvironments (sources); are basis of developing environmental standards and evaluating their implementation	require measurement of all microenvironments to determine total exposure; do not reflect individual respiratory rates
nicotine	Specific and sensitive to tobacco smoke; Of intrinsic health interest (known cardiovascular agent)	Different decay rate than other SHS constituents, so complicates estimation of exposure to those other constituents; Requires laboratory analysis
particulate matter	Sensitive to SHS; Can be measured in real time and get information directly without laboratory analysis	Not specific to tobacco smoke therefore not distinguishable from other sources of PM at lower SHS concentrations; Initial investment in equipment expensive, but little operating cost
Biomarkers	Can assess the exposure dose; integrate exposure from all microenvironments	Cannot distinguish exposure locations; Cannot account for individual biological variances in metabolizing chemicals; Require bio-samples and laboratory analysis
Models	Cost-effective; can be used to evaluate effect of various mitigation strategies prior to implementation	Difficult to explain modeling results to general audience

1.4 SHS Concentrations in Restaurants and Bars

Smoking restrictions in workplaces and public places are increasing but restaurants and bars are often exempt from these restrictions. As of January 2012, a total of 66 nations worldwide have enacted 100% smoke-free law, while only 46 of the 66 include both restaurants and bars (ANRF 2012). Table A1 in the Appendix lists the 100% smoke-free laws in workplaces and hospitality venues around the world. In the United States, legislations on restricting smoking in restaurants have lagged behind legislations in public places and other workplaces (USDHHS 2006) (Figure 1.6). Restaurant and bar workers are far less likely than other workers to be protected by smoke-free workplace policies, more likely than other workers to have these policies violated where they do exist, and more likely to be exposed to high levels of SHS on the job (USDHHS 2006).

SHS concentrations in restaurants and bars are often higher than in other public places. Hyland et al measured SHS derived fine particles (SHS PM) for at least 30 minutes in indoor public places in 32 countries from 2003 to 2007, and they found that the geometric mean (GM) of SHS PM during peak patronage time was 303 μg/m^3 in smoking bars and 157 μg/m^3 in smoking restaurants, comparing to 127 μg/m^3 in transportation and 119 μg/m^3 in other public places (Hyland, Travers et al. 2008). Navas-Acien et al. reported time weighted average (TWA) airborne nicotine concentrations over 7 or 14 days in public places in 7 Latin America countries from 2002 to 2003, with the median concentration of 1.24 μg/m^3 in restaurant and 3.65 μg/m^3 in bars, which were relatively higher than in other public places (Navas-Acien, Peruga et al. 2004). Nebot et al. also measured airborne nicotine concentration in different public places in seven European cities and found that, bars and discos were the places with the highest nicotine concentration, with median ranged from 19 to 122 μg/m^3, followed by restaurants; nicotine concentrations in airports and in train stations were much lower and schools had the lowest concentrations (Nebot, Lopez et al. 2005).

Many studies have reported ambient SHS concentration measured in restaurants and/or bars. Table A2-A3 and Figure 1.7- 1.8 list those reported SHS concentrations indicated by ambient RSP and nicotine in different countries worldwide. The majority of studies applied real-time monitoring of RSP during peak patronage time, while sampling time of airborne nicotine varies, ranging from 2 hours by active sampling to a week by passive sampling. The median (range) of aggregated RSP concentration reported in studies conducted in different regions worldwide is highest in restaurants with smoking permitted everywhere (187 [68-663] μg/m^3), followed by designated smoking sections (79 [50-310] μg/m^3) and designated nonsmoking sections (64 [14-89] μg/m^3); it was lowest in restaurants that ban smoking everywhere, 23 (12-92) μg/m^3. For bars not restricting smoking, the median (range) of aggregated RSP concentration reported in different countries is 192 (36-465) μg/m^3, and for bars that ban smoking, 16 (13-20) μg/m^3 (Figure 1.6). Ghana and Pakistan were reported to have the highest aggregated RSP levels in restaurants, while Israel was reported to have the highest aggregated RSP in bars.

The median (range) of aggregated airborne nicotine concentration over a week reported in studies is 7.10 (0.01-60) μg/m^3 in restaurants with smoking permitted everywhere, 16.80 (0.60-60) μg/m^3 in designated smoking sections, 1.90 (0.10-30.0) μg/m^3 in designated nonsmoking sections and below 0.05 μg/m^3 in nonsmoking restaurants (Figure 1.7). In bars with smoking allowed everywhere, the median (range) of air nicotine concentration is 8.5 (1.60-31.43) μg/m^3 and below 1.0 in nonsmoking bars (Figure 1.7). Due to the fact that nicotine is more specific to tobacco smoke than RSP, the reduction of airborne nicotine concentrations in venues/sections without smoking restrictions and in venues with smoking banned everywhere is larger than the reduction of RSP.

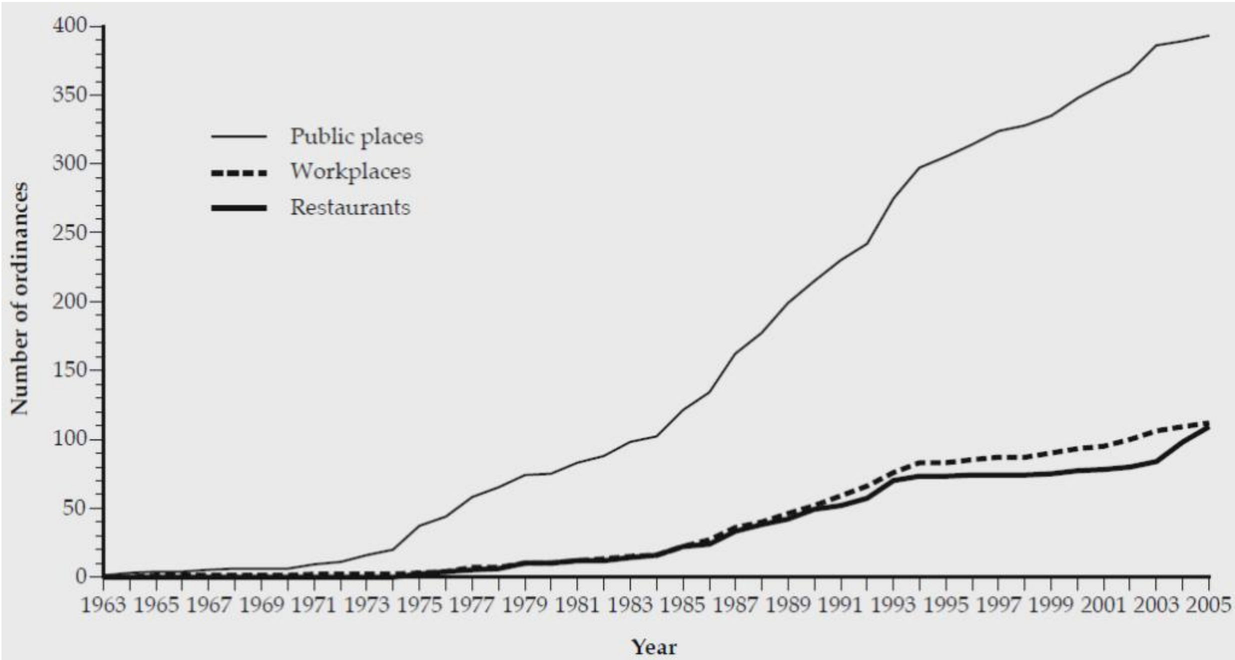


Figure 1.6 Number of state laws and amendments enacted for clean indoor air, 1963-2005 (USDHHS 2006)

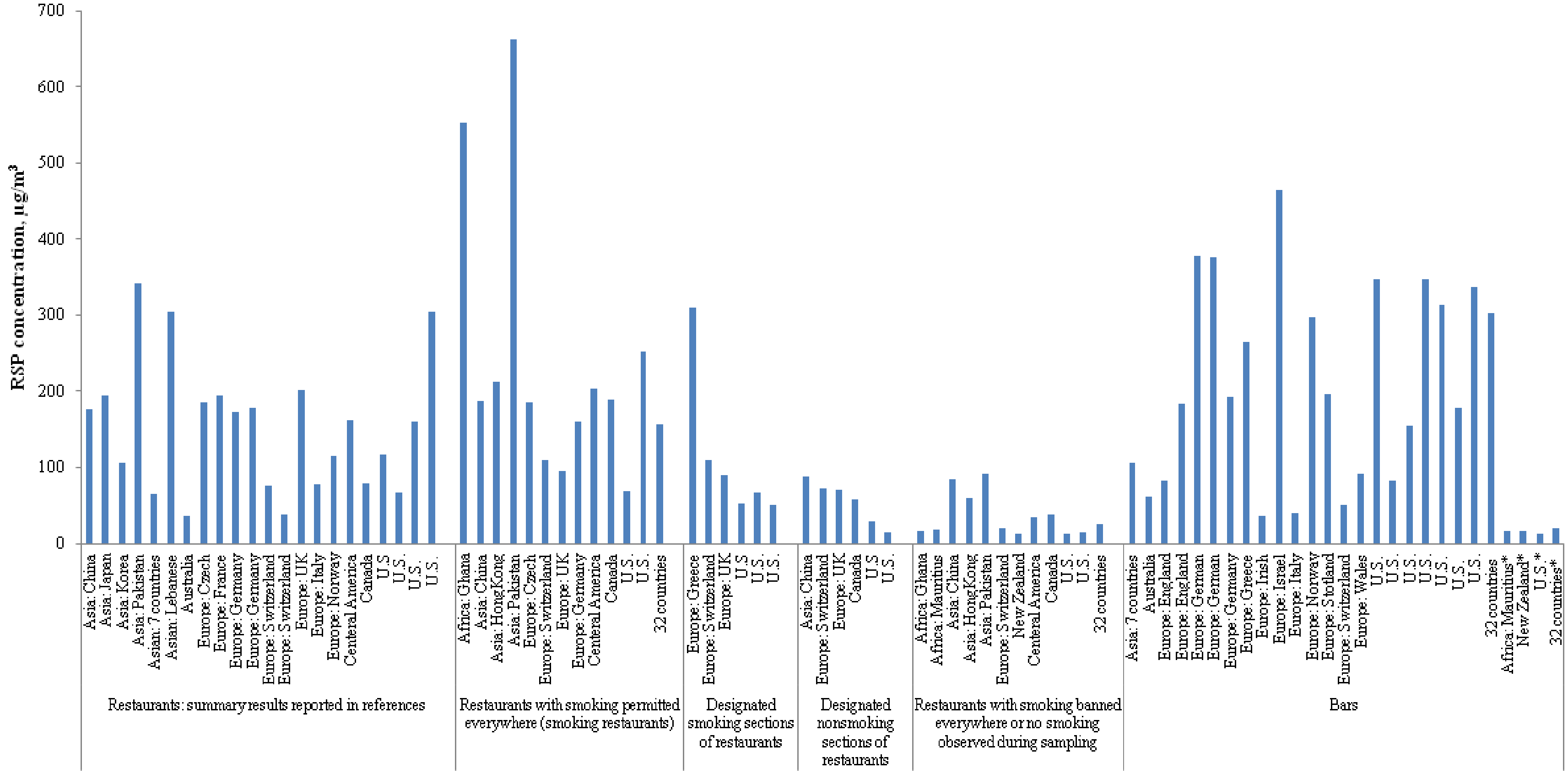


Figure 1.7 SHS concentrations indicated by particulate matter in restaurants and bars reported in literature

Notes: * bars with smoking banned or no smoking observed during sampling

This figure was based on literature reviews of SHS concentrations in restaurants and bars, which were summarized in Table A2 in the Appendix.

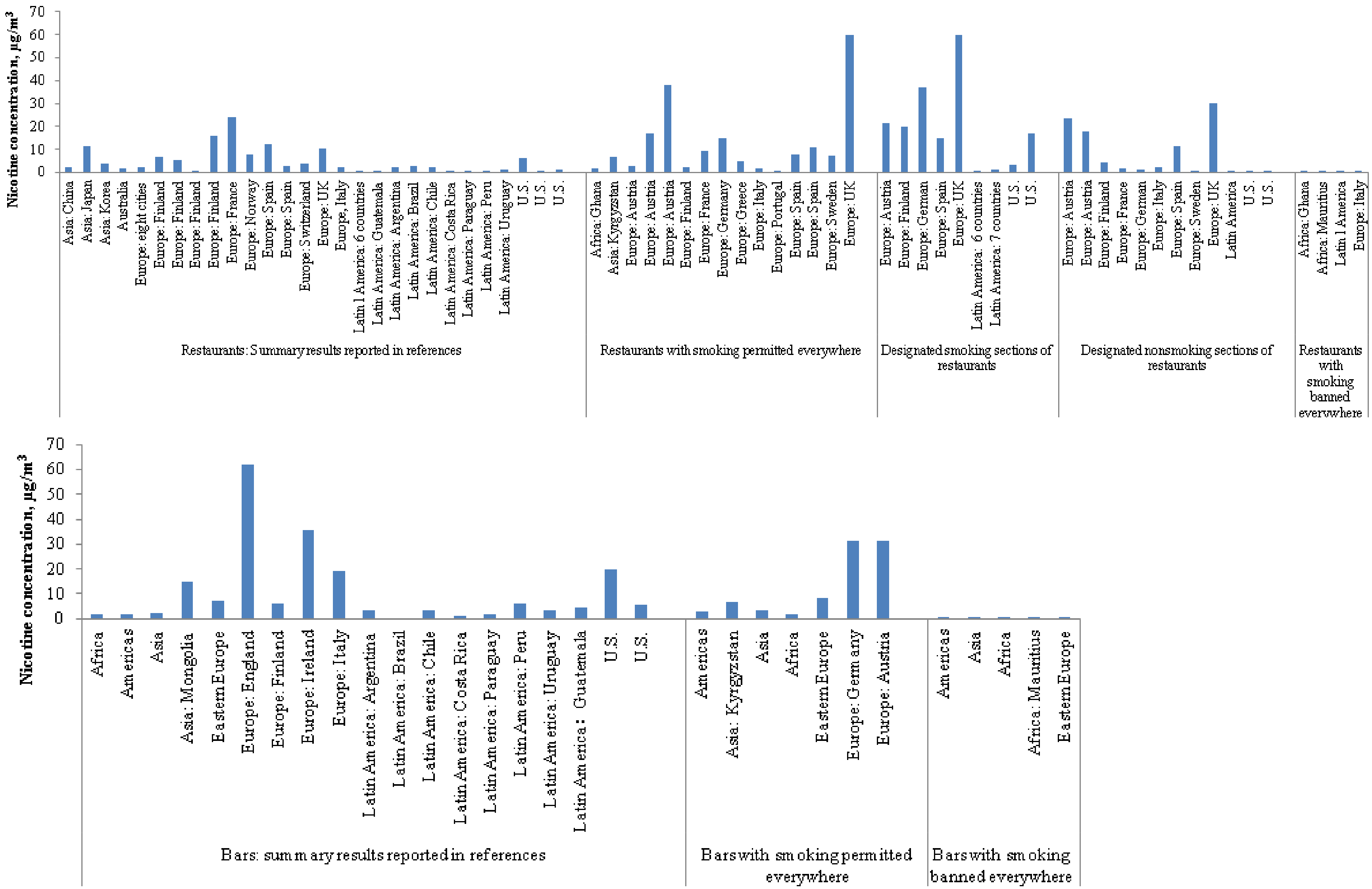


Figure 1.8 SHS concentrations indicated by airborne nicotine restaurants and bars reported in literature

This figure was based on literature reviews o SHS concentrations in restaurants and bars, which were summarized in Table A3 in the Appendix.

1.5 Strategies to Reduce SHS Exposure

Both technological approaches and policy approaches can be used to control SHS exposure by reducing/eliminating sources and increasing SHS removal rate. Technological strategies include creating designated nonsmoking and smoking areas, using controlled ventilation and improved filtration of returned air and applying devices to remove particles and vapor phase organic compounds based on principles of electrostatic precipitation, solid media filtration, gas-phase filtration, ozone generation, catalytic oxidation or bipolar air ionization (USDHHS 2006). Policies strategies include voluntary smoking restrictions and mandatory legislative smoking restrictions, both of which include complete smoking bans (not allowing smoking anywhere in a venue) and partial bans (permitting smoking in designated sections or separated rooms). Voluntary restrictions are ineffective because there is no force of law, and ultimately the industry fails to comply with its own voluntary regulations (WHO 2009). The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRE) stated in its document on environmental tobacco smoke (ETS, another term for SHS) in 2008 that (ASHRAE 2008):

• At present, the only means of effectively eliminating health risk associated with indoor exposure is to ban smoking activity.

• Although complete separation and isolation of smoking rooms can control ETS exposure in non-smoking spaces in the same building, adverse health effects for the occupants of the smoking room cannot be controlled by ventilation.

• No other engineering approaches, including current and advanced dilution ventilation or air cleaning technologies, have been demonstrated or should be relied upon to control health risks from ETS exposure in spaces where smoking occurs. Some engineering measures may reduce that exposure and the corresponding risk to some degree while also addressing to some extent the comfort issues of odor and some forms of irritation.

There is no safe level of SHS exposure, and the only effective way to protect people from adverse health effects of SHS is to create 100% smoke-free environments (WHO 2009). Studies show that complete smoking bans significantly improve air quality and reduce SHS exposure, with a greater reduction for hospitality workers compared to the general population (Callinan, Clarke et al. 2010). Polanska et al reviewed 12 papers published after 2000 on smoking bans and hospitality workers' exposure to SHS (Polanska, Hanke et al. 2011). They found that the legislation to ban smoking in hospitality venues protects workers from SHS exposure when the venues are 100% tobacco smoke free, with 57-89% reduction in cotinine levels in biological samples and about 90% of reduction in airborne nicotine and PM levels after the implementation of smoke free law. The Cochrane Collaboration reviewed 31 studies of legislative bans in workplaces and/or hospitality venues and found 71%-100% reduction of SHS exposure duration and 22%-85% reduction of SHS exposure prevalence (Callinan, Clarke et al. 2010). As a result of reduction of SHS exposure, legislative smoking bans can improve the public's health. Consistent evidence showed that legislative smoking bans can reduce respiratory symptoms and sensory symptoms among hospitality workers (USDHHS 2006; Callinan, Clarke et al. 2010). The smoking ban in public places in Scotland reduced respiratory symptoms not only among both smoking and nonsmoking workers in bars after its one-year implementation (Ayres, Semple et al. 2009), but also among general populations in subsequent years. Hospital admissions of preschool and school-age children for asthma decreased 18% per year comparing to the rate before implementation of the ban (Mackay, Haw et al. 2010). Three independent reviews of the effect of smoking bans in public places on acute myocardial infarction (AMI) consistently show that smoking bans reduce individual risk and hospitalization for AMI (Institute of Medicine 2009; Lightwood and Glantz 2009; Meyers, Neuberger et al. 2009).

Additional benefits of legislative smoking bans include reductions in daily consumption of cigarettes, increases in attempts to stop smoking and increases in smoking cessation rate (USDHHS 2006). Smoke-free policies also challenge the perception of smoking as a normal adult behavior and thus change the attitudes and behaviors of adolescents, resulting in a reduction in tobacco use initiation (Task Force on Community Preventive Services 2005).

1.6 Outline of This Dissertation

This dissertation focuses on exposure and risk assessment related to SHS in a specific type of microenvironment, that is, restaurants and bars. There are six more chapters in this dissertation. Chapter 2 assesses SHS exposure in restaurants and bars using different ambient air sampling approaches and examines the quantitative relationships between these different approaches to explore appropriate sampling approaches for the purpose of risk assessment; Chapter 3 presents the assessment of SHS exposure in Chinese restaurants and bars based on mass balance modeling and Monte Carlo simulations; Chapter 4 presents the evaluation of the efficacy of different smoking policies designed to reduce SHS exposure in Beijing restaurants and bars during the period of 2006 to 2010; Chapter 5 assesses the health risks and deaths of asthma induction, ischemic heart diseases and lung cancers among restaurant and bar servers and patrons due to their exposure to SHS in restaurants and bars in Minnesota and in the United States; Chapter 6 used similar approaches as in Chapter 5 to assess the health risks and deaths attributed to SHS exposure in Chinese restaurants and bars for patrons and servers, based on SHS exposure estimated from modeling in Chapter 3; and the last chapter, Chapter 7, summarizes the findings from all previous chapters and also suggests topics for future studies in this area.

Chapter 2 Assessing Exposure to Secondhand Smoke in Restaurants and Bars in Beijing, China, by Field Monitoring

2.1 Background

Although a large number of studies on the effects of secondhand smoke (SHS) exposure have been conducted in the U.S. and some European countries, SHS exposure has only recently attracted public attention in China. Only a few studies have monitored SHS exposure in different types of environments in this country. Hammond et al. measured airborne nicotine in some Chinese homes in 1998 (Hammond, Tian et al. 1999). Stillman et al. measured airborne nicotine concentrations in public places in four cities and three rural towns in 2005 (Stillman, Navas-Acien et al. 2007) and Gan et al. monitored airborne nicotine levels in 14 Chinese office buildings in 10 provinces from 2005 to 2006 (Gan, Hammond et al. 2008); all these studies used 7-day passive area nicotine sampling method. Another three studies measured SHS for half an hour during peak patronage times via the tracer of $PM_{2.5}$ (the fine particulate matter which has a 50% collection efficiency cutpoint at 2.5 µm aerodynamic diameter,) in Chinese restaurants and bars in 2006 and 2007 (Kang, Jiang et al. 2007; Lee, Lim et al. 2010; Liu, Yang et al. 2010).

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). Monitoring SHS exposure levels is also essential to evaluate the efficacy of a smoking policy before and after its adoption. In 2008, the Beijing government implemented a smoking restriction requiring public places, including large restaurants and bars, to restrict smoking. In 2007, as part of the study on SHS exposure in five Chinese cities, a convenience sample of 85 restaurants and bars were selected from two districts in Beijing (Liu, Yang et al. 2010). In each venue, SHS levels via $PM_{2.5}$ were monitored with SidePak 510 for about 30 minutes during peak patronage times; number of patrons and lit cigarettes were counted for every 15 minutes during monitoring, and the venue size was also measured or estimated.

This chapter reports a follow-up study of the 2007 study to assess SHS exposure in restaurants and bars two years after the implementation of the Beijing governmental smoking restriction. The study was designed to examine profiles of SHS exposure by servers and patrons of restaurants and bars, that is, to measure SHS concentrations in restaurants and bars during typical peak patronage times, during servers' full working shifts, during a typical 24-hour period, and in one typical week. Another purpose was to use different approaches towards ambient air sampling of airborne nicotine and $PM_{2.5,}$ and to examine the quantitative relationships between these different sampling approaches in order to explore relatively simple but appropriate sampling methods of SHS exposure for the purpose of risk assessment. The monitor protocol was approved by the Committee for Protection of Human Subjects at University of California, Berkeley.

2.2 Methods

2.2.1 Overview of Sampling Approaches Used in This Study

2.2.1.1 Week-long passive area nicotine sampling

A passive monitor developed by Hammond and Leaderer (1987) was used to sample vapor phase airborne nicotine. A filter (EMFAB, Pall part #7217) treated with sodium bisulfate is held in a 4 cm diameter polystyrene cassette, a membrane filter serves as a windscreen, and nicotine passively diffuses to the treated filter, where it is trapped. The effective sampling rate is 24 mL/min. A passive monitor was affixed to items on walls or ceilings where the monitor could rest undisturbed and sample nicotine for one or two continuous weeks. The concentration of nicotine calculated for each monitor reflected the average area level during those sampling periods.

2.2.1.2 One-day active area nicotine sampling

The active nicotine monitor used was quite similar to the passive monitor described above, except that a top polystyrene cassette replaced the windscreen, and a pump was used to draw air through the cassettes so that air nicotine reached the filter and was trapped. The effective sampling rate was set as 150 mL/min. Each active monitor sampled 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. The flow rate was checked both before and after the sampling, and the average rate was used for the concentration calculation. To prevent the possible loss of the sampling pumps and to keep them charged during sampling, active monitors was placed on cashier bars or near outlets where they could stay undisturbed during the time when the venue was open. The concentration of nicotine estimated by this sampling approach reflected the time-weighted average area concentration in a workday.

2.2.1.3 One-day active personal nicotine sampling

In this approach, an active nicotine monitor with a battery-charged mini pump was worn by a voluntary nonsmoking server who worked for a full daytime shift. The flow rate of the mini pump was set at about 150 mL/min. The cassette was clipped to clothes around a server’s waist and the mini pump was placed in his/her pocket or was clipped to his/her waist belt. Investigators helped the server wear a personal monitor, turned on the pump around the time when the venue was open to the public and collected the monitor at the end of the working shift or around the time when the venue was about to close to the public. 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 off the pump during the break to avoid SHS exposure in other places. The flow rate was checked both before and after each sampling, and the average rate was used for the concentration calculation. The concentration of nicotine estimated by this sampling approach reflected the time-weighted average personal exposure level in a working shift.

2.2.1.4 One-hour peak-patronage-time monitoring and observations

Peak patronage time was defined as lunch (11:30 AM to 2:00 PM) or dinner time (5:00 PM to 8:30 PM) for restaurants, and evening time (8:00 PM to 2:00 AM) for bars; for cafés, peak time was more flexible, usually in the afternoon. Investigators visited each venue during peak patronage time as patrons, carrying out monitoring and making discreet observations in order not to disturb the occupants’ normal behavior.

An investigator wore an active nicotine monitor with the cassette outside of a bag and the pump inside the bag. Two investigators visited a venue during peak patronage time as patrons, seated themselves at a table as close to the central dining area as possible, put the bag with the monitor on a chair, and conducted the monitoring for about one hour. The flow rate of the pump was set at around 2 L/min. This sampling approach was used to assess airborne nicotine concentrations during peak patronage times.

Area $PM_{2.5}$ was measured using a TSI SidePak AM510 Aerosol Monitor (TSI, Inc., St. Paul, MN, USA). The method of using the SidePak to measure SHS exposure via $PM_{2.5}$ levels has been described in detail by Hyland et al. (Hyland, Travers et al. 2008). Briefly, the SidePak, which is a portable light-scattering aerosol monitor, was fitted with a 2.5 μm impactor. The equipment was set to a one-minute log interval which averages the previous 60 one-second measurements, and was zero-calibrated prior to each use by attaching a high-efficiency particulate air (HEPA) filter according to the manufacturer's specifications.

The SidePak was placed in the same bag as the nicotine monitor, with the outlet of the sampling tube placed side by side with the nicotine cassette outside the bag. Outdoor $PM_{2.5}$ levels were monitored for at least 10 minutes before or after entering the venue and indoor $PM_{2.5}$ levels were monitored for about one hour. For each venue, the first and last minutes of logged data were omitted because they could represent a mixture of outdoors and entryway air. The remaining data points were averaged to provide average $PM_{2.5}$ concentrations within and outside the venue during peak patronage time. 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. This calibration factor was determined in an experiment with the SidePak collocated with another light-scattering instrument that had been previously calibrated against standard pump-and-filter gravimetric methods and used in SHS exposure studies; this calibration factor was also confirmed by comparison of SidePak measurements of SHS to gravimetric measurements using a Personal Environmental Monitor (PEM for $PM_{2.5}$, MSP Corporation, Shoreview, Minnesota, USA) (Hyland, Travers et al. 2008).

During each peak-time sampling, investigators counted the number of patrons, the number of employees, and the number of lit cigarettes right after entering each venue, before leaving the venue and every 15 minutes during the interval. They also made observations on whether any non-smoking signs were obvious to be observed by patrons, availability of ashtrays and compliance to smoking restrictions. This approach was used to estimate the average number of lit cigarettes exposed by servers and patrons during peak patronage time.

To characterize the physical features of each venue, the venue dimensions were measured via Straint-line® Sonic laser tape (Huntersville, NC, USA) or by estimates when the sampling space was irregular. Also, 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 minutes outdoor and for about one hour indoor. These sampling was conducted simultaneously with airborne nicotine and $PM_{2.5}$ sampling.

2.2.1.5 Continuous monitoring

Continuous monitoring of real-time $PM_{2.5}$ and CO_2 was conducted in one venue allowing smoking and in one venue restricting smoking to a designated section for at least 24 hours. Sequential area nicotine sampling was also conducted, with new nicotine samplers replaced every one to two hours, except during evenings and intervals between peak patronage times.

2.2.2 Venue Selection

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 nonsmoking signs in venues. A total of 66 venues were re-identified. According to the inquiries, 43 venues allowed smoking (no restriction at all) or restricted smoking to designated sections. Owners or managers of the 43 venues were contacted by phone or in person for permission for one-week passive area nicotine sampling, one-day active area nicotine sampling and one-day active personal air nicotine sampling. Permission for at least one sampling approach was obtained from 27 of the 43 venues. To increase the sample size for comparisons between different sampling approaches, permission was sought from another 14 venues allowing or restricting smoking located in the same two districts as the 27 return venues. With the 38 restaurants and bars which prohibited smoking (smoking not allowed at all) according to inquiries or where sampling permissions were not obtained, a total of 79 venues were included in the 2010 study. In all these 79 venues, one-hour sampling of $PM_{2.5}$ and air nicotine and observations on patrons' smoking behavior were conducted discreetly during peak patronage time (Figure 2.1). One venue allowing smoking and one venue restricting smoking from the 41 venues where sampling permission was obtained were selected to conduct continuous sampling of $PM_{2.5}$, air nicotine, CO_2, temperature and relative humidity.

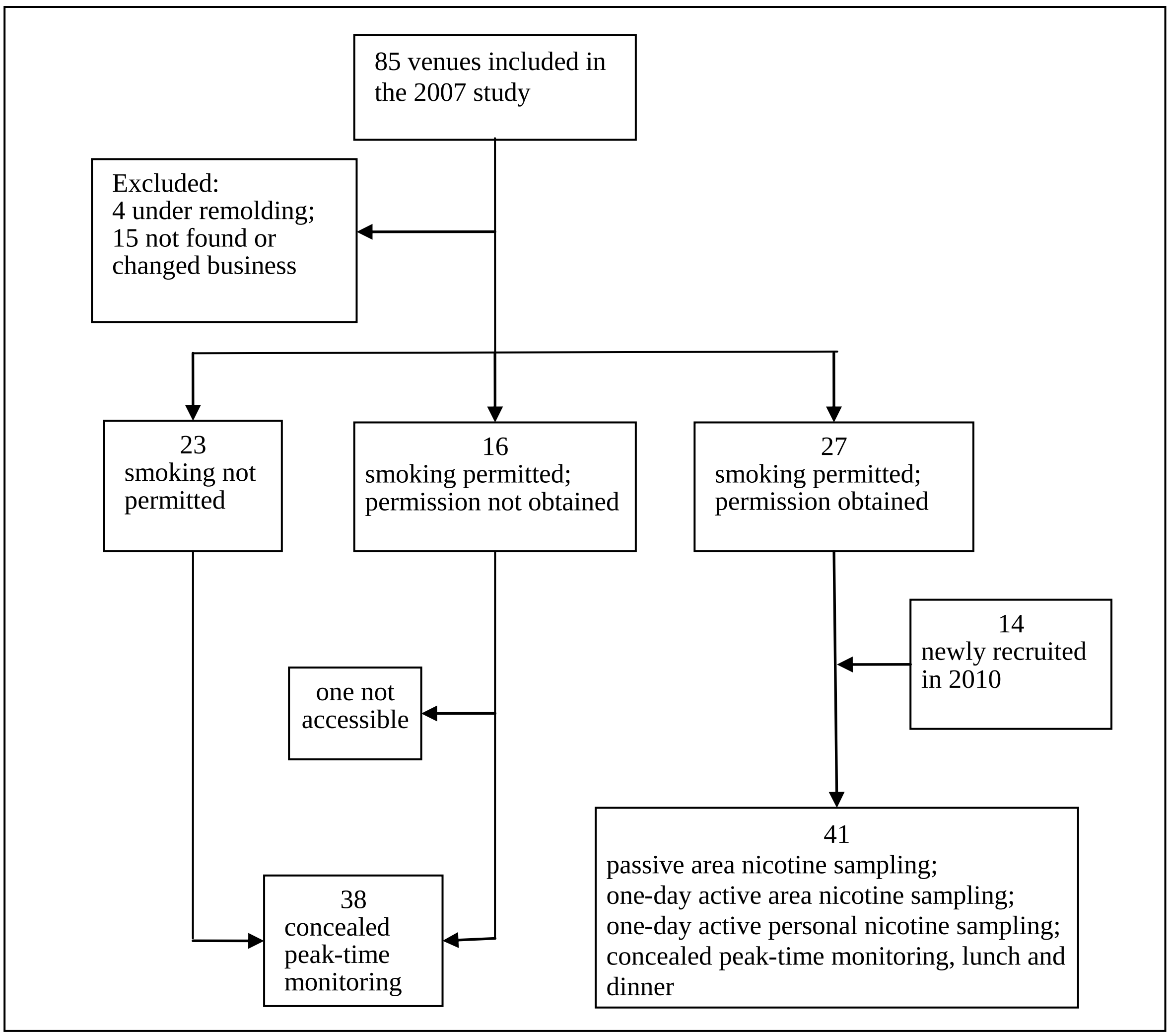


Figure 2.1Venue selection procedure and sampling approaches applied for the follow-up study on assessing secondhand smoke exposure in restaurants and bars, Beijing, 2010

2.2.3 Sampling Design

2.2.3.1 General sampling in all selected venues

Whenever possible, in each of the 41 venues where sampling permission was obtained, two week-long passive area nicotine monitors were placed at different locations in the main dining area to sample air nicotine for one or two weeks. On one day of this time period, one active area nicotine monitor was placed on the cashier bar or near an electricity outlet in the main dining area where the monitor could be charged and stay undisturbed for a whole working day. On the same day, one to three nonsmoking volunteering servers were recruited to wear an active personal sampling monitor for a whole working shift. Also, one-hour peak-patronage-time monitoring and observation were made during both lunch and dinner time for restaurants and once for cafés and bars on the same day. In venues with well defined smoking and nonsmoking sections (according to locations of nonsmoking signs), all the sampling approaches were conducted in both sections whenever possible. For the other 38 venues which prohibited smoking according to inquiries, or where sampling permissions were not obtained, only one peak-time monitoring and observation was made. For venues which were included in the 2007 study, the sampling day (Monday to Thursday, Friday, or the weekend) and time periods (lunch, dinner or evening) was scheduled to be identical to the sampling day or time periods in the 2007 study for that venue, whenever it was possible. For the 14 venues newly included in the study, the sampling day and time periods were decided arbitrarily. For all the nicotine samplings, one blank sampler was carried around by each team on each day of sampling.

2.2.3.2 Continuous Monitoring of SHS

The restaurant allowing smoking everywhere (Restaurant 1) had two floors, and sampling was conducted on the first floor, frequented most by patrons. The floor plan of the first floor is shown in figure 2.2. The floor plan of the restaurant with designated smoking and nonsmoking areas (Restaurant 2) is shown in figure 2.3; there was no physical separation between the two areas. Sampling was conducted at locations with easy access to an electricity outlet and between doors, except that one set of sampling was conducted on the cashier bar of Restaurant 1. Sampling locations were labeled by numbers in Figure 2.2 and Figure 2.3. Real-time sampling of $PM_{2.5}$ and CO_2, sequential sampling of nicotine and one-day continuous active area nicotine sampling was conducted at each location at the same time whenever possible (Table 2.1). In addition, one passive area nicotine sampling was conducted in Restaurant 1 and in each area of Restaurant 2; three volunteering servers were recruited for active personal nicotine sampling in Restaurant 1.

All passive area nicotine sampling was conducted for two weeks: from around 16:00, 7/28/10 to around 17:00, 8/11/10 in the two restaurants. Other sampling was conducted during the time periods shown in Table 2.1. Pump flow rates were all set around 2 L/min for sequential active area nicotine sampling, and separate new nicotine samplers were replaced every one to 1.5 hours for each pump, except during intervals between lunch and dinner time and during the night, when only one sampler was used for each pump. Outdoor $PM_{2.5}$ and CO_2 was monitored for at least 10 minutes right before or after a new sequential nicotine sampler was replaced. For active area nicotine sampling, the pump flow rate was set as 150mL/min and a single nicotine sampler was used for the whole day during open hours. Observations on the number of occupants and lit cigarettes were also made during peak patronage time in both restaurants. In addition, three non-smoking servers (according to self report) were recruited in restaurant 1 to each wear an active personal air nicotine monitor during their working hours on the same day as other active sampling, with the pump flow rates set as 150mL/min. The monitors were placed on the cashier bar during their break hours between lunch and dinner time. The manager in restaurant 2 did not allow volunteer recruitment for personal sampling.

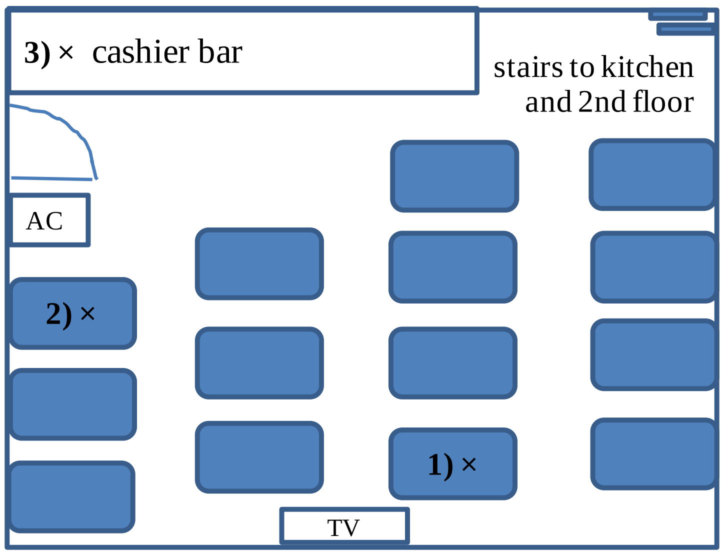


Figure 2.2 Floor plan of Restaurant 1 with smoking allowed everywhere

Notes: AC: cabinet air conditioner, about 1.4 meters in height; TV: television, hung on wall, about 2 meters in height; Dimension of the sampling area: 10m × 6m × 3.5m; Total number of seats: 56

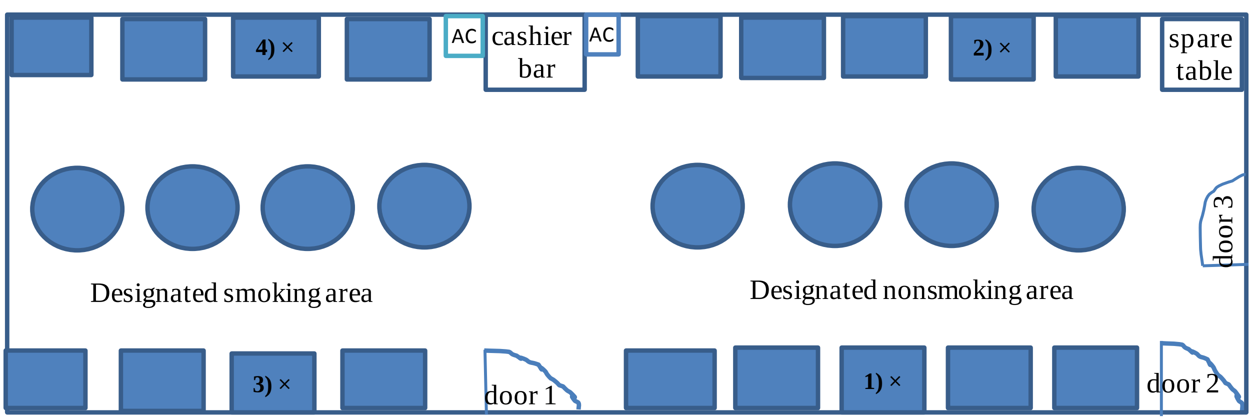


Figure 2.3 Floor plan of Restaurant 2 with designated smoking area and nonsmoking area

Notes: AC: cabinet air conditioner, about 1.4 meters in height; Door 1 and door 2 were open to patrons and door 3 was open to the kitchen and stairs to 2nd floor; all doors had curtains from the top all the way to the floor; Dimension of the designated smoking area: 14m × 7m × 2.6m, with total seats of 88; Dimension of the designated nonsmoking area: 18m × 7m × 2.6m, with total seats of 108.

Table 2.1 Sampling conducted at each location of the two restaurants, Beijing, 2010

location	nicotine active, area sequential (n of samplers)	nicotine active, area, one-day (n of samplers)	$PM_{2.5}$, active, area, continuous (n of devices)	nicotine active, personal, one-day (n of samplers)
Restaurant 1				
1)	Failed		8/9/10 22:00 - 8/10/10 9:30 (failed in other times)	8/9/10 10:47-8/9/10 20:15 8/9/10 10:50-8/9/10 21:40 8/9/10 10:53-8/9/10 20:10 (3)
2)	8/9/10 10:15 - 8/10/10 9:30 (9)		8/9/10 10:15 - 8/9/10 12:30 (1)	
3)	8/9/10 10:15 - 8/10/10 9:30 (9)	8/9/10 11:00 - 8/9/10 21:30 (1)	8/9/10 10:15 - 8/10/10 9:30 (1)	
Restaurant 2				
1)	8/8/10 21:30 - 8/10/10 10:00 (10)	8/9/10 11:00 - 8/9/10 21:30 (1)	8/9/10 11:00 - 8/9/10 22:00 (1)	Permission was not obtained to recruit volunteering servers
2)	8/8/10 21:30- 8/9/10 22:00 (9)	8/9/10 11:00 - 8/9/10 21:30 (1)		
3)	8/8/10 21:30 - 8/10/10 10:00 (10)	8/9/10 11:00 - 8/9/10 21:30 (1)	8/9/10 12:00 - 8/10/10 10:00 (1)	
4)	8/8/10 21:30 - 8/10/10 10:00 (10)	8/9/10 11:00 - 8/9/10 21:30 (1)	8/9/10 11:00 - 8/10/10 10:00 (1)	

2.2.3.3 Pump Calibration

Sampling pumps were calibrated every day before sampling started at the Chinese Center for Diease Control and Prevention (CDC). A rotameter with a scale of 1000 mL/min was used for the calibration of pumps for one-day active area nicotine sampling and of pumps for one-day active personal nicotine sampling; another rotameter with a scale of 5 L/min was used for the calibration of pumps for one-hour peak-patronage-time nicotine sampling. Both of these two rotameters were calibrated using Sensidyne's GILIBRATOR-2® System at University of California, Berkeley before their use for pump calibration. Air flow rates were checked before and after sampling each day and the average sampling rate was used for concentration calculation.

2.2.4 Consistency of Sampling Devices

Five TSI SidePaks were used to monitor $PM_{2.5}$ levels in this study, and two TSI 8854 Qtraks, two Hobo/Telaires and one Fluke 975 AirMeters were used to monitor CO_2. Two side-by-side tests with some or all of the devices were conducted to examine the consistency between different devices. One test was conducted in a hotel room with relatively low levels of $PM_{2.5}$. The average of measurements by the five SidePaks was 24 $\mu g/m^3$ (SD=1), with differences between the measurements by each device and the average of measurements by the five SidePaks within ±10% of the average. The other test was conducted in a restaurant with relatively higher levels of $PM_{2.5}$, and the average of the measurements by the four SidePaks was 196 $\mu g/m^3$ (SD=16), with differences also falling into ±10% of the average (Figure 2.4). For the CO_2 monitors, the average of the measurements by four of the monitors in the hotel room was 944 ppm (SD=133), with differences between the average and the measurement by each device falling into ±20% of the average, and the average of the five monitors in the restaurant was 530 ppm (SD=55), with differences falling into ±16% of the average (Figure 2.4). For measurements of temperature and relative humidity, differences between the average and the measurement by each monitor were within ±5% of the average.

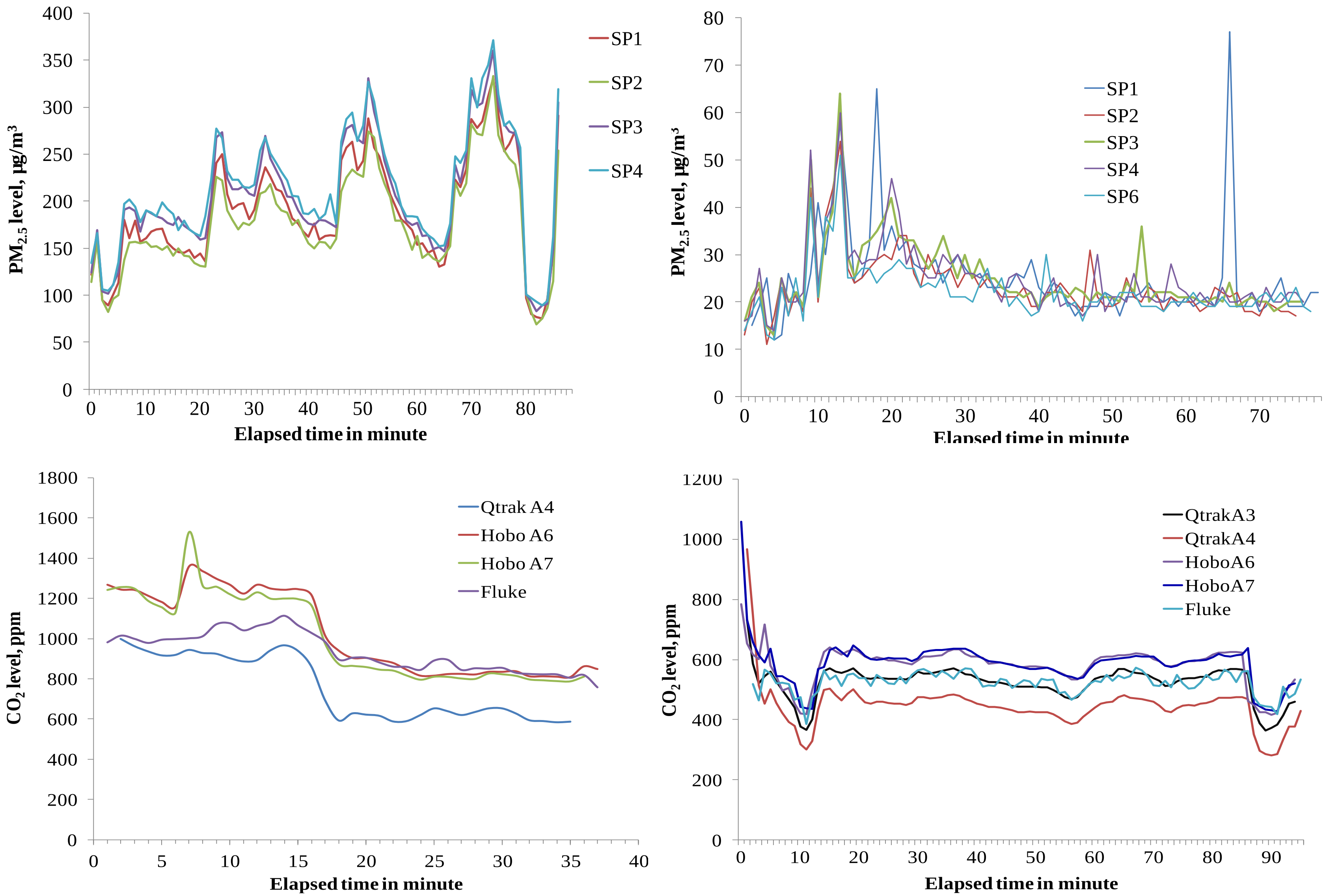


Figure 2.4 Side-by-side tests of consistencies between different SidePaks used for $PM_{2.5}$ samplings (upper panel), and between different CO_2 monitors (lower panel), Beijing, 2010

2.2.5 Laboratory Analysis

Nicotine sampling filters were placed in centrifuge tubes with 2 mL 5% ethanol solution (5 mL ethanol diluted into 100 mL mixture with deionized water) and were vortexed for one minute. Then 2 mL of 20N sodium hydroxide and 250 µl of ammoniated heptanes (gaseous ammonia bubbled through heptanes for 2 minutes) was added to the centrifuge tubes, and again vortexed for 2 minutes. The sodium hydroxide was used to form the free base of nicotine and ammoniated heptanes were used to concentrate nicotine. An aliquot of the heptane layer was removed immediately for analysis.

Samples were analyzed on a GC 7890A gas chromatograph system equipped with a nitrogen-phosphorus selective detector. An auto-sampler 7630 injector injected 3 µl of solution for each analysis. A 30-meter long, 320 µm diameter and 0.25 µm film thickness capillary column of J&W DB-5 with cross linked 5% ME Siloxane was used to separate constituents of cigarette smoke and was operated isothermally at 320 ℃. The laboratory limit of detection (LOD) was 0.001 µg per filter, the coefficient of variability for replicate analysis was less than 5% and the efficiency of extracting nicotine from filters were more than 90%. In this study, all 39 field blank samples and three laboratory field blanks were below the LOD, and all the other samples were above LOD.

The nicotine concentration was calculated by dividing the mass of nicotine (µg) collected by a filter by the volume of air estimated to diffuse or be drawn through the filter. The volume was determined by sampling duration multiplied by the effective sampling rate of the monitor, 24 mL/min for passive monitors (Hammond and Leaderer 1987), and the average of the flow rate before and after each sampling for active monitors. The LOD for airborne nicotine was below 0.008 µg/m^3 for one-hour peak-patronage time sampling or for sequential nicotine sampling, below 0.014 µg/m^3 for active area and personal sampling and below 0.004 µg/m^3 for week-long passive sampling.

2.2.6 Data Analysis

Descriptive analyses were conducted for both observed patrons' smoking behaviors and SHS concentrations by different sampling approaches. Patrons' smoking behavior was indicated by active smoker density (ASD, average number of active smokers observed per 100m^3) and active smoking rate (ASR, percentage of counted adult patrons that were observed smoking during sampling time). SHS were indicated by SHS PM or airborne nicotine. 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-time sampling. If only nonsmoking signs were observed and smoking areas were not observed, it was categorized as prohibiting smoking and the venue was referred as a nonsmoking venue; if both smoking and nonsmoking signs were observed or a designated nonsmoking section was observed, it was categorized as restricting smoking and the venue was referred as a venue with designated and nonsmoking section; and if nonsmoking signs were not observed anywhere, it was categorized as allowing smoking and the venue was referred as a smoking venue. If a venue or section was sampled during both lunch and dinner peak patronage times, the average concentration of these two periods were used to represent SHS concentration in the venue or section.

The quantitative relationships between SHS PM, airborne nicotine concentrations and observed ASD during peak-patronage time were examined using simple linear regression analysis and scatter plots. The quantitative relationships between any two nicotine sampling results conducted in the same venues or sections were examined using both paired *t*-tests and nonparametric Wilcoxon signed rank tests. Simple linear regression analysis, scatter plots and quantile-quantile plots were also used. When compared to results of personal airborne nicotine sampling, results of parallel area nicotine sampling in venues with smoking and nonsmoking sections were weighted by the number of seats in each section to represent the concentration in the whole venue. Stata IC11 (College Station, Texas) was used for all the data analysis.

2.3 Results

The sampling field work was conducted from late July to the end of August, 2010. For sampling visits during patronage peak times, the medians of outdoor and indoor temperatures were 29 ℃ and 27 ℃, respectively, and the medians of the outdoor and indoor relative humidity were 56% and 53%, respectively. The median of the outdoor $PM_{2.5}$ level (when calibration factor = 1) was 95 μg/m^3 (range 9-581 μg/m^3).

2.3.1 General Characteristics of Venues Included and Number of Samplers Collected in the Study

Forty six Chinese dining restaurants, eight Chinese fast food, three Western dining, five Western fast food restaurants, 11 bars and six cafés were included in the study (Table 2.2). The median (range) of the venue areas was 102 m^2 (16-600 m^2), of venue volume 317 m^3 (48-2100 m^3), of total seats 72 (10-266) and of occupancy rate (number of patrons/total number of seats) of the sampling sections, 31% (5%-74%). Thirty seven venues nominally prohibited smoking, with a median (range) area of 110 m^2 (25-600 m^2); 14 restricted smoking, with a median area (range) of 212 m^2 (88-525 m^2), and 28 allowed smoking, with a median (range) area of 57 m^2 (16-250 m^2). Bars, cafes and venues with smaller dining areas or less seats were more likely to allow smoking, while fast food restaurants were more likely to prohibit smoking. Eight of 40 venues with dining area larger than 106 m^2 allowed smoking everywhere (Table 2.2). Of the 14 venues restricting smoking, five restricted smoking to separate rooms or different floors, three had half walls between smoking and nonsmoking sections and the rest, six venues had no walls to separate smoking and nonsmoking sections. For venues restricting smoking, the median (range) of the percentage of total areas designated to be nonsmoking sections was 40% (9-90%) and the median (range) of the percentage of total seats located in designated nonsmoking sections was 48% (11-84%).

There were 27 venues with all of the first four sampling approaches described in section 2.2.1 applied. Two of the 27 venues had continuous sampling for at least 24 hours. One-hour peak-patronage-time sampling and observation was conducted during 121 visits to all the 79 venues, with 25 venues visited during both lunch and dinner time. Eleven of the 14 venues nominally restricting smoking were visited simultaneously in both smoking sections and nonsmoking sections. Two passive area nicotine samplers were placed at different locations of the dining area in 37 venues. A total of four passive samplers were lost. See Table 2.3 and Figure 2.5 for the final sampling approaches applied and number of samplers collected.

Table 2.2 Type of venues and smoking policies of venues included in the study, Beijing, 2010

	Nominal smoking policy			
	prohibit (%)	restrict (%)	allow (%)	Total (%)
venue types				
Chinese dining	24 (52%)	8 (17%)	14 (30%)	46 (100%)
Chinese fast food	6 (75%)	0 (0%)	2 (25%)	8 (100%)
Western dining	1 (33%)	2 (67%)	0 (0%)	3 (100%)
Western Fast food	4 (80%)	1 (20%)	0 (0%)	5 (100%)
Bar	1 (9%)	1 (9%)	9 (82%)	11 (100%)
Café	1 (17%)	2 (33%)	3 (50%)	6 (100%)
venue area (m^2)				
16-58	5 (26%)	0 (0%)	14 (74%)	19 (100%)
59-105	12 (60%)	2 (10%)	6 (30%)	20 (100%)
106-169	13 (62%)	3 (14%)	5 (24%)	21 (100%)
170-600	7 (37%)	9 (47%)	3 (16%)	19 (100%)
number of seats				
10-48	8 (38%)	0 (0%)	13 (62%)	21 (100%)
49-72	12 (63%)	2 (11%)	5 (26%)	19 (100%)
73-106	10 (50%)	4 (20%)	6 (30%)	20 (100%)
107-266	7 (37%)	8 (42%)	4 (21%)	19 (100%)
Total	37 (47%)	14 (18%)	28 (35%)	79 (100%)

Table 2.3 Description of sampling approaches finally applied in selected venues, Beijing, 2010

sampling approach	sampling duration	n of venues	n of venues with samples in both sections*	total n of samplers	notes
passive area nicotine sampling	7 or 14 days	39	6	91	Four samplers from two venues were lost; 37 venues or 42 sections each had two samples
active area nicotine sampling	one day (open hours)	33	5	38	All the 33 venues had passive sampling conducted
active personal nicotine sampling	one day (open hours)	30	NA	43	12 venues each had two personal samples, one had three personal samples and the other 17 each one sample
peak time active nicotine sampling	one hour	79	10	121	25 venues or 30 sections each had sampling during both lunch and dinner
peak time active $PM_{2.5}$ sampling	one hour	77	9	114	22 venues or 26 sections each had sampling during both lunch and dinner
peak time CO_2, RH and Temp monitoring	one hour	61	6	83	12 venues each had sampling during both lunch and dinner; Data from 38 visits to 18 venues were not available because of the data logging or downloading problem of two monitors.

*designated smoking section and nonsmoking section

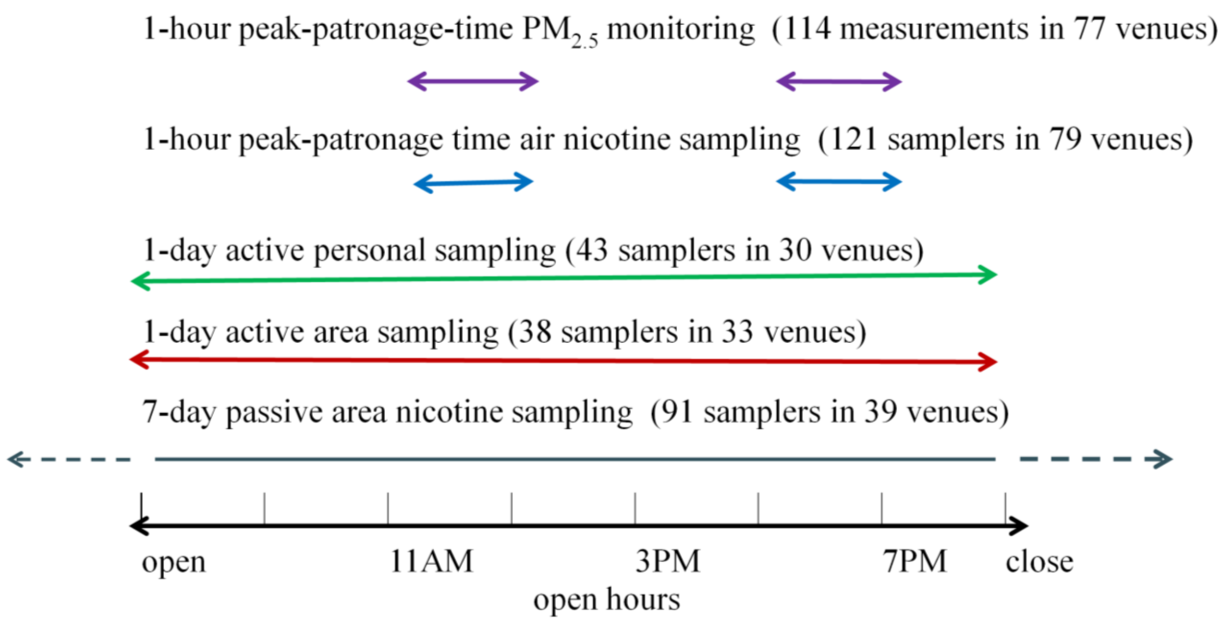


Figure 2.5 SHS sampling approaches applied in restaurants and bars, Beijing, 2010

2.3.2 Observations and Sampling during Peak Patronage Time

2.3.2.1 Observations

Ashtrays were observed on tables in three venues of the 37 venues nominally prohibiting smoking; although ashtrays were not available on dining tables, they would be provided if requested by patrons in another 20 of the 37 nominal nonsmoking venues and in two designated nonsmoking sections of the 14 venues nominally restricting smoking.

Smoking was observed in 77 of the 121 visits, including 30 visits to 22 of the 37 (59%) nominal nonsmoking venues and six visits to four of the 14 (29%) nominal nonsmoking sections. The median of active smoking rates among patrons (defined as number of patrons observed smoking divided by the total number of patrons) was 4.4% (interquartile range [IQR] 1.5-11.3%) in smoking sections and 4.3% (IQR 2.7-8.1%) in smoking venues; it was higher in nominal nonsmoking venues (0.8%, IQR 0-4.3%) than in nonsmoking sections (0, IQR 0-0.7%) (Table 2.4). Intervention to stop violations of smoking prohibitions was observed during one of the 121 visits (0.8%) only.

Similarly, observed number of active smokers per 100 m^3 (active smoker density, ASD100 thereafter) during peak patronage times was lowest in nominal nonsmoking sections (median 0, IQR 0-0.03), followed by nonsmoking venues (median 0.08, IQR 0-0.28). It was higher in smoking sections and smoking venues, both with a median above 0.25. The highest ASD100 was observed in a smoking bar, with 2.5 active smokers per 100m^3. Non-parametric Kruskal-Wallis rank tests showed significant differences of ASD100 among venues or sections with different nominal smoking policies (χ^2 = 29.5, df = 3, p = 0.0001) while non-significant differences among visits during different day of a week (χ^2 = 3.67, df = 5, p = 0.57). In addition, Wilcoxon rank-sum tests showed non-significant differences between ASD100 in restaurants and bars (p = 0.37) and during lunch and dinner (p = 0.99). See Table 2.5 and Figure 2.6 for details.

2.3.2.2 SHS PM sampling during peak patronage time

The median (IQR) of SHS PM concentrations was about 43 (7-198) µg/m^3 in smoking sections, similar to that in smoking venues (40 [8-152] µg/m^3); SHS PM levels were lower in nonsmoking sections (15 [1-36] µg/m^3) than in nonsmoking venues (27 [0-72] µg/m^3). It was 60 (4-127) µg/m^3 in bars and 27 (4-80) µg/m^3 in restaurants. The highest SHS PM concentration (985 µg/m^3) was observed in a nonsmoking restaurant where no smoking or other obvious indoor sources of $PM_{2.5}$ were observed during the sampling period. Kruskal-Wallis rank test showed significant differences of peak-time SHS PM levels among venues or sections with different smoking policies (χ^2 = 7.91, df = 3, p = 0.048) and Wilcoxon rank-sum test showed that peak-time SHS PM levels were significantly higher during visits with smoking observed than during visits without smoking observed ($p < 0.0001$). Non-significant differences of SHS PM levels were found in bars and restaurants, during visits on different days of a week or in lunch or dinner time periods. See Table 2.5 and Figure 2.6 for details.

2.3.2.3 Nicotine sampling during peak patronage time

The median (IQR) of airborne nicotine levels during peak patronage time was 1.40 (0.69-2.26) µg/m^3 in nonsmoking venues, 0.63 (0.29-1.44) µg/m^3 in nonsmoking sections, 1.67 (1.16-6.11) µg/m^3 in smoking sections and 2.68 (1.32-4.68) µg/m^3 in smoking venues. It was 2.25 (1.34-4.56) µg/m^3 during visits with smoking observed and 0.67 (0.19-1.23) µg/m^3 during visits when smoking was not observed. The highest nicotine level (19.42 µg/m^3) was observed in the smoking section of a bar. Non-parametric Kruskal-Wallis rank tests showed significant differences of peak-time nicotine levels among venues or sections with different smoking policies (χ^2 = 14.4, df = 3, p = 0.002) while non-significant differences among visits during different day of a week (χ^2 = 9.1, df = 5, p = 0.1). Wilcoxon rank-sum tests showed that peak-time nicotine levels were significantly higher during visits with smoking observed than during visits without smoking observed ($p < 0.0001$), and they were significantly higher in bars than in restaurants (p = 0.02). There were non-significant differences during lunch and dinner (p = 0.78). See Table 2.5 and Figure 2.6 for details.

2.3.2.4 Simultaneous sampling in designated smoking sections and nonsmoking sections during peak patronage time

Simultaneous observation and airborne nicotine sampling were conducted in designated smoking sections and nonsmoking sections during 15 peak-patronage times in 11 venues nominally restricting smoking. $PM_{2.5}$ was only monitored simultaneously in two sections during 13 of the 15 peak-patronage times because of the availability of instruments. Active smoker density (ACD100) in smoking sections (median [IQR]: 0.27 [0.04-0.79]) was significantly higher than in nonsmoking sections (median [IQR]: 0 [0-0.03]); the median (IQR) of SHS concentrations in nonsmoking sections was 15 (1-36) µg/m^3, indicated by SHS PM, and 0.63 (0.29-1.44) µg/m^3, indicated by airborne nicotine, much lower than that of smoking sections (43 [7-198] µg/m^3 by SHS PM and 1.67 [1.16-6.11] µg/m^3 by nicotine) (Table 2.6). The median (IQR) of ratios of nonsmoking section SHS concentrations to smoking-section concentrations was 0.31 (0.11-1.36) by nicotine and 0.69 (0.11-0.83) by SHS PM; the ratios of both SHS PM and nicotine were lowest in venues with separate rooms or floors for smoking, followed by venues with half walls between the two sections, and were highest in venues with no walls between the two sections (Table 2.6). Wilcoxon matched-pairs signed-rank test showed $p < 0.01$ for comparison of ACD100, SHS PM and airborne nicotine between smoking and nonsmoking sections.

In addition, nicotine concentrations in designated nonsmoking sections were linearly related with nicotine concentrations in designated smoking sections ($\beta_0 = 0.24$, $\beta = 0.27$, $R^2 = 0.77$) (Figure 2.8); while the relationship of SHS PM concentrations in the two sections formed two clusters, one including data points for eight visits, and the other, for five visits. Of the eight visits, six were in venues with no walls between smoking and nonsmoking sections and of the five visits, four were in a venue with separate room or different floor for smoking (Figure 2.7).

2.3.2.5 Sampling during lunch and dinner in the same venues

There were 31 venues or sections with observation and sampling during both lunch and dinner time. Paired *t*-tests showed no significant difference of active smoker density, airborne nicotine levels or SHS PM levels during dinner peak patronage time and during lunch peak patronage time (Table 2.5).

Table 2.4 Observed smoking behaviors among patrons in restaurants and bars, Beijing, 2010

		active smoking rate [a]				active smoking density [b]			
	N	mean	SD[c]	median	IQR[d]	mean	SD[c]	median	IQR[d]
Nominal smoking policy									
nonsmoking venues	51	2.9%	4.4%	0.8%	0-4.3%	0.22	0.37	0.08	0-0.28
nonsmoking sections	21	0.5%	0.9%	0.0%	0-0.7%	0.01	0.02	0.00	0-0.03
smoking section	16	6.2%	5.1%	4.4%	1.5-11.3%	0.57	0.64	0.27	0.04-0.79
smoking venue	33	5.8%	5.8%	4.3%	2.7-8.1%	0.49	0.55	0.34	0.11-0.68
Type of establishment									
restaurants	101	3.1%	4.0%	1.8%	0-4.5%	0.28	0.43	0.08	0-0.31
bars/cafés	20	6.6%	7.7%	4.2%	0-10.1%	0.43	0.65	0.14	0-0.56
Total	121	3.7%	5.0%	2.3%	0-5.2%	0.30	0.47	0.10	0-0.38

[a] active smoking rate: number of patrons observed smoking divided by the total number of patrons;
[b] active smoking density: number of active smokers observed per 100m^3;
[c] SD standard deviation;
[d] IQR interquartile range.

Table 2.5 SHS PM and airborne nicotine levels during peak-patronage time in restaurants and bars, Beijing, 2010

	SHS PM					airborne nicotine				
	N	mean	SD[a]	median	IQR[b]	N	mean	SD[c]	median	IQR[d]
Nominal smoking policy										
nonsmoking venues	48	79	171	27	0-72	51	1.93	1.94	1.40	0.69-2.26
nonsmoking sections	20	22	24	15	1-36	21	1.25	1.44	0.63	0.29-1.44
smoking sections	15	90	90	43	7-198	16	4.24	5.21	1.67	1.16-6.11
smoking venues	31	78	76	40	8-152	33	3.45	2.80	2.68	1.32-4.68
Smoking observed or not										
No	43	47	155	4	0-28	44	1.08	1.46	0.67	0.19-1.23
Yes	71	84	99	44	22-134	77	3.36	3.20	2.25	1.34-4.56
Type of establishment										
restaurants	94	65	122	27	4-80	45	2.23	2.34	1.73	0.65-2.68
bars/cafés	20	97	132	60	4-127	76	2.71	3.20	1.49	1.24-5.52
Peak time period										
lunch	43	57	86	26	4-70	45	2.23	2.34	1.73	0.70-2.68
dinner	71	78	142	31	2-101	76	2.71	3.20	1.49	0.69-3.38
Sampling day										
Monday	9	49	65	26	4-43	11	1.65	2.63	0.45	0.06-1.90
Tuesday	18	36	51	27	0-40	19	1.84	2.23	1.32	0.89-1.87
Wednesday	29	90	193	27	9-81	30	2.38	2.01	2.00	1.04-3.04
Thursday	19	43	60	22	8-39	21	2.11	2.76	1.30	0.51-2.35
Friday	14	97	97	67	11-200	14	3.15	2.96	2.60	0.63-4.95
Sat/Sun	25	86	121	40	0-134	26	3.59	4.09	1.98	1.05-5.45
Total	114	70	124	27	4-93	121	2.53	2.91	1.53	0.69-3.10

[a] SD standard deviation; [b] IQR interquartile range.

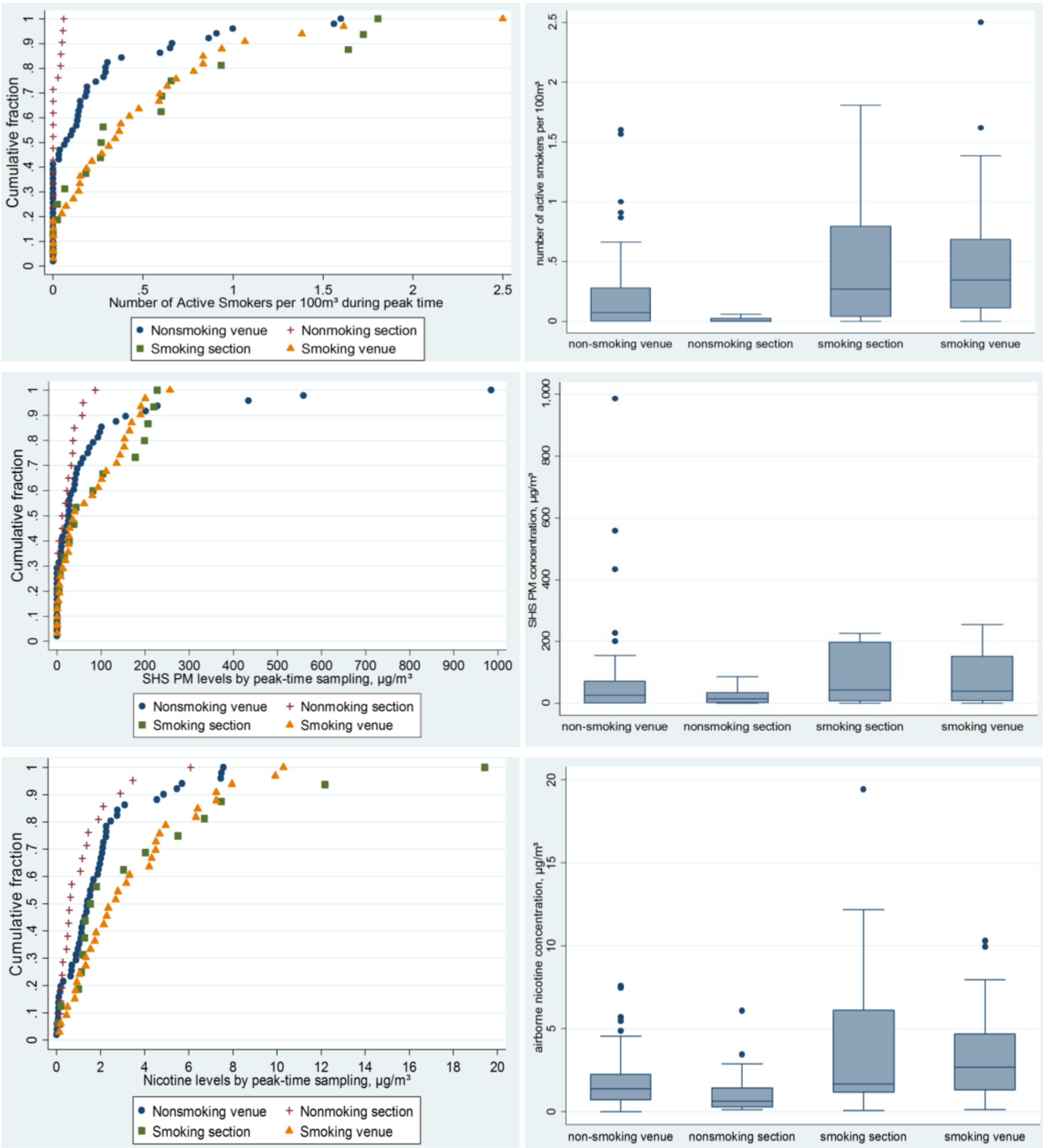


Figure 2.6 Cumulative distributions and box plots of active smoker density per 100m^3 (upper panel), SHS PM concentration (middle panel) and airborne nicotine concentration (lower panel) by nominal smoking policies Beijing, 2010

Note: A box plot depicts the median of a dataset (indicated by the line in the box, the first and third quartiles (the upper edge and lower edge of the box, respectively) and the extreme values (within 1.5 times the inter-quartile range [IQR] from the first or third quartile, indicated by the ends of the whisker lines extending from the IQR). Points at a greater distance from the median than 1.5 times the IQR are plotted individually beyond the whisker lines and they represent potential outliers)

Table 2.6 Active smoker density (ACD100), SHS PM and airborne nicotine concentrations and ratios in restaurant or bar designated smoking and nonsmoking sections by simultaneous sampling, Beijing, 2010

	ACD100		SHS PM			airborne nicotine		
	smoking section	non-smoking section	smoking section (a)	non-smoking section (b)	ratio (b/a)	smoking section (c)	non-smoking section (d)	ratio (d/c)
separate room or different floor								
N	7	8	6	7	5	7	8	7
mean	0.95	0.01	148	16	0.27	4.89	0.83	0.15
SD	0.75	0.02	86	16	0.41	3.78	1.07	0.10
median	0.60	0.00	188	11	0.11	4.04	0.27	0.11
IQR	0.28-1.73	0-0.02	81-206	2-36	0.05-0.19	1.54-6.70	0.17-1.37	0.06-0.24
half wall								
N	3	3	3	3	2	3	3	2
mean	0.42	0.00	111	48	0.54	9.57	3.34	0.39
SD	0.46	0.00	113	44	0.40	8.99	2.82	0.10
median	0.27	0.00	104	59	0.54	7.47	3.45	0.39
IQR	0.06-0.93	0-0.00	1-227	0-86	0.26-0.83	1.81-19.42	0.46-6.09	0.31-2.59
no wall								
N	6	10	6	10	6	6	10	6
mean	0.19	0.02	22	18	4.84	0.83	0.95	2.61
SD	0.25	0.02	17	19	10.37	0.56	0.52	3.23
median	0.10	0.00	22	15	0.76	1.07	0.88	1.52
IQR	0.02-0.26	0-0.04	7-38	0-32	0.69-0.84	0.20-1.28	0.54-1.37	0.84-2.59
Total								
N	16	21	15	20	13	16	21	15
mean	0.57	0.01	90	22	2.42	4.24	1.25	1.16
SD	0.64	0.02	90	24	7.09	5.21	1.44	2.29
median	0.27	0.00	43	15	0.69	1.67	0.63	0.31
IQR	0.04-0.79	0-0.03	7-198	1-36	0.11-0.83	1.16-6.11	0.29-1.44	0.11-1.36

Notes: SD: standard deviation; IQR: interquartile range

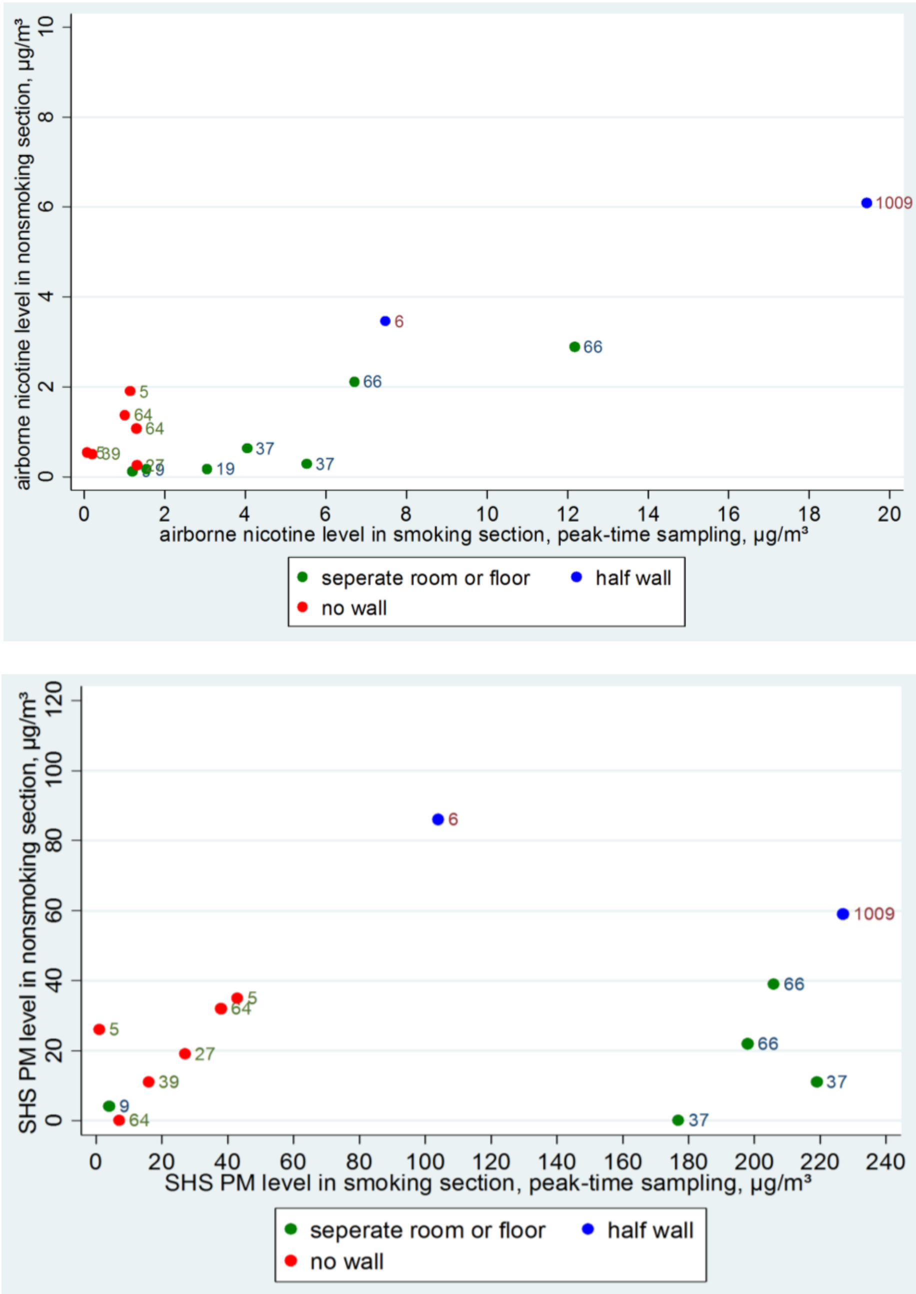


Figure 2.7 Relationship between simultaneous measurements of nicotine levels (upper panel) and SHS PM levels (lower panel) during peak patronage times in smoking sections and nonsmoking sections, Beijing, 2010

Note: marks are labeled with venue identification numbers; different colors indicate different separation between smoking and nonsmoking sections

2.3.3 One-day active area nicotine sampling

A total of 38 samples were conducted in 33 venues, with simultaneous sampling in both smoking and nonsmoking sections of five venues restricting smoking. The median duration of one-day active sampling time was 11 hours (range 8-16 hours), thus these one-day active area sampling results reflected the time-weighted average area concentrations during open hours.

The median (IQR) of airborne nicotine concentrations was 1.37 (0.55-4.80) μg/m^3 in smoking venues and 0.96 (0.30-4.02) μg/m^3 in smoking sections; it was higher in nonsmoking venues (median 0.85, IQR 0.11-2.98) μg/m^3 than in nonsmoking sections (median 0.47, IQR 0.02-2.65] μg/m^3) (Table 2.7). Nonparametric rank test showed no significant differences of nicotine levels in venues or sections with different nominal smoking policy or in restaurants or bars (Table 2.7). For the five venues restricting smoking with simultaneous measurements, the median of airborne nicotine was 1.67 μg/m^3 in smoking sections and 0.47 μg/m^3 in nonsmoking sections; No significant difference was showed according to paired *t*-test (p = 0.67) or Wilcoxon matched pairs signed rank test (p = 0.68).

2.3.4 One-day active personal nicotine sampling.

One-day active personal sampling was conducted concurrently with one-day active area nicotine sampling. A total of 43 volunteers from 30 venues were recruited for personal sampling. Two samples were suspect and excluded from subsequent analyses: airborne nicotine concentration calculated from one personal sampler from a nominal nonsmoking restaurant was 60.4 μg/m^3, while it was 1.2 μg/m^3 from the other personal sampler in the same venue, 0.06 from the one-day active area sampler, and 1.9 μg/m^3 and 1.6 μg/m^3 from the lunch-time and dinner-time sampling, respectively. Airborne nicotine concentration based on another personal sampler from a restaurant nominally restricting smoking was 284 μg/m^3, while it was 6.8 μg/m^3 based on the other personal sampler in the same venue, 4.7 μg/m^3 and 0.02 μg/m^3 from one day active area sampling in the designated smoking section and nonsmoking section, respectively, 12.2 μg/m^3 and 6.7 μg/m^3 from one hour sampling during lunch and dinner time, respectively, in the designated smoking section, and 2.9 μg/m^3 and 2.1 μg/m^3 from one hour sampling during lunch and dinner time, respectively, in the designated nonsmoking section. Furthermore, airborne nicotine concentrations from the rest 28 venues (39 samplers) were all less than 10 μg/m^3. Therefore, the two personal samplers, which had nicotine concentration of 60.4 μg/m^3 and 284 μg/m^3, respectively, were suspected to be contaminated by other sources of tobacco smoke rather than SHS in the sampling venues, so they were excluded for this data analysis.

Two volunteering servers were recruited for personal sampling in each of 12 venues; after excluding the two samples above, 10 venues had two personal samples and the rest two had one. The difference of nicotine levels between each paired samples (higher level – lower level) ranged from 0.28 to 7.96 μg/m^3, with an average of 2.00 μg/m^3 (SD 2.43 μg/m^3) and a median of 1.08 μg/m^3. The ratios (higher level/ lower level) ranged from 1.1 to 9.0, with an average of 2.6 (SD 2.4) and a median of 1.6. Three volunteer servers were recruited for personal sampling in one venue, which showed almost the same air nicotine levels: 1.4, 1.5 and 1.6 μg/m^3. For each of these 11 venues with two or three personal samplers, the average of the different samplers (if there were any) was used to represent the personal nicotine exposure level in the venue.

The median of airborne nicotine levels by personal sampling in venues with different nominal smoking policies was quite similar, which ranged from 2.44 to 2.92 μg/m^3. Kruskal-

Wallis test showed no difference between the airborne nicotine exposure of volunteers working in venues with different nominal smoking policies or in restaurants or bars (Table 2.7).

2.3.5 Week-long passive area sampling.

Four of the 91 week-long passive area samplers were lost; of the rest 87 samplers from 39 venues, 30 sampled seven days, 47 sampled 14 days, 6 sampled 12 days and 4 sampled 13 days. Two passive samplers were placed at different locations of each of the 42 sections or venues, and the difference of nicotine levels between each pair of samplers (higher level – lower level) ranged from 0.00 to 2.18 μg/m^3, with an average of 0.52 μg/m^3 (SD 0.59 μg/m^3) and a median of 0.27 μg/m^3. The ratios for nicotine concentrations by different samplers in the same venues (higher level /lower level) ranged from 1.0 to 2.6, with an average of 1.3 (SD 0.4) and a median of 1.2 (0.5). The average of different samplers (if there were any) was used to represent the time weighted nicotine level by passive area sampling in the venue or section.

The median (IQR) of time weighted nicotine levels by passive area sampling was 2.12 (1.38-3.45) μg/m^3 in smoking venues, quite similar to that in smoking sections (median 2.32, IQR 0.83-3.03 μg/m^3) and non-significantly higher than that in nonsmoking sections (median 1.53, IQR 0.64-2.69 μg/m^3) or nonsmoking venues (median 1.38, IQR 0.85-2.18 μg/m^3) (Table 2.7).

For the six venues restricting smoking with simultaneous measurements, the median airborne nicotine was 2.27 μg/m^3 in designated smoking sections and 1.53 μg/m^3 in nonsmoking sections; No significant difference was showed according to paired *t* test ($p = 0.09$).

Table 2.7 Nicotine levels (μg/m^3) in restaurants and bars by different sampling approaches, Beijing, 2010

	N	mean	SD	median	IQR	GM	GSD	min	max	stat test
peak-time sampling										
nominal smoking policy										
smoking venue	28	3.22	2.50	2.52	1.33-4.59	2.22	2.75	0.13	9.93	χ^2=14.4
smoking section	11	4.60	5.75	1.81	1.15-7.47	2.28	3.77	0.20	19.42	df=3
nonsmoking section	14	1.35	1.65	0.77	0.46-1.22	0.77	2.97	0.14	6.09	p=0.002
nonsmoking venue	37	1.79	1.90	1.37	0.65-2.26	0.87	4.61	0.02	7.49	
type of establishments										
restaurants	62	2.08	2.12	1.38	0.75-2.62	1.11	3.95	0.02	9.93	p=0.02
bars/cafes	17	3.72	3.30	2.78	1.34-4.95	2.41	2.93	0.25	12.76	
Total	79	2.43	2.49	1.61	0.87-3.31	1.31	3.84	0.02	12.76	
one-day active area sampling										
nominal smoking policy										
smoking venue	8	2.58	2.72	1.37	0.55-4.80	1.06	6.66	0.02	7.22	χ^2=0.94
smoking section	9	1.96	2.02	0.96	0.30-4.02	0.63	11.59	0.00	4.92	df=3
nonsmoking section	7	1.47	2.07	0.47	0.02-2.65	0.37	9.35	0.02	5.66	p=0.82
nonsmoking venue	14	1.62	1.91	0.85	0.11-2.98	0.61	5.89	0.02	6.49	
type of establishments										
restaurants	25	1.83	1.99	1.08	0.38-2.98	0.69	7.04	0.00	7.22	p=0.99
bars/cafes	8	1.91	2.40	0.87	0.35-3.16	0.72	6.20	0.02	6.49	
Total	33	1.85	2.06	1.08	0.38-2.98	0.70	6.64	0.00	7.22	
one-day active personal sampling										
nominal smoking policy										
allow	6	3.46	2.16	2.92	1.79-6.04	2.87	2.01	1.04	6.09	χ^2=0.12
prohibit	14	3.42	2.63	2.62	1.18-5.27	2.50	2.38	0.55	9.56	df=2
restrict	10	3.35	2.83	2.44	1.22-6.63	2.25	2.73	0.41	8.10	p=0.94
type of establishments										
restaurants	22	3.09	2.40	2.47	1.22-4.98	2.27	2.34	0.41	9.56	p=0.18
bars/cafes	8	4.27	2.84	4.76	1.14-6.42	3.20	2.45	0.85	8.10	
Total	30	3.41	2.53	2.62	1.22-5.40	2.48	2.36	0.41	9.56	
week-long passive sampling										
nominal smoking policy										
smoking venue	12	2.68	1.74	2.12	1.38-3.45	2.21	1.94	0.71	6.56	χ^2=3.6
smoking section	10	2.39	1.60	2.32	0.83-3.03	1.84	2.29	0.52	5.13	df=3
nonsmoking section	6	1.60	1.12	1.53	0.64-2.69	1.19	2.52	0.29	2.92	p=0.30
nonsmoking venue	17	1.71	1.22	1.38	0.85-2.18	1.29	2.38	0.13	4.14	
type of establishments										
restaurants	28	1.84	1.18	1.62	0.84-2.68	1.43	2.21	0.13	4.14	p=0.23
bars/cafes	11	2.79	1.81	2.46	1.31-3.81	2.27	2.00	0.71	6.56	
Total	39	2.11	1.43	1.83	0.92-3.21	1.63	2.20	0.13	6.56	

Note: N indicates number of venues; because some venues have both nonsmoking 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.

2.3.6 Comparison of Different Sampling Approaches to Estimate SHS Exposure

Both SHS PM and airborne nicotine levels measured during peak patronage times were significantly related to observed active smoker density (active smokers per 100 m^3, ASD100) (Table 2.8 and Figure 2.8). ASD100 could explain 29% of the variance of SHS PM concentrations and 40% of the variance of airborne nicotine levels. An increase of every one active smoker in a space of 100 m^3 could increase the SHS PM concentration by 100 $\mu g/m^3$ and airborne nicotine by 3.30 $\mu g/m^3$. An increase of 1 $\mu g/m^3$ of airborne nicotine level corresponded with an increase of 17 $\mu g/m^3$ of SHS PM according to 111 parallel measurements during peak time (two influential data points, one with SHS PM level >900 $\mu g/m^3$ and the other with nicotine level >18 $\mu g/m^3$ were excluded from the regression analysis) (Table 2.8 and Figure 2.8).

There were 27 venues with four different nicotine sampling approaches used. The median (range) airborne nicotine concentration by one-day active area sampling in these 27 venues was 1.08 $\mu g/m^3$ (0-7.22 $\mu g/m^3$), lower than the median concentration by peak-patronage-time sampling (median 1.78 $\mu g/m^3$, range 0.02-12.76 $\mu g/m^3$) and by week-long passive sampling (median 2.28 $\mu g/m^3$, range 0.56-4.95 $\mu g/m^3$). One-day personal air sampling showed the highest concentration, with a median of 2.54 $\mu g/m^3$, and a range of 0.41-8.10 $\mu g/m^3$ (Figure 2.9).

Paired *t*-tests and ratios of airborne nicotine levels measured in the same venues/sections by different area sampling approaches showed that, as expected, peak-time active sampling results tended to over-estimate the one-day active sampling results by a median of two times (mean [SD] of difference: 1.62 [3.45] $\mu g/m^3$) and week-long passive sampling results by a median of 1.6 times (mean [SD] of difference: 1.39 [2.97] $\mu g/m^3$); contrary to expectation, one-day active sampling results tended to underestimate week-long passive sampling results by a median of 60%, though paired *t* tests showed no significant absolute difference (mean [SD] of difference: -0.24[1.93] $\mu g/m^3$) (Table 2.9). Simple regression analysis showed that airborne nicotine levels by peak-time area, one-day active area and week-long passive area sampling were significantly related to each other (Table 2.10 and Figure 2.10).

To compare results by area sampling methods to results by personal air nicotine sampling method, results of parallel area sampling in venues with smoking and nonsmoking sections were weighted by the number of seats in each section to represent the concentration in the whole venue. Paired *t*-tests and ratios of area nicotine sampling results to personal nicotine sampling results showed that peak-time area sampling results were closer estimates of one-day personal airborne nicotine sampling results than one-day active area and week-long passive area sampling results in terms of both absolute difference or ratio (mean [SD] of difference: -0.45 [2.64] $\mu g/m^3$, median of ratio: 0.8). Simple regression analysis showed that both peak-time area sampling and one-day active area sampling results were significantly related to personal nicotine sampling results, but not week-long passive area sampling results (Table 2.11 and Figure 2.11). An increase of 1 $\mu g/m^3$ of SHS PM or airborne nicotine during peak time corresponded to an increase of 0.03 $\mu g/m^3$ or 0.47 $\mu g/m^3$ of airborne nicotine, respectively, exposed by servers during the work day when the sampling took place; and an increase of 1 $\mu g/m^3$ of airborne nicotine by one-day active area sampling corresponded to an increase of 0.75 $\mu g/m^3$ of servers' exposure. The intercepts for all the three area sampling results were about 2 $\mu g/m^3$. Peak-time area SHS PM concentrations and airborne nicotine concentration explained 25% and 29%, respectively, of the variance of servers' work-day SHS exposure and one-day active area sampling explained 46% of the variance.

Table 2.8 Simple linear regression analyses on active smoker density, nicotine levels and SHS PM levels during peak time, Beijing, 2010

Independent variable	Peak-time SHS PM levels					Peak-time nicotine levels				
	n	Slope(95%CI)	Constant(95%CI)	*P* value	R^2	n	Slope(95%CI)	Constant(95%CI)	*P* value	R^2
ASD	113	100 (44, 156)	33 (18-48)	0.0006	0.29	120	3.30 (2.03, 4.57)	1.38 (0.99, 1.76)	<0.0001	0.40
nicotine levels	111	17 (14, 20)	12 (0, 23)	<0.0001	0.54					

Note: ASD: active smoking density; SHS PM level was defined as the difference between indoor and outdoor $PM_{2.5}$ levels multiplied by an adjustment factor of 0.32 (suitable for SHS); if the indoor level was lower than the outdoor level, SHS PM was assumed to be 0.

Table 2.9 Paired *t* tests and nonparametric Wilcoxon signed rank tests of nicotine levels in the same venues/sections by different sampling approaches, Beijing, 2010

sampling approach	N of visits, mean(SD) of differences (row-column) and paired *t* test,									median(IQR) of ratios (row/column)		
	one-day active area			week-long passive area			one-day personal [a]			One-day active area	week-long passive area	one-day personal
	n	mean (SD)	*p*	n	mean (SD)	*p*	n	mean (SD)	*p*			
peak time area	37	1.62 (3.45)	0.007	43	1.39 (2.97)	0.0037	30	-0.45 (2.64)	0.36	2.0 (1.1-9.5)	1.6(1.0-2.1)	0.8(0.5-1.5)
one day active area				35	-0.24 (1.93)	0.47	28	-1.42 (1.73)	0.0002	1.0	0.6(0.1-1.6)	0.5(0.2-0.7)
passive area							28	-1.39 (2.49)	0.006	1.5(0.6-9.3)	1.0	0.6(0.4-1.2)

[a] When compared to results of personal airborne nicotine sampling, results of each stationary area sampling were weighted by the number of seats in smoking and nonsmoking section to represent the concentration in the whole venue

Table 2.10 Simple linear regression analysis on area nicotine samplings, Beijing, 2010

Independent variable	one-day active area nicotine sampling					One or two-week passive area nicotine sampling				
	n	Slope (95%CI)	Constant (95%CI)	*P* value	R^2	n	Slope (95%CI)	Constant (95%CI)	*P* value	R^2
peak-time area	36	0.61 (0.43, 0.79)	0.07 (-0.48, 0.62)	<0.0001	0.51	42	0.42 (0.25, 0.60)	0.78 (0.26, 1.29)	<0.0001	0.46
one-day active area						35	0.30 (0.11, 0.50)	1.61 (1.03, 2.20)	0.0038	0.23

Table 2.11 Simple linear regression analysis on personal nicotine sampling and area samplings, Beijing, 2010

Independent variable	One-day personal nicotine sampling				
	n	Slope (95%CI)	Constant (95%CI)	*P* value of slope	R^2
one-hour peak-time area SHS PM	26	0.03(0.007, 0.05)	2.15 (0.80, 3.50)	0.009	0.25
one-hour peak-time area nicotine	30	0.47 (0.18, 0.75)	2.03 (0.86, 3.19)	0.002	0.29
one-day active area nicotine	28	0.75 (0.43, 1.08)	1.83 (0.98, 2.68)	0.0001	0.46
week-long passive area nicotine	28	0.59 (-0.14, 1.31)	2.20 (0.444, 2.60)	0.108	0.096

Note: For one-day personal nicotine sampling in each venue, the average was used if there were multiple samplers; for all the area sampling, results were weighted by the number of seats in smoking and nonsmoking section to represent the concentration in the whole venue

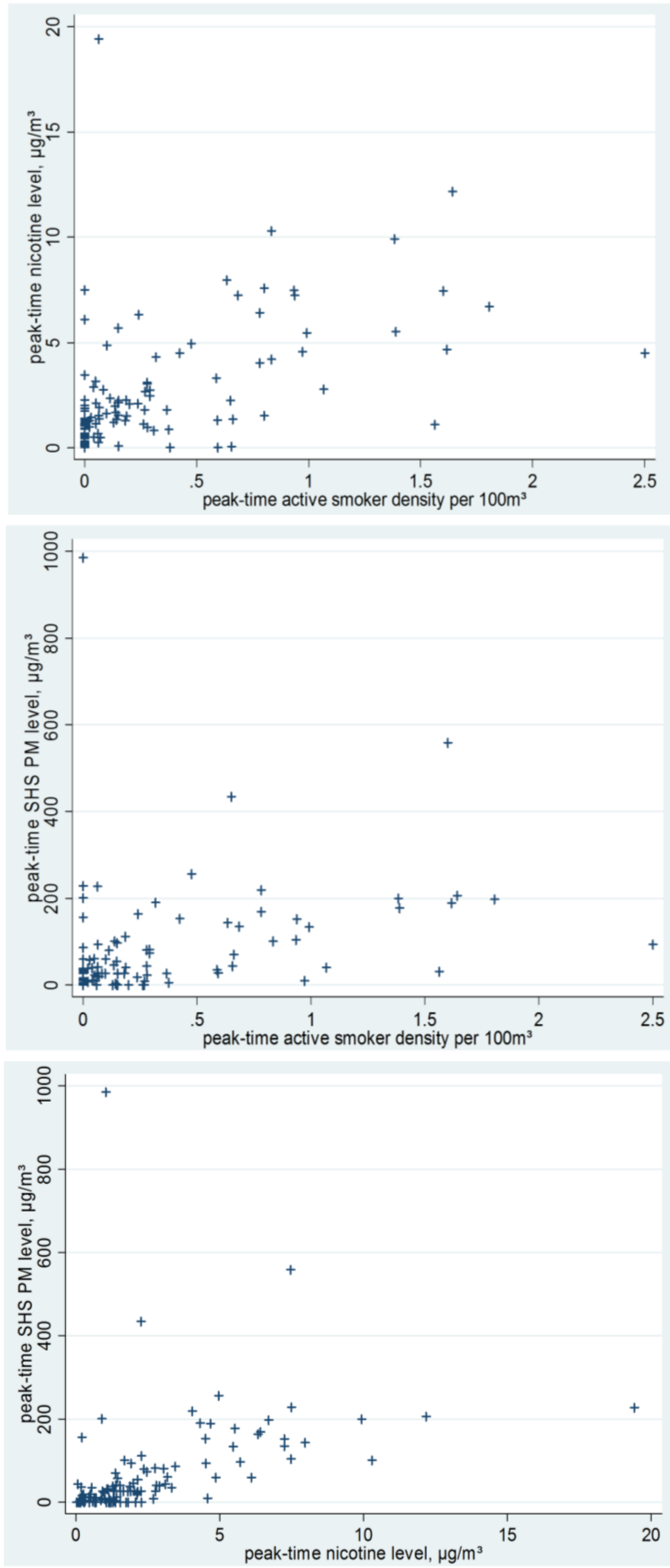
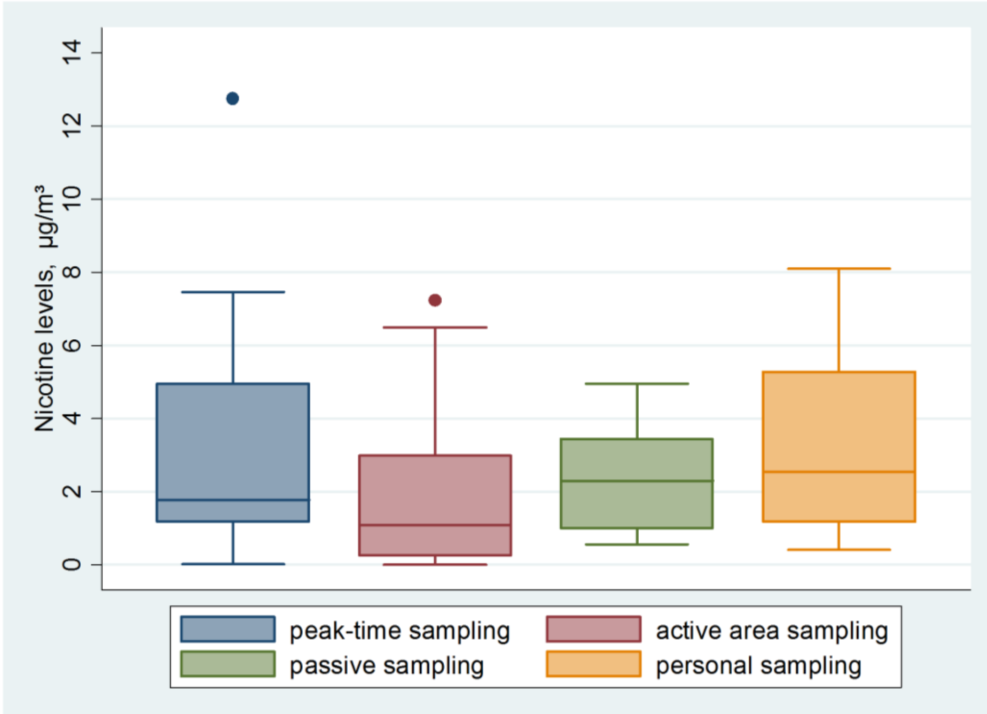


Figure 2.8 Scatter plots of peak-time nicotine levels, SHS PM levels and active smoker density, Beijing, 2010



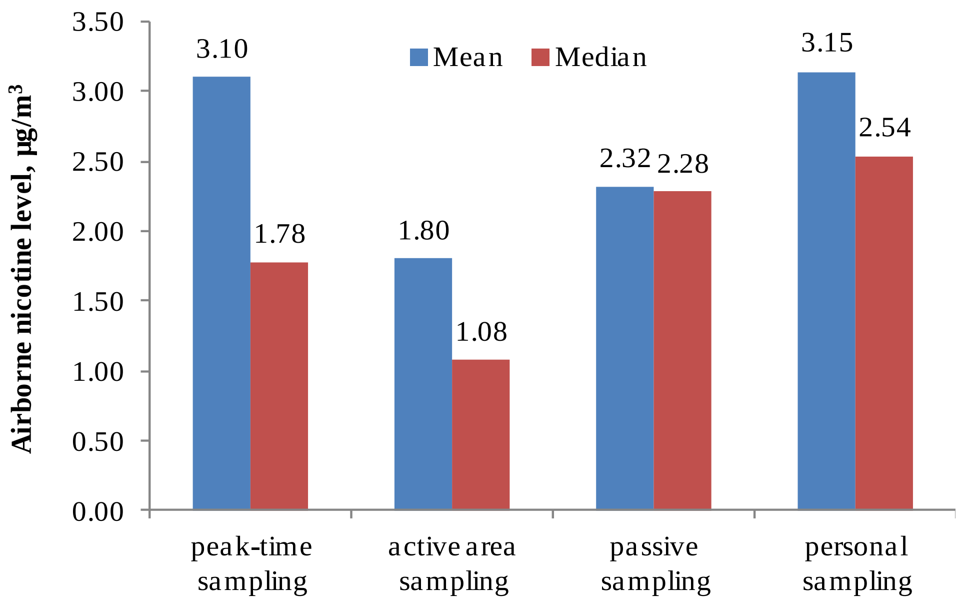


Figure 2.9 Nicotine levels by different sampling approaches in the 27 venues where all four approaches were used

Note: peak-time sampling was conducted for about one hour during peak patronage time, active area sampling and personal air sampling was conducted for a full working day; all these three sampling was conducted on the same day. Passive area sampling was conducted for one or two weeks, which containing the day when other sampling was performed.

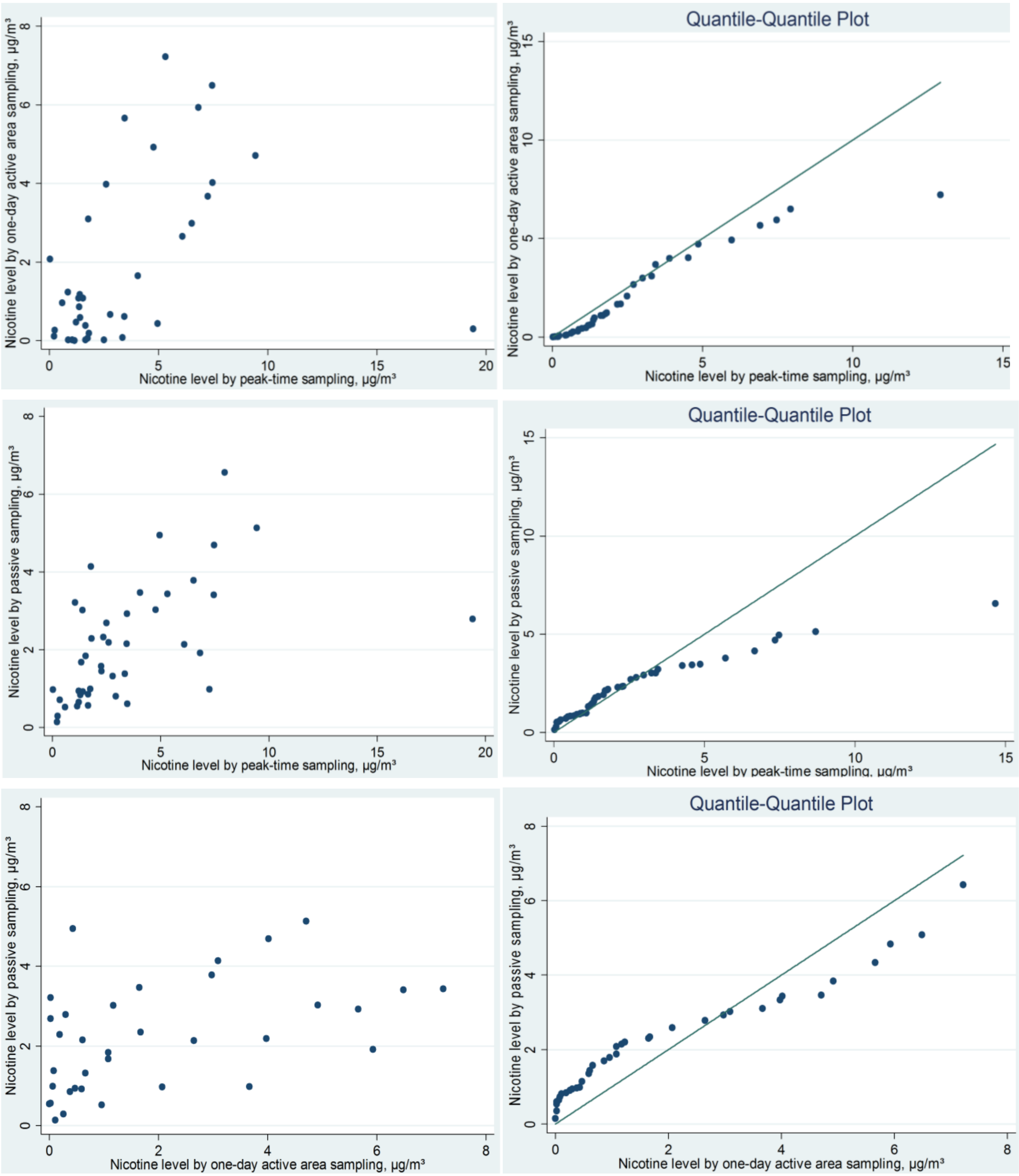


Figure 2.10 Scatter plots (left panel) and quantile-quantile plots (right panel) of different area nicotine samplings, Beijing, 2010

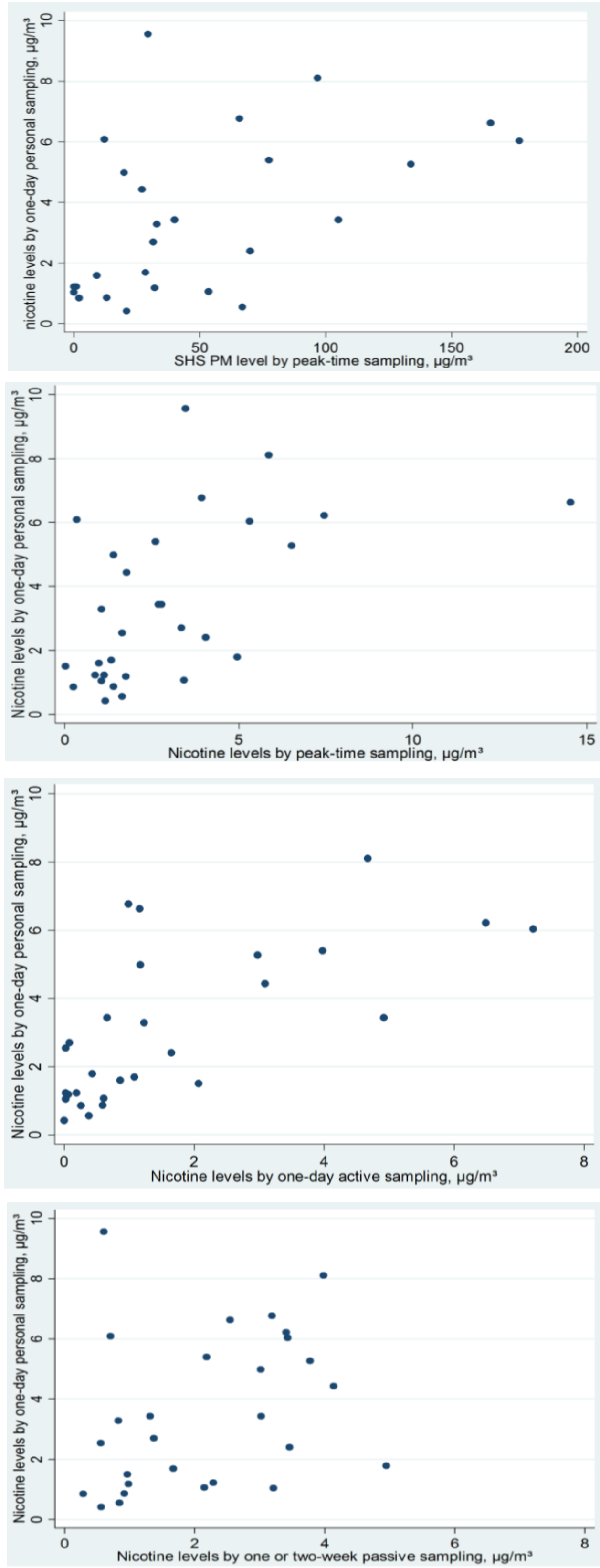


Figure 2.11 Scatter plots of different area samplings with personal airborne nicotine sampling, Beijing, 2010

2.3.7 Continuous monitoring

2.3.7.1 Restaurant 1

The temperature in restaurant 1 ranged from 26 °to 30°C, with an average of 28° C during the sampling time from 08/09/10 10:30 to 08/10/10; the relative humidity (RH) ranged from 41% to 71%, with an average of 59%. Sampling at location 1 of the restaurant failed and sampling at location 2 and location 3 was shown in Figure 2.12. The restaurant was open at 10:00 and closed at 22:00 or when the last customer left, whenever was later. The peak patronage time began around 11:30 and ended around 14:30 at lunch and began around 18:00 and ended about 21:00 at dinner. The average patronage was 15.2 during the lunch peak time and 14.6 during the dinner peak time, with average of observed smokers of 0.8 and 0.6, respectively (Figure 2.13). During dinner time, many patrons were observed eating right outside of the restaurants.

Nicotine concentration by sequential sampling was 1.2 and 0.8 μg/m^3 at location 2 and location 3, respectively, in the hour before the lunch peak time; it rose to about 3 to 12 times higher during the lunch peak time, then decreased to about 1.5 μg/m^3 at both locations and increased up to five times at location 2 and more than three times at location 3 during the dinner peak time, after which it decreased to less than 1.0 μg/m^3 overnight at both locations (Table 2.12 and Figure 2.14). The time weighted average (TWA) nicotine concentrations during lunch and dinner peak time (5.7 μg/m^3 at location2 and 5.5 μg/m^3 at location3) were three to four times that of TWA concentrations during other day times (1.7 μg/m^3 at location 2 and 1.2 μg/m^3 at location 3) at both locations and the concentrations during operating hours (from 10:15 to 22:00) were about four to five times of those overnight (from 22:00 to 9:30) at both locations. TWA nicotine levels by eight sequential area samplers from 10:15 to 22:00 were more than 1.5 times of TWA nicotine level by work-day area nicotine sampling (with one sampler) from 11:00 to 21:30 at location 3. Personal airborne nicotine sampling from 10:50 to 21:40 showed very similar exposure of the three volunteer servers, which ranged from 1.4 to 1.8 μg/m^3. Probably because servers needed to serve outdoor patrons during dinner time, nicotine levels by personal airborne sampling were slightly lower than that by work-day active area nicotine sampling, which was conducted indoor for almost the same period of time, and they were about half of the concentration by sequential sampling of the same time period. Two-week TWA nicotine concentration by passive sampling (1.0 μg/m^3) was about half of the 23-hour (8/9/10 10:15 - 8/10/10 9:30) TWA concentration. Although there might be up to three times' difference in nicotine concentrations by any two parallel sequential sampling at the two locations, the TWA concentrations over longer time, such as over peak times and during the day time, were quite similar at the two locations.

$PM_{2.5}$ measurements during the whole day were available at location 3 only, and its change pattern was quite similar to the changes of nicotine concentration at location 3, except that it remained about half of the dinner time concentration (about 400 μg/m^3) overnight (215 μg/m^3) (Table 2.12 and Figure 2.14). CO_2 concentration was about 500 ppm in the morning, went up to 1100 ppm during lunch peak time, then decreased to 500 ppm. It then increased up to 1800 ppm during the dinner peak time and remained around 500 ppm overnight (Figure 2.15).

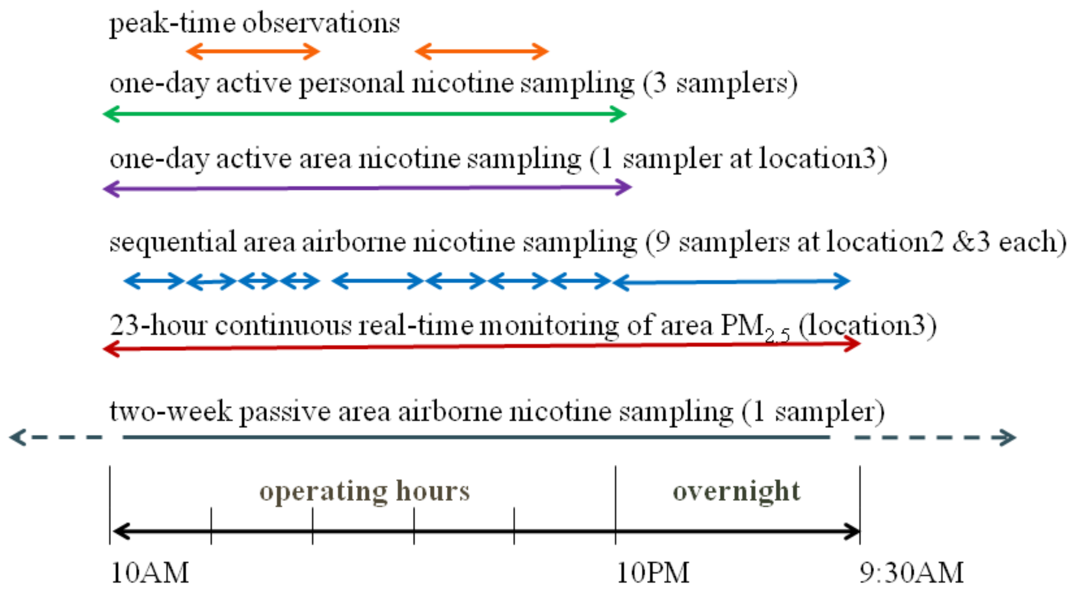


Figure 2.12 SHS sampling conducted in Restaurant 1, Beijing, 2010

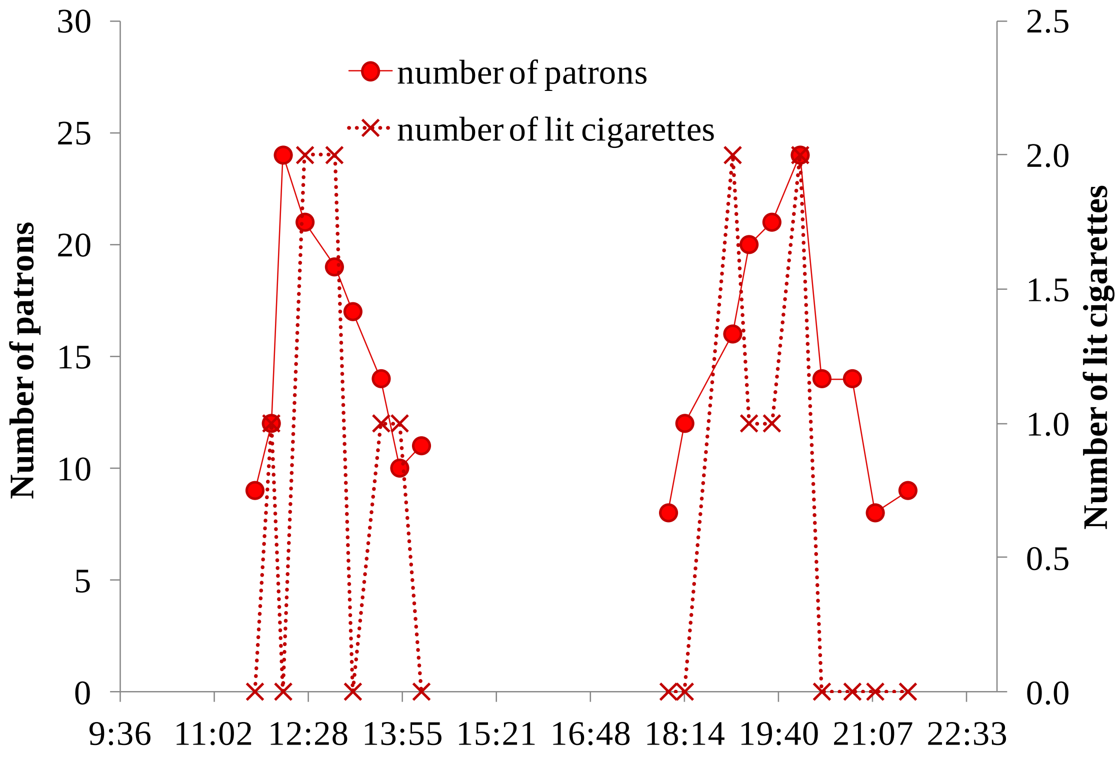


Figure 2.13 Observed numbers of patrons and lit cigarettes during peak patronage time in Restaurant 1

Table 2.12 Results of nicotine and SHS PM sampling in Restaurant 1, Beijing, 2010

Start Time	End Time	location 2		location 3	
		nicotine	SHS PM	nicotine	SHS PM
sequential/real time sampling					
8/9/10 10:15	8/9/10 11:25	1.2	0	0.8	0
8/9/10 11:25	8/9/10 12:30	7.2	198	2.7	199
8/9/10 12:30	8/9/10 13:30	4.9	--	7.4	419
8/9/10 13:30	8/9/10 14:30	7.7	--	10.8	713
8/9/10 14:30	8/9/10 18:00	1.6	--	1.5	119
8/9/10 18:00	8/9/10 19:50	2.8	--	4.1	449
8/9/10 19:50	8/9/10 21:00	8.4	--	3.6	418
8/9/10 21:00	8/9/10 22:00	2.6	--	0.7	249
8/9/10 22:00	8/10/10 9:30	0.9	--	0.7	215
Peak-time TWA		5.8		5.5	439
Other day-time TWA		1.7		1.2	119
Day-time TWA 8/9/10 10:15 -22:00		3.8	--	3.4	284
24-hr TWA 8/9 9:30 -8/10/10 9:30 [a]		2.4	--	2.0	242
one-day area nicotine sampling					
8/9/10 11:00	8/9/10 21:30	--	--	2.0	284
one-day personal nicotine sampling					
8/9/10 10:50	8/10/10 20:10	1.6			
8/9/10 10:50	8/10/10 20:10	1.8			
8/9/10 10:50	8/10/10 21:40	1.4			
two-week passive nicotine sampling					
7/28/10 16:00	7/28/10 17:00	1.0			

Note: TWA: time weighted average
[a]: the average concentrations of both nicotine and $PM_{2.5}$ from 8/9 9:30-10:15 were assumed the same as those from 8/9 10:15-11:25;
light shade indicates sampling during lunch and dinner peak time;
dark shade indicates sampling during night.

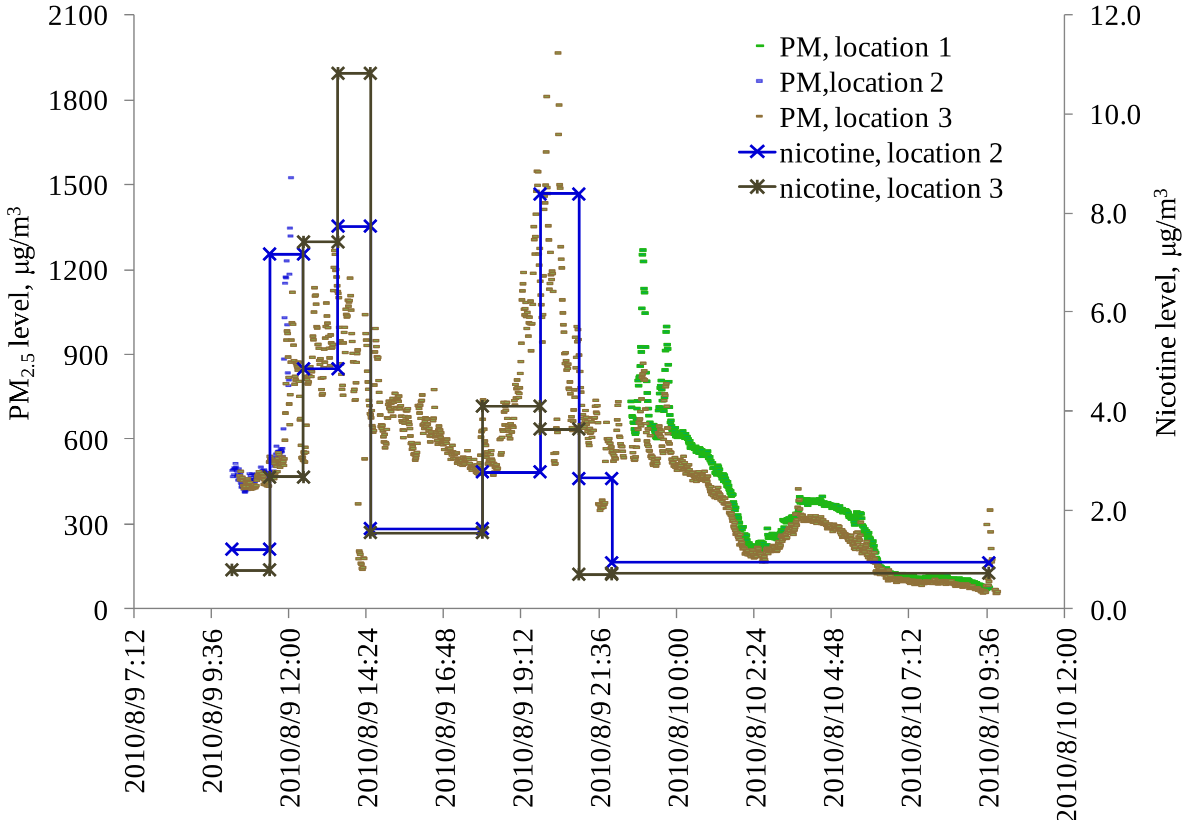


Figure 2.14 $PM_{2.5}$ (unadjusted) and sequential nicotine sampling results in Restaurant 1, Beijing, China, 2010

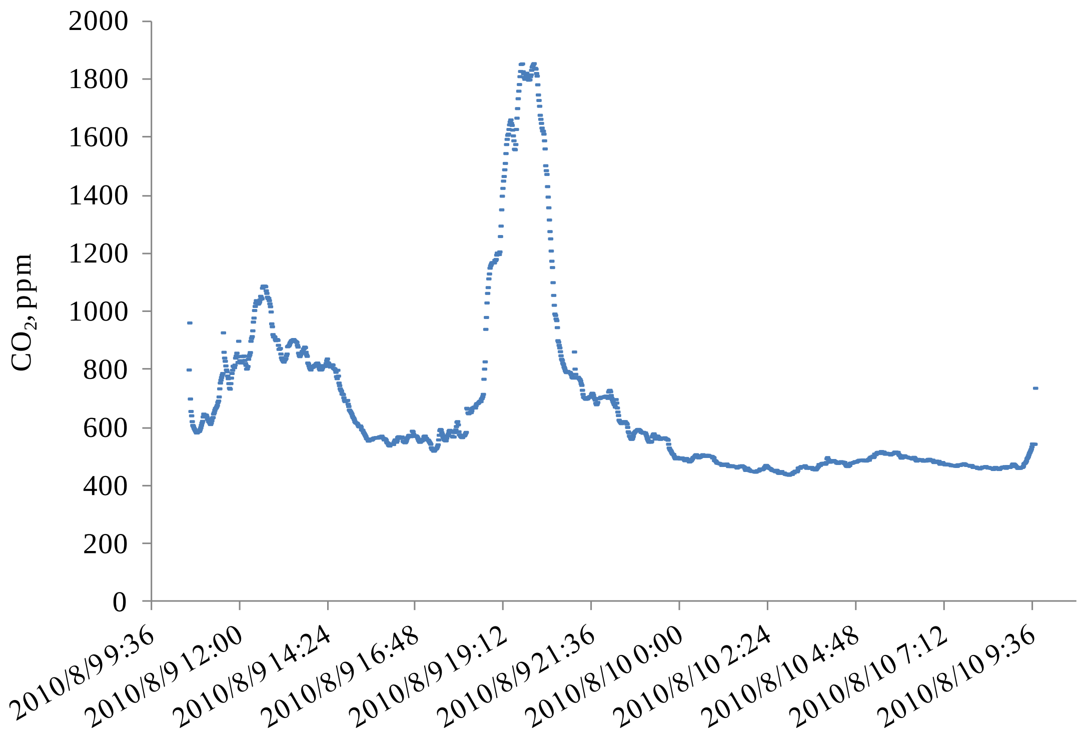


Figure 2.15 CO_2 (unadjusted) results at location 3 in restaurant 1, Beijing, China, 2010

2.3.7.2 Restaurant 2

The temperature in restaurant 2 ranged from 26 to 30°C, with an average of 28°C during the sampling time from 08/08/10 22:00 to 08/10/11 10:00; the relative humidity ranged from 40% to 69%, with an average of 57%. All the sampling conducted was shown in Figure 2.16. The restaurant was open at 11:00 and closed at 22:00 or when the last customer left, whenever was later. Two staff were observed smoking after the restaurant was closed to the public around 22:00 in the designated nonsmoking section when the overnight sampling was set up at the first night, and staff smoking was also observed the following morning around 10:30 when the staff were having their breakfast in the venue. However, it was unknown how many cigarettes had been smoked by then. In the designated nonsmoking section, the average patronage was 42 during the lunch peak patronage times from 12:00 to 14:00 and 35 during dinner peak time from 18:00 to 21:00, with average observed smokers of 0 and 0.5, respectively; while in the designated smoking section, the average patronage was 15 during lunch peak time and 22 during dinner peak time, with average observed smokers of 0.9 and 2.7, respectively (Figure 2.17).

Generally speaking, nicotine concentrations as measured by sequential sampling and SHS PM concentrations were higher during dinner peak time than during lunch peak time and higher during the two peak times than in other times at all four locations, except that the concentrations as measured in the first overnight sampling (8/8 21:30 – 8/9/10 11:00) were higher than or very close (SHS PM at location 1) to the concentrations during the lunch peak time and that SHS PM and airborne nicotine remained high after the diner peak time and in the second night in the designated smoking section. Similar to the sampling results in Restaurant 1, although SHS concentrations can differ up to 13 times between any set of parallel sequential nicotine sampling or SHS PM sampling, the TWA concentrations over longer time, such as over peak time, other day time, the whole working day or during 24 hours, were quite close to each other at all the four locations, though they were slightly higher at the two locations of the designated smoking section (Table 2.13 and Figure 2.18-19).

TWA nicotine concentrations by sequential area sampling during peak time were about two to four times of those during other day times, about 1.5 times of those during the whole working day from 11:00 to 22:00, and similar to those during 24 hour periods, including the 1st sampling night, but were 1.5–2.5 times of those during 24 hours including the 2nd sampling night. Work-day TWA concentrations by eight sequential area nicotine samplers at each location were two to three times as of concentrations found in the one-day active area sampling (one sampler at each section from 11:00 to 21:30) (Table 2.12). The two-week TWA concentrations by passive area nicotine sampling were similar to the day time concentration by work-day active area sampling while lower than the 24-hour TWA concentrations by sequential area sampling (Table 2.13). CO_2 concentrations at the four different locations showed quite similar results (Figure 2.20).

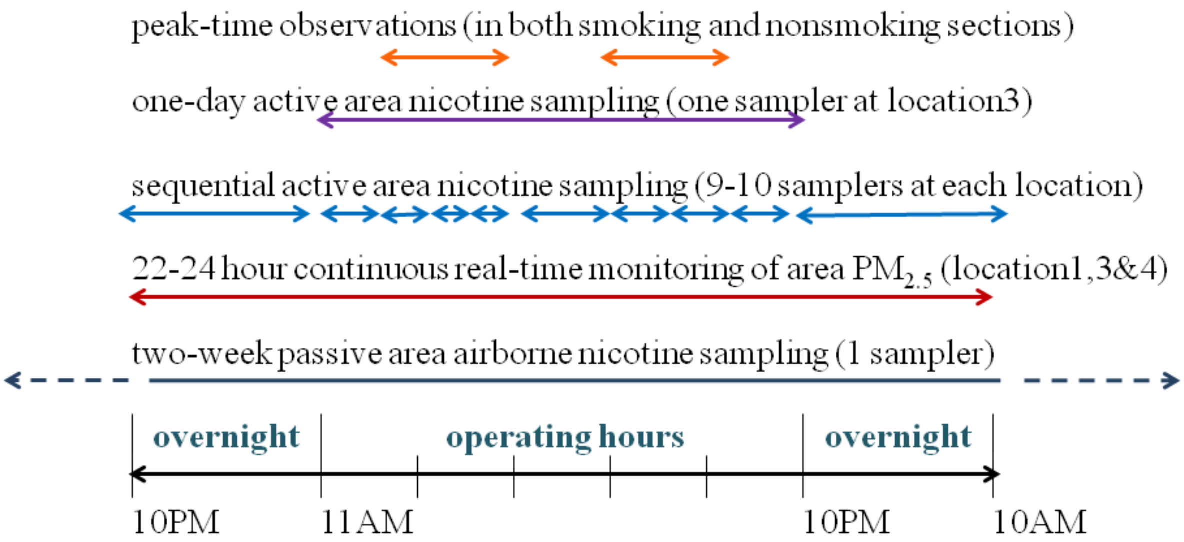


Figure 2.16 SHS sampling in Restaurant 2, Beijing, China, 2010

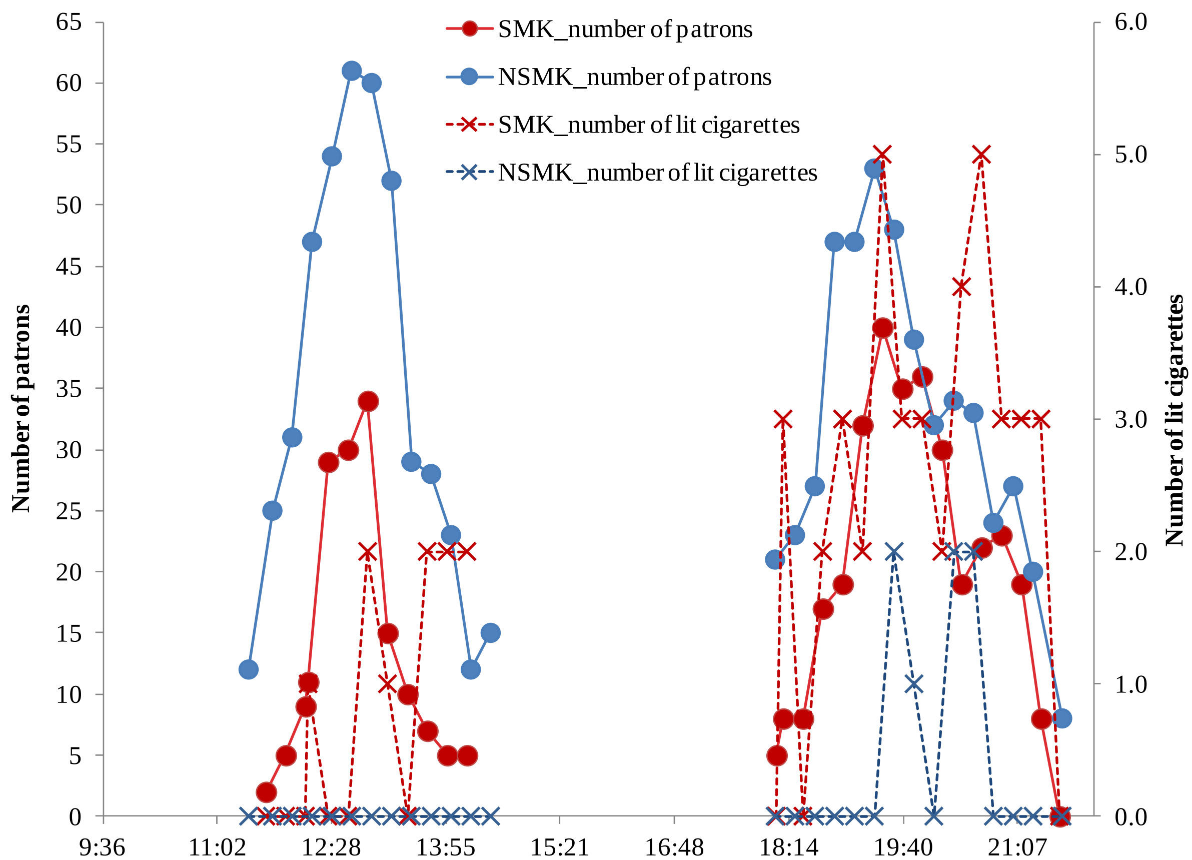


Figure 2.17 Observed number of patrons and lit cigarettes during peak patronage time in Restaurant 2, Beijing, China, 2010

Note: SMK: nominal smoking section; NSMK: nominal nonsmoking section

Table 2.13 Results of nicotine and SHS PM sampling in Restaurant 2, Beijing, 2010

Start Time	End Time	Designated nonsmoking section				Designated smoking section			
		location 1		location 2		location 3		location 4	
		nicotine	SHS PM	nicotine	SHS PM	nicotine	SHS PM	nicotine	SHS PM
sequential/real time sampling									
8/8/10 22:00	8/9/10 11:00	2.8	26	3.0	--	3.7	--	2.1	--
8/9/10 11:00	8/9/10 12:00	0.2	10	0.4	--	0.6	--	2.6	0
8/9/10 12:00	8/9/10 13:10	1.9	26	1.1	--	2.6	0	1.1	0
8/9/10 13:10	8/9/10 14:10	1.0	27	0.6	--	3.0	11	2.0	7
8/9/10 14:10	8/9/10 18:00	0.7	24	0.5	--	1.1	0	0.6	7
8/9/10 18:00	8/9/10 19:10	0.5	35	1.8	--	1.6	53	0.1	43
8/9/10 19:10	8/9/10 20:10	3.5	130	5.8	--	2.2	150	6.1	160
8/9/10 20:10	8/9/10 21:10	5.4	116	3.0	--	3.9	176	7.9	183
8/9/10 21:10	8/9/10 22:00	0.8	140	4.0	--	2.9	182	4.2	186
8/9/10 22:00	8/10/10 10:00	0.7	--	--	--	1.41	68	1.57	72
Peak-time TWA		2.4	66	2.4		2.6	76	3.3	76
Other day-time TWA		0.6	35	0.9		1.3	--	1.4	28
Day-time TWA 8/9/10 11:00 -8/9/10 22:00		1.5	49	1.6	--	1.9	--	2.3	51
24-hr TWA 8/8 22:00 -8/09/10 22:00		2.2	36	2.3	--	2.9	--	2.2	--
8/9 10:00 -8/10/10 10:00 [a]		1.0	--	--	--	1.6	56	2.0	60
one-day area sampling									
8/9/10 11:00	8/9/10 21:30	0.5	49	0.6	--	--	--	1.0	51
two-week passive nicotine sampling									
7/28/10 16:00	7/28/10 17:00	0.5				0.9			

Note: TWA: time weighted average

[a]: the average nicotine concentration from 8/9/10 10:00-11:00 was assumed to be the same as the average concentration from 8/9/10 11:00-12:00; the average $PM_{2.5}$ concentration at both location 3 and 4 from 8/9/10 10:00-12:00 was assumed to be 0;

light shade indicates sampling during lunch and dinner peak time;

dark shade indicates sampling during night.

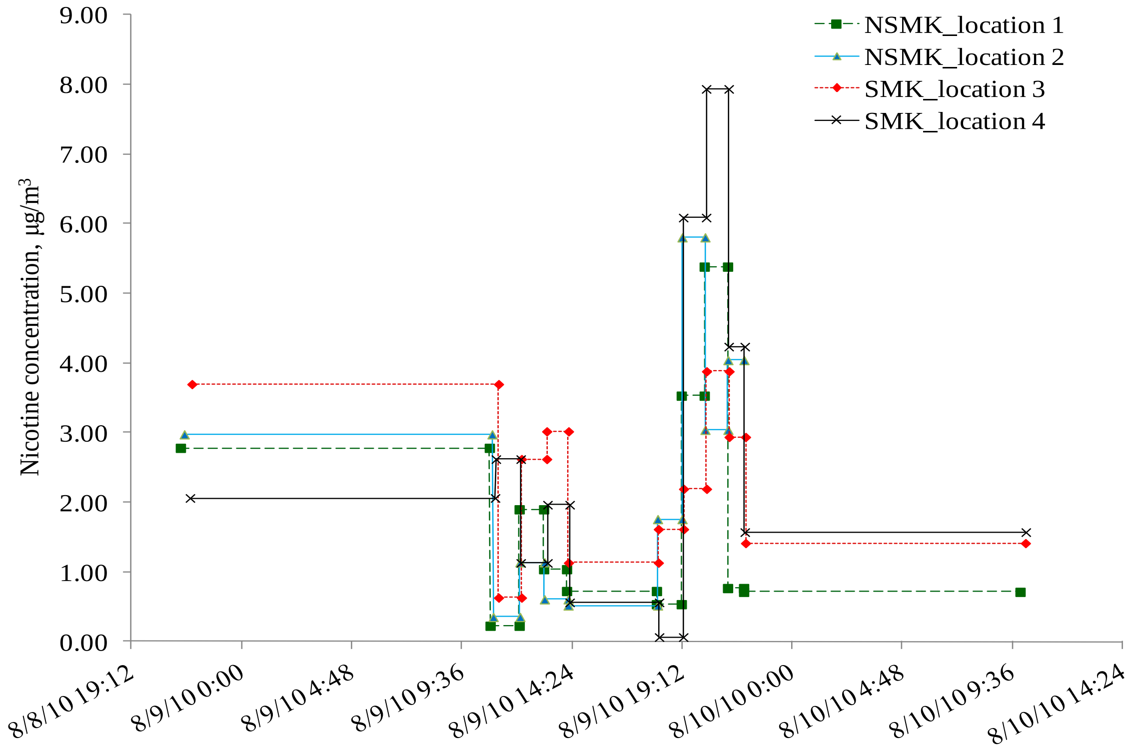


Figure 2.18 Sequential Nicotine sampling results at four locations of Restaurant 2, Beijing, China
Note: SMK: nominal smoking section; NSMK: nominal nonsmoking section

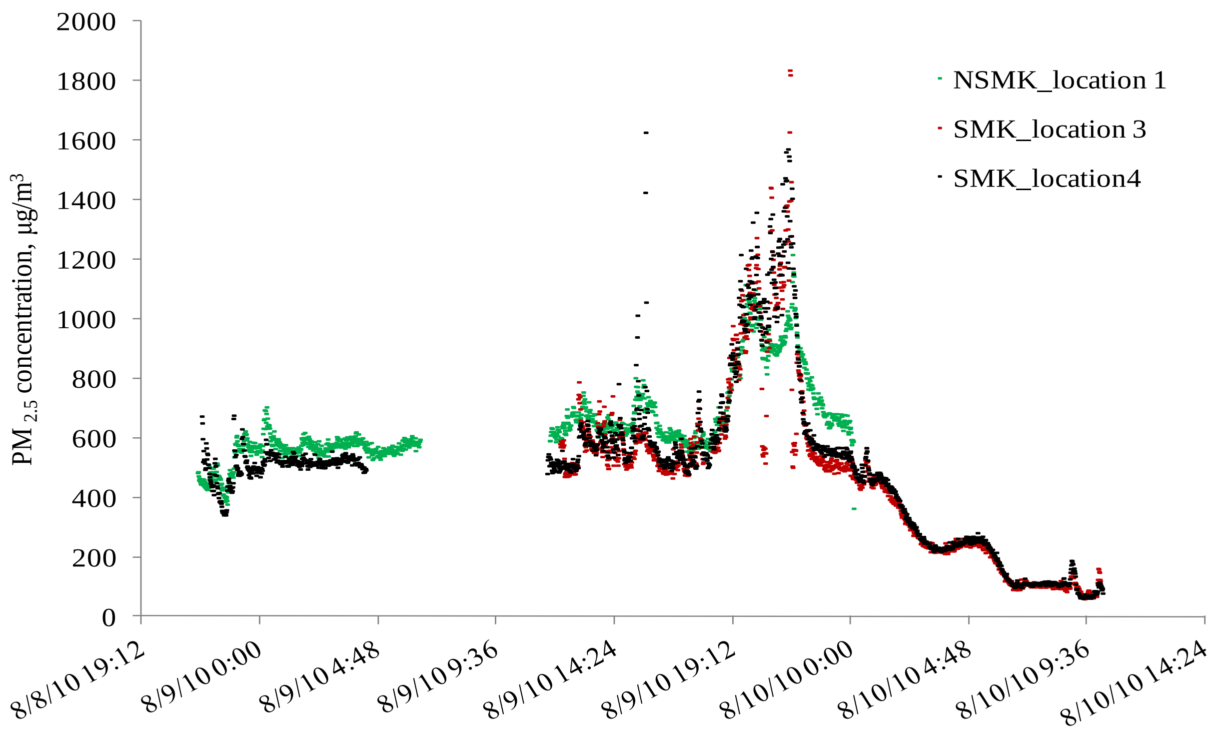


Figure 2.19 Real time sampling of $PM_{2.5}$ (unadjusted of outdoor levels) at three locations of Restaurant 2, Beijing, China, 2010
Note: SMK: nominal smoking section; NSMK: nominal nonsmoking section

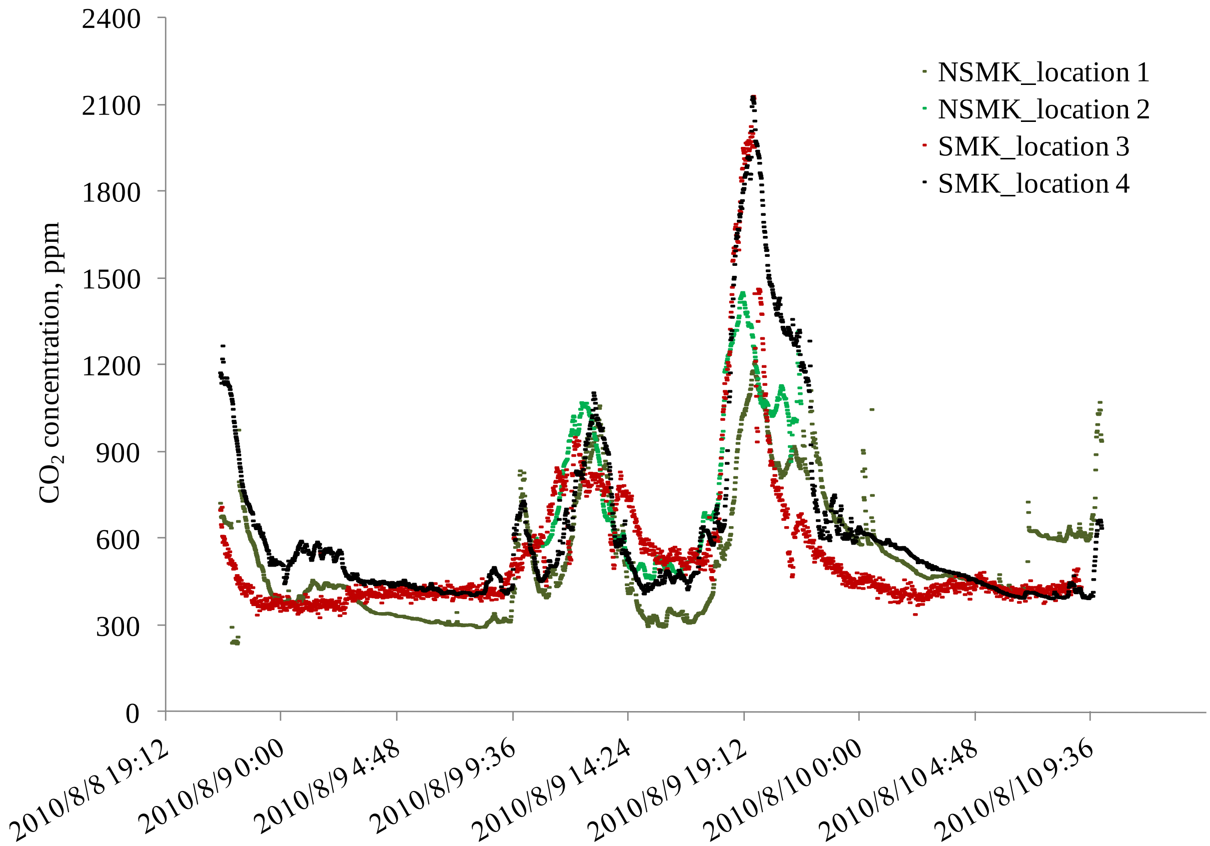


Figure 2.20 Real time sampling of CO_2 at four locations of Restaurant 2, Beijing, China
Note: SMK: nominal smoking section; NSMK: nominal nonsmoking section

2.4 Discussion

2.4.1 Implementation of the 2008 Beijing Governmental Smoking Restriction in 2010

The 2008 Beijing governmental smoking restriction requires large restaurants to designate no less than 50% of their dining area as nonsmoking. However, it does not define “large” and does not include bars. For the 79 venues included in this study, larger venues were more likely to nominally prohibit or restrict smoking; however, about 10% (eight of 79) venues with dining areas larger than 100m^2 were observed to allow smoking. In addition, there are no specifications on how the designated smoking sections and nonsmoking sections should be separated: about 70% (nine of 14) the venues restricting smoking in this study did not have full walls between the two sections. These two aspects only indicate that the 2008 Beijing governmental smoking restriction is not enforceable. Furthermore, it does not provide universal protection to servers and patrons because of the exemption of small venues or bars.

The implementation of the governmental restriction was poor. Thirty seven of the 79 venues nominally prohibited smoking according to investigators’ observation, while only 23 venues were reported to be smoke-free by staff, indicating that staff of around one third of the venues nominally prohibiting smoking didn’t know about or intentionally ignored the smoking policy. The median percentage of designated nonsmoking sections of the total dining areas of venues restricting smoking was lower than the 50% required by the restriction. Though 56% of the 62 restaurants visited in this study nominally prohibited smoking and 18% nominally restricted smoking to designated smoking sections, smoking was commonly observed during field visits while interventions to stop smoking was observed during only one of the 101 restaurant visits. Furthermore, ashtrays were either observed or were provided per request in many of these nominal nonsmoking venues/sections. Larger percentages of patrons were observed smoking in nominal nonsmoking venues than in nonsmoking 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 nonsmoking signs in nonsmoking 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 nonsmoking venues than in nonsmoking sections. A complete evaluation of the Beijing smoking policy is presented in Chapter 4.

2.4.2 SHS Exposure in Restaurants and Bars in Beijing Compared to Other Countries/Regions

Consistent with other studies, SHS exposure levels in venues with smoking observed were significantly higher than in venues without smoking observed (Hyland, Travers et al. 2008; Agbenyikey, Wellington et al. 2011). The median of peak-patronage-time SHS PM concentrations reported in this study was lower than concentrations reported in most other studies worldwide for both restaurants and bars by different smoking policies, except that it was comparable to those reported for nonsmoking restaurants and higher for nonsmoking bars. (Figure 2.21). Similarly for airborne nicotine, the median of week-long time-weighted-average levels was lower in smoking venues than those reported in most other countries (Jane, Nebot et al. 2002; Navas-Acien, Peruga et al. 2004; Mulcahy, Evans et al. 2005; Gorini, Moshammer et al. 2008; Lopez, Nebot et al. 2008; Nebot, Lopez et al. 2009; Barnoya, Arvizu et al. 2011; Ochir, Shahrir et al. 2011; Jones, Wipfli et al. 2012) but they were higher in both nonsmoking restaurants and bars than those reported in other countries (Gorini, Moshammer et al. 2008; Lopez, Nebot et al. 2008; Nebot, Lopez et al. 2009; Barnoya, Arvizu et al. 2011; Lopez, Burhoo et al. 2011; Jones, Wipfli et al. 2012) (Figure 2.22). This is not a surprise given that the Beijing governmental smoking restriction was poorly enforced.

2.4.3 Simultaneous Monitoring of SHS Exposure in Designated Smoking Sections and Nonsmoking Sections

The median of ratios of nonsmoking-section SHS concentration to smoking-section SHS concentration by simultaneous sampling was 0.69 for SHS PM and 0.31 for airborne nicotine. This result was comparable to those previously reported in the literature. Six studies which also conducted simultaneous measurements of SHS PM in designated smoking and nonsmoking sections in restaurants or clubs showed that SHS PM levels in designated nonsmoking sections were 28% to 78% of the levels in designated smoking sections (Lambert, Samet et al. 1993; Akbar-Khanzadeh 2003; Bohanan, Piade et al. 2003; Carrington, Watson et al. 2003; Cains, Cannata et al. 2004; Huss, Kooijman et al. 2010) and another ten studies showed that this ratio ranges from 3% to 109% for airborne nicotine (Lambert, Samet et al. 1993; Jane, Nebot et al. 2002; Akbar-Khanzadeh 2003; Bohanan, Piade et al. 2003; Carrington, Watson et al. 2003; Cains, Cannata et al. 2004; Moshammer, Neuberger et al. 2004; Navas-Acien, Peruga et al. 2004; Kuusimaki, Peltonen et al. 2007; Schneider, Seibold et al. 2008). The difference between the ratios for airborne nicotine and for SHS PM may be attributed to other sources of indoor PM.

The ratios also differed by extents of separation between smoking and nonsmoking sections, with the ratios highest in venues with no separation between the two sections and lowest in venues with separate rooms or floors as smoking sections. However, nonsmoking-section SHS levels were still 11% of smoking-section levels in venues with complete separation between the two sections. Intensive continuous monitoring in Restaurant 2, which did not separate its two sections without any walls, showed that both airborne nicotine and SHS PM concentrations in the nonsmoking section were almost the same as in the smoking section. For airborne nicotine concentration based on longer time sampling, e.g. one-day area sampling and week-long passive area sampling, non-significant differences existed between designated smoking sections and nonsmoking sections, which may be due to the diffusion of SHS from designated smoking sections to nonsmoking sections over the sampling time.

According to WHO and the Surgeon General Report in 2006, 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). Obviously, results from this study strongly support the point made by WHO FCTC that the use of designated smoking areas (whether with separate ventilation systems or not) is ineffective in eliminating SHS exposure (WHO 2007).

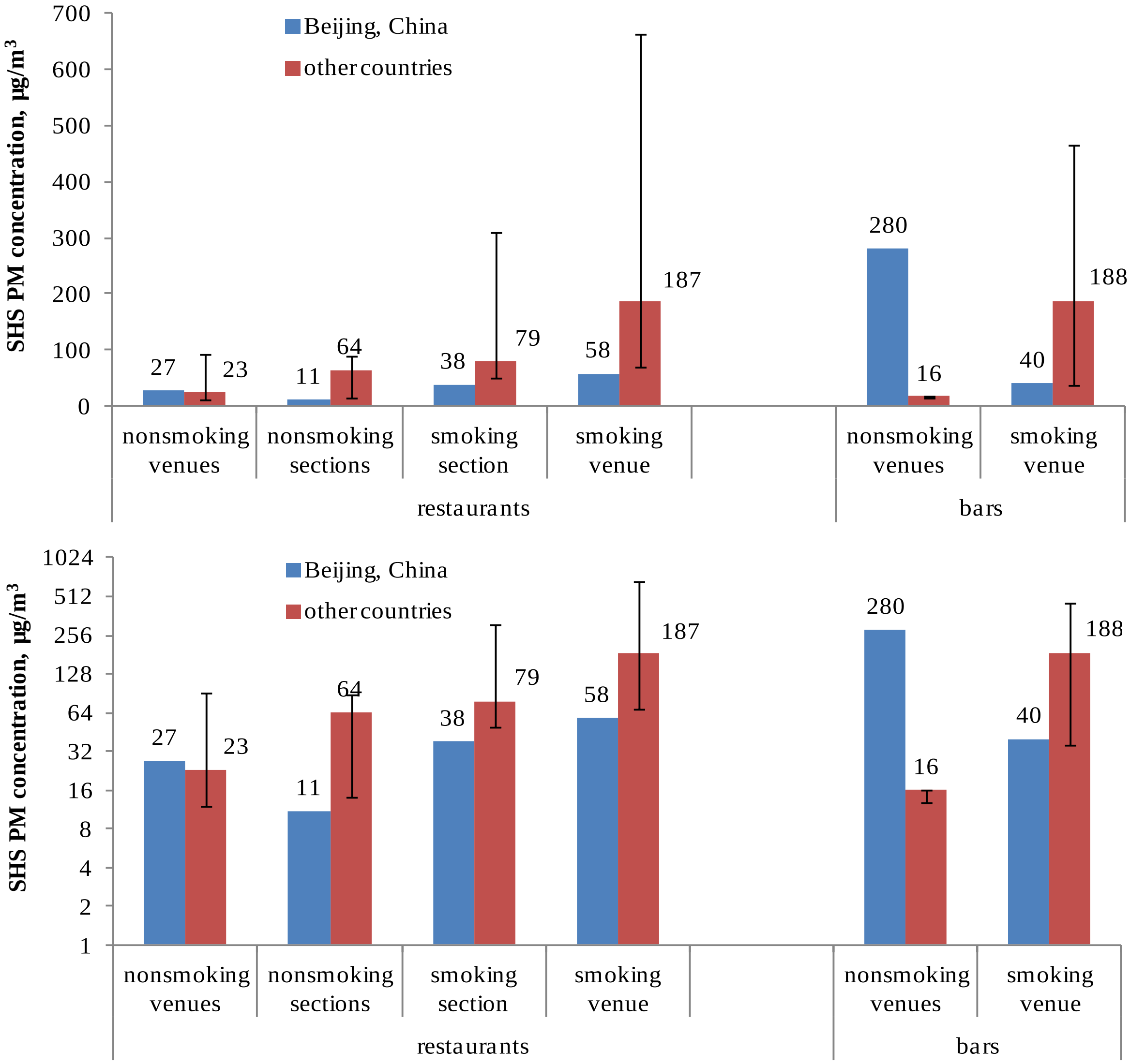


Figure 2.21 Comparison of median SHS PM concentrations reported in this study and median of aggregated concentrations reported in other countries by smoking policies (upper panel: original scale; lower panel: log scale)

Note:1) error bars indicate the maximal and minimal aggregated concentrations, respectively, reported by studies reviewed; Only two bars/cafes of the 17 bars included in this study banned smoking, thus the concentration of 280 µg/m^3 was the median of measurements in those two bars/cafes only.

2) Data were reported by 11 studies for smoking restaurants (Alfaro 1997; Brauer and Mannetje 1998; Branis, Rezacova et al. 2002; Carrington, Watson et al. 2003; Travers 2008; Proescholdbell, Steiner et al. 2009; Huss, Kooijman et al. 2010; Agbenyikey, Wellington et al. 2011; Gleich, Mons et al. 2011; Lai, Hedley et al. 2011; Zaidi, Moin et al. 2011), by six studies for restaurant designated smoking sections (Lambert, Samet et al. 1993; Akbar-Khanzadeh 2003; Carrington, Watson et al. 2003; Vardavas, Kondilis et al. 2007; Proescholdbell, Steiner et al. 2009; Huss, Kooijman et al. 2010), by five studies for restaurant designated nonsmoking sections(Lambert, Samet et al. 1993; Brauer and Mannetje 1998; Akbar-Khanzadeh 2003; Carrington, Watson et al. 2003; Huss, Kooijman et al. 2010) and by 10 studies for nonsmoking restaurants (Alfaro 1997; Brauer and Mannetje 1998; Wilson, Edwards et al. 2007; Travers 2008; Proescholdbell, Steiner et al. 2009; Huss, Kooijman et al. 2010; Agbenyikey, Wellington et al. 2011; Lai, Hedley et al. 2011; Lopez, Burhoo et al. 2011; Zaidi, Moin et al. 2011); data for smoking bars were reported by 19 studies (Siegel 1993; Maskarinec, Jenkins et al. 2000; Gee, Watson et al. 2005; Ellingsen, Fladseth et al. 2006; Repace, Hughes et al. 2006; Goodman, Agnew et al. 2007; Valente, Forastiere et al. 2007; Vardavas, Kondilis et al. 2007; Waring and Siegel 2007; Bolte, Heitmann et al. 2008; Lee, Hahn et al. 2008; Schneider, Seibold et al. 2008; Travers 2008; Brennan, Cameron et al. 2010; Daly, Schmid et al. 2010; Lee, Lim et al. 2010; Semple, van Tongeren et al. 2010; Gleich, Mons et al. 2011; Rosen, Zucker et al. 2011) and for nonsmoking bars by three studies (Wilson, Edwards et al. 2007; Travers 2008; Lopez, Burhoo et al. 2011).

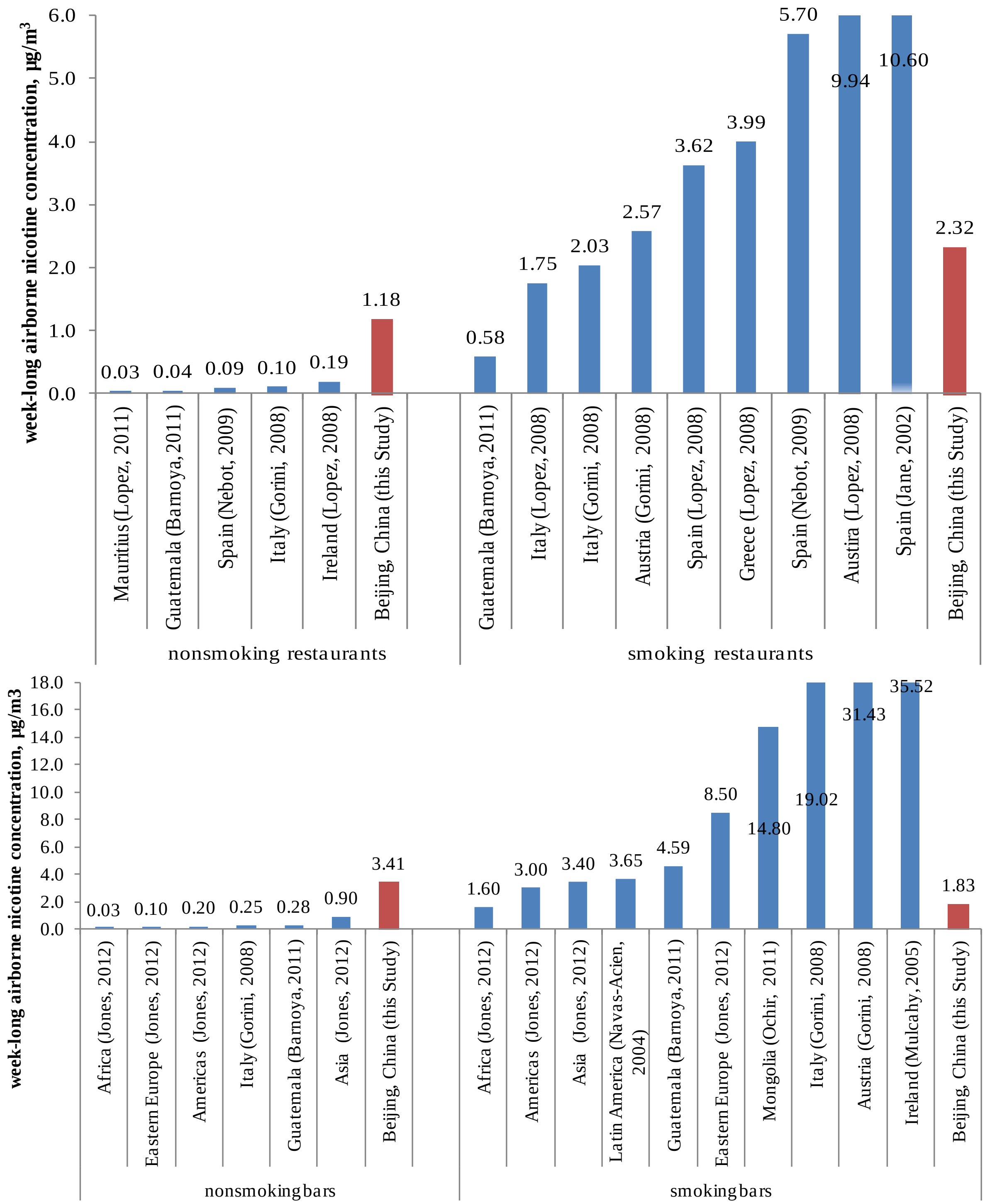


Figure 2.22 Comparison of week-long airborne nicotine levels by passive area sampling in restaurants and bars in Beijing to those reported in the literature

Note: two bars/cafes of the 17 bars included in this study banned smoking, and passive area nicotine sampling was conducted in one of the two bar/cafes only, thus the concentration of 3.41 $\mu g/m^3$ was measured in one bar only.

2.4.4 Profiles of SHS Exposure by Restaurant and Bar Servers and Patrons

Because there are peak patronage times in restaurants and bars, in venues not restricting smoking, SHS concentrations are higher during these peak times due to higher smoking activity. Continuous monitoring in two restaurants in this study showed obvious spikes of number of patrons, number of lit cigarettes and concentrations of indoor $PM_{2.5}$ and airborne nicotine during lunch and dinner time periods. Though the time-weighted average concentration of airborne nicotine during dinner peak time was lower than during lunch peak time in Restaurant 1 and higher in Restaurant 2, monitoring during both lunch and dinner peak times in the same 31 venues or sections showed no significant differences for active smoker density (ASD), airborne nicotine or $PM_{2.5}$ concentration during these two peak patronage times. SHS concentrations were usually lower during intervals between patronage peak times and overnight. However, in Restaurant 2 SHS concentrations during the two nights of monitoring were comparable to those during peak patronage times, which was probably due to smoking by staff in the evenings after the restaurant was closed to the public or in the early mornings before it was open to the public, as observed by field investigators. The study was conducted in a summer from late July to August; thus, the seasonal changes of SHS concentrations in restaurants and bars are unknown.

Continuous monitoring of SHS exposure for more than 20 hours in two restaurants showed that, although nicotine concentrations at different locations may be quite different in a short time period, for example, one hour, TWA concentrations over longer times, such as over the whole peak time and the whole working day time, are quite similar. Passive area nicotine sampling at two different locations of each of the 42 venues/sections sampled also showed that the absolute differences of higher concentrations to low concentrations was close to 0 $\mu g/m^3$ and the ratios of higher to lower concentrations were close to 1.0. These results indicate that it is reasonable to assume a well mixed space for relatively longer time.

In aspects of a patron's exposure during his/her visit to a restaurant or bar, his/her exposure could be either under estimated or overestimated by a short time sampling result, depending on when the sampling starts and how long it lasts, thus a single snapshot of SHS exposure during peak time may not be good enough to capture a patron's exposure during a visit. However, for the patron population, aggregated results of short-time sampling starting at different time during peak patronage times may be good enough to capture the general exposure by this population.

2.4.5 Comparison of Different Sampling Approaches

2.4.5.1 Relationships between active smoking density, airborne nicotine and $PM_{2.5}$

Indoor SHS concentration depends on the volume of the space and the rate of generation and removal. Observed active smoker density (number of active smokers per $100m^3$, ASD) gives information on both the space volume and SHS generation rate. Regression analysis showed that both measured SHS PM and airborne nicotine concentrations were significantly related to ASD; ASD could explain 29% of the variance of the difference of indoor and outdoor $PM_{2.5}$ concentrations and 40% of the variance of airborne nicotine concentrations, indicating that both $PM_{2.5}$ and airborne nicotine are sensitive to SHS while airborne 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.

The U.S. Surgeon General Report in 2006 on involuntary smoking reviewed four studies published before 1999 and found that the slopes for the increase of respirable particulate matter (RPM) concentration with nicotine concentration ranged from 8.6 to 10.9 μg/m^3 of RPM per one μg/m^3 of nicotine (Leaderer and Hammond 1991; USDHHS 2006), based on parallel area sampling of RPM and airborne nicotine in homes, office and other workplaces, and on parallel mobile personal sampling. A more recent study reported a slope of 7.1 μg/m^3 of total dust per one μg/m^3 of nicotine (Ellingsen, Fladseth et al. 2006). This study found a slope of 17 μg/m^3 of $PM_{2.5}$ per one μg/m^3 of nicotine, higher than slopes reported in literature. It is probably due to different emission rates of nicotine and $PM_{2.5}$ from cigarettes in China compared to those in other countries.

2.4.5.2 Relationships among different area nicotine sampling approaches

Though the sampling time periods were quite different for the three area nicotine sampling approaches, their results were significantly related to each other. One-hour peak-time area nicotine sampling results could explain about half of the variance of the results by one-day active area sampling or by week-long passive area sampling, and one-day active area nicotine sampling could explain 23% of variance of week-long passive area nicotine sampling results. As expected, one-hour peak-time nicotine sampling results tended to over-estimate one-day area sampling results (by two times) and week-long passive area nicotine sampling results (by 1.6 times), while contrary to what is expected, one-day active nicotine sampling results were lower than week-long nicotine sampling results (the median [IQR] of ratios: 0.6 [0.1-1.6]), though the absolute differences (mean [SD]: -0.24 [1.93]) was not significant. One possible reason might be that nicotine was adsorbed from surfaces during nights. However, it is unlikely that the resulting air nicotine concentration due to adsorption can exceed the day-time nicotine concentrations, which are resulted directly from cigarette smoking, which can be supported by the overnight nicotine sampling results in Restaurant 1 and by the second overnight nicotine sampling in Restaurant 2. Another reason might be due to staff smoking beyond venue operating hours, as shown by the first overnight observation and nicotine sampling results in Restaurant 2. The big difference of sampling time (operation hours on one working day versus one or two weeks) might also be a reason causing the discrepancy of the relationship with what is expected.

2.4.5.3 Area sampling and personal sampling

Airborne nicotine concentrations estimated by one-day personal air nicotine sampling and one-day area active sampling, conducted almost simultaneously, were significantly related, consistent with findings from other studies (Jenkins and Counts 1999; Ellingsen, Fladseth et al. 2006); as expected, area sampling results tended to underestimate personal sampling results because servers needed to move around and might have frequent near-field exposure when serving tables with active smokers.

One-day personal air nicotine sampling results were also significantly related to one-hour peak-time area sampling results of either SHS PM or airborne nicotine, this was also not surprising because servers' exposure to SHS at work mostly happened during peak patronage time. The high intercepts (about 2 μg/m^3) of regression analyses of each area sampling and personal sampling could be attributed to servers' frequent near-field exposure to SHS when they served tables with active smoking patrons.

As for week-long passive sampling and one-day personal sampling, because of the difference in both the sampling time and sampling approach (area and personal) and great variances of SHS concentrations on different days, it is not surprising that their results were not significantly related to each other. Week-long personal sampling conducted exclusively during working hours is needed to examine whether week-long passive sampling, including overnight sampling, can be used to estimate servers' week-long SHS exposure at work. However, this may be much more challenging to conduct than one-day personal sampling.

Peak-time area nicotine sampling results could also be used to estimate patrons' exposure because the sampling was conducted in dining areas where investigators seated themselves and patrons usually do not move so much in dining restaurants and no-dancing bars/cafés. However, patrons who sit with smokers on the same tables (near field to sources) or who move a lot might have higher exposure than that estimated by peak-time area sampling because sampling was always conducted in nonsmoking tables (far field to sources). In recent years short-time sampling (about 30 minutes) of $PM_{2.5}$ during peak patronage time has been frequently conducted to estimate SHS exposure in restaurants and bars due to the availability of sampling devices and technical supports (Hyland, Travers et al. 2008; Travers 2008). Since peak-time area SHS PM sampling results were significantly related to peak-time area nicotine sampling results and to one-day personal nicotine sampling results, peak-time sampling of indoor and outdoor (as background) $PM_{2.5}$ can be used to proximate both patrons' and servers' exposure to SHS, especially when nicotine sampling and/or laboratory analyses are not available due to cost or technical issues.

Considering the accuracy, simplicity (sampling permission, requirement of sampling devices involvement of human subjects and attendance of investigators) and cost of different sampling approaches, both one-day active area and personal air nicotine sampling are least frequently used because of their relatively higher requirements for sampling devices and/or involvement of human subjects. Week-long passive area nicotine sampling using samplers developed by Leaderer and Hammond (1991) has the least requirement for sampling devices and attendance from investigators, though sampling permission and laboratory analysis are required; its relationship with personal exposure by either servers or patrons are to be determined. Peak-time area nicotine sampling may be the most feasible, while a reasonably accurate way to access patrons' SHS short time exposure during their visits and servers' exposure during peak time and relatively longer time (full shift), and thus can be used for assessment of acute health risks or chronic health risks; compared to peak-time area nicotine sampling, peak-time $PM_{2.5}$ sampling is less expensive while easier to operate, though $PM_{2.5}$ is not specific to SHS, it is significantly related to observed active smoking density and airborne nicotine in smoking venues, and thus, it has been used for risk assessment purposes (Repace and Lowrey 1990; Repace, Jiang et al. 2011); and because of the health risks from $PM_{2.5}$ itself (Pope, Burnett et al. 2009) and the real-time feature of $PM_{2.5}$ sampling, it has also been frequently used for public health education program of promoting smoke-free environments (Avila-Tang, Travers et al. 2010).

2.4.6 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, including one hour during peak patronage time, full shift during operation hours, more than

20 hour including nights and one or two weeks. It explored the relationships between these different sampling approaches and examined their utility in risk assessment. The limitations of this study included that: 1) the venues were not representative of restaurants and bars in Beijing, thus the results might not be able to represent SHS concentrations or servers' SHS exposure in all restaurants and bars in Beijing; 2) the study was conducted in a summer only, and there might be great seasonal variations due to different ventilation, door and/or window opening, etc. 3) most of the area sampling during peak time, operating hours and one or two weeks were not conducted at the same location; thus the differences among sampling results of different time periods might not only contribute to the differences over time but also to the differences over space; 4) 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 to 0.328 (Jenkins, Ilgner et al. 2004; Klepeis, Ott et al. 2007; Travers 2008; Bohac, Hewett et al. 2010), thus, it is not likely that the calibrating factor for SHS in Beijing restaurants and bars (if measured) will be significantly different from the one used in this study.

2.5 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 indicated either by airborne nicotine or $PM_{2.5}$ concentrations in nonsmoking restaurants and bars in Beijing are comparable to or higher than those in other countries while they are lower in smoking restaurants and bars than in other countries. Setting designated smoking and nonsmoking sections is ineffective in preventing patrons and servers from SHS exposure.

There are obvious spikes of SHS concentrations during peak patronage times in restaurants and bars. Servers' exposure to SHS during operating hours can vary by nine times in the same venue. Although SHS concentrations at different locations in a short time period can vary widely, the space becomes reasonably well mixed in a relatively longer period of time.

Both airborne nicotine and $PM_{2.5}$ are useful to trace SHS exposure, and nicotine is more specific to SHS. Results by area nicotine sampling during different time periods, e.g. one hour during peak patronage time, one day during operation hours and one or two weeks including nights, are significantly related to each other, and peak-time sampling results overestimate one-day and week-long area sampling results. One-day area nicotine sampling results underestimate one-day personal nicotine sampling results, and both peak-time area sampling of nicotine and $PM_{2.5}$ can be used to estimate patrons' and servers' exposure to SHS. More studies are needed to exam the relationship between week-long passive area sampling results and personal exposure by either servers or patrons.

Chapter 3 Assessing the Exposure to Secondhand Smoke in Restaurants and Bars in China by Modeling

3.1 Background

While measurements of the distribution of SHS concentrations are important for the purpose of risk assessment and health policy, obtaining statistically valid random samples in field studies to provide representative measurements is challenging. Because of the Chinese society's lag of awareness of health risks caused by SHS exposure and because of the limited resources available, much less has been done to assess exposure to SHS in various environments in China compared to Western countries. Stillman et al. measured airborne nicotine concentrations in public places in some rural and urban areas in China and reported that the median of week-long time-weighted average of airborne nicotine concentrations ranged from 0.10 to 0.68 $\mu g/m^3$ in schools, hospitals, governmental buildings and transportations, 2.17 $\mu g/m^3$ in restaurants, and 7.48 $\mu g/m^3$ in entertainment venues (Stillman, Navas-Acien et al. 2007). Gan et al. reported the median of week-long nicotine concentrations as 1.15 $\mu g/m^3$ in 14 office buildings in China (Gan, Hammond et al. 2008). Hammond found a median of week-long nicotine concentrations of 0.2 $\mu g/m^3$ in Chinese homes (Hammond, Tian et al. 1999). Kang et al. reported an arithmetic mean of indoor $PM_{2.5}$ concentration of 253 $\mu g/m^3$ and outdoor concentrations of 125 $\mu g/m^3$ during peak-patronage time visits to 92 restaurants and bars in Beijing, 2006; Liu et al. reported geometric means of indoor $PM_{2.5}$ concentrations ranging from 90 to 323 $\mu g/m^3$ and of outdoor concentrations ranging from 32 to 190 $\mu g/m^3$ from peak-patronage time visits to 404 restaurants and bars in five Chinese cities in 2007 (Liu, Yang et al. 2011). Lee et al. reported a geometric mean of indoor $PM_{2.5}$ concentrations of 58 $\mu g/m^3$ during peak-patronage time in 5 restaurants and 15 entertainment venues in Beijing, 2008 (Lee, Lim et al. 2010).

None of the studies above used a representative sample, and the results may not represent SHS concentrations in similar environments in China. Models are useful in predicting SHS concentrations when resources are limited to collect field data; they are also useful to generalize environmental measurements when representative samples are not available. Furthermore, models have great potential for assisting building designers and public health specialists in achieving and maintaining adequate levels of indoor air quality in a scientifically valid manner (Ott 1999).

Considerable progress has been made over decades in developing, testing, and validating mathematical models to predict the pollutant concentrations present in indoor settings due to smoking activity. Many of these models were summarized by Repace (Repace 1987) and Ott (Ott 1999), who showed that all the models have a similar mathematical structure, and are all based on the mass balance law, that is, mass can be neither created nor destroyed. Experimental results show that these models can predict indoor pollutant concentrations from smoking activity in indoor settings with high accuracy (Ott, Langan et al. 1992; Klepeis, Ott et al. 1996; Klepeis 1999).

No study in China has used the modeling approach to predict SHS levels in indoor environments. The issue of SHS exposure has only recently gained the attention of the public and researchers in China, and both environmental measurements of indoor SHS and experimental chamber studies of SHS are still in their early stages. China has the largest population of smokers worldwide and SHS exposure is very common in public places, including restaurants and bars. However, China has lagged behind the rest of the world in banning smoking in public places, especially in restaurants and bars. Predicting SHS concentrations in restaurants and bars by models can provide very important information for decision makers when field measurements are limited due to a lack of resources or other reasons.

The purpose of this chapter is to develop and evaluate models based on the mass balance law to predict SHS levels in hospitality venues and use these models to estimate SHS concentrations in Chinese restaurants and bars.

3.2 Methods

3.2.1 Mass Balance Models to Predict SHS Concentrations

Exposure to SHS in indoor environments depends on smoking activities, the volume into which SHS is emitted and dispersed, the dynamic processes like ventilation removal and some physicochemical properties of SHS like deposition and re-emission, and sorption and desorption. A venue allowing smoking everywhere can be considered as a single compartment, see Figure 3.1.

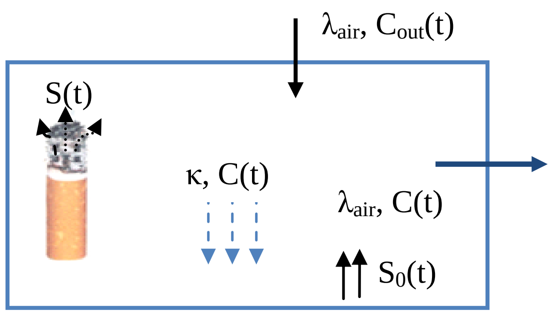


Figure 3.1 Generation and removal of a SHS tracer in a smoking venue: single compartment model

For a specific SHS tracer in a smoking venue without a non-smoking area, the basic mass-balance equation can be presented as following, with an assumption of a well mixed condition:

$$\frac{dC}{dt} = p\lambda_{air}C_{out}(t) + \frac{S(t)}{V} + \frac{S_0(t)}{V} - (\lambda_{air} + k)C(t) \qquad [3.1]$$

Where $C(t)$ is the indoor concentration of a SHS tracer as a function of time, μg/m^3

$C_{out}(t)$ is the outdoor concentration of the SHS tracer as a function of time, μg/m^3

$S(t)$ is the source generation rate of the SHS tracer in the venue, μg/hr

$S_0(t)$ is the generation rate of other indoor sources in the venue, μg/hr

λ_{air} is the ventilatory air change rate, hr^{-1}

k is the combined removal rate of mechanisms like deposition, absorption, etc, hr^{-1}

V is the volume of the microenvironment, m^3

p is the penetration factor, dimensionless

If a steady state is assumed, then equation 3.1 = 0, and

$$C_{ss} = \frac{p\lambda_{air}}{\lambda_{air}+k}C_{out} + \frac{S}{V(\lambda_{air}+k)} + \frac{S_0}{V(\lambda_{air}+k)} \qquad [3.2]$$

Since we are interested in predicting indoor concentration of SHS derived compounds for the purpose of risk assessment of SHS exposure, we ignore the outdoor sources and other indoor sources, and use equation 3.3 to predict the concentration of a SHS tracer specifically from SHS

$$\text{SHS\_est } (\mu g/m^3) = \frac{S}{V(\lambda_{air}+k)} = \frac{G_{SHS} \cdot \left(N_{occ} \cdot (P_{sm} \cdot m) \cdot r\right)}{V \cdot (\lambda_{air}+k)} \qquad [3.3]$$

Where $G_{SHS} \cdot (N_{occ} \cdot (P_{sm} \cdot m) \cdot r) = S$ in equation 3.2;

G_{SHS} is the generation rate of SHS per cigarette, µg/cig;
N_{occ} is the number of occupancy;
P_{sm} is the prevalence of current smoker of the general population;
m is the adjustment factor of current smoking prevalence among restaurant or bar patrons so that $(P_{sm} \cdot m)$ is the current smoking prevalence of restaurant or bar patrons;
r is the active smoking rate of a smoker, cig/hr;
V is the volume, m^3;
λ_{air} is the air exchange rate, hr^{-1};
k is the combined removal rate of mechanisms like deposition, absorption, etc, hr^{-1}

Measuring ventilation rates separately for the smoking section and nonsmoking section in venues with non-smoking areas is difficult, as is measuring the connectivity between the two sections. For each section the inflow air rate is assumed to equal the outflow air rate, the air exchange rate in hr^{-1} is the same for the two sections, and the air flow rate from the smoking section to the nonsmoking section equals the flow rate of air goes the other way around. SHS is assumed to be generated in the smoking section only and to be in steady state in each section and in equilibrium between the two sections during patronage peak time (See figure 3.2).

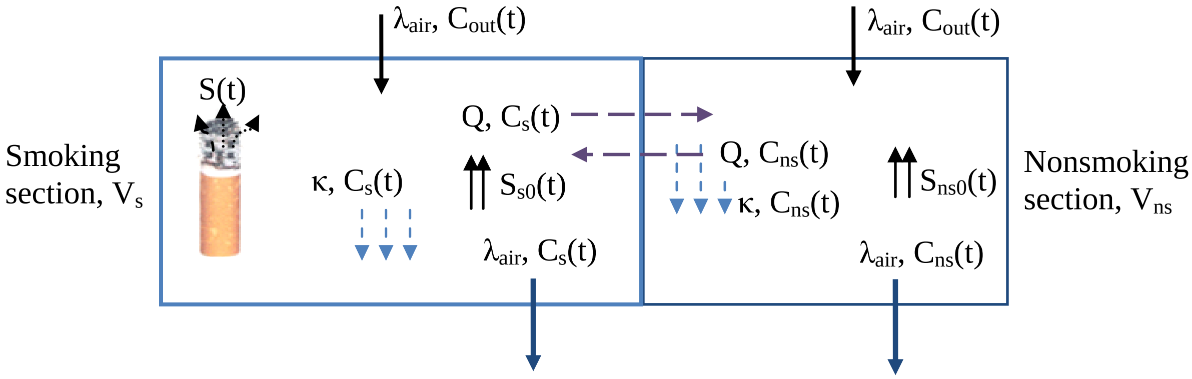


Figure 3.2 Generation and removal of a SHS tracer in a smoking venue: two-compartment model

$$\frac{dC_s(t)}{d(t)} = p\lambda_{air}C_{out}(t) + \frac{S(t)}{V_s} + \frac{S_{s0}(t)}{V_s} + \frac{Q\cdot C_{ns}(t)}{V_s} - (\lambda_{air} + k)\cdot C_s(t) - \frac{Q\cdot C_s(t)}{V_s} \qquad [3.4]$$

$$\frac{dC_{ns}(t)}{d(t)} = p\lambda_{air}C_{out}(t) + \frac{S_{ns0}(t)}{V_{ns}} + \frac{Q\cdot C_s(t)}{V_{ns}} - (\lambda_{air} + k)\cdot C_{ns}(t) - \frac{Q\cdot C_{ns}(t)}{V_{ns}} \qquad [3.5]$$

Where $C_s(t)$ is the indoor concentration of a SHS tracer in the smoking section as a function of time, µg/m^3

$C_{out}(t)$ is the outdoor concentration of the SHS tracer as a function of time, µg/m^3

$C_{ns}(t)$ is the indoor concentration of the SHS tracer in the nonsmoking section as a function of time, µg/m^3

$S(t)$ is source generation rate of the SHS tracer in the smoking section, µg/hr

$S_{s0}(t)$ is generation rate of other indoor sources in the smoking sections, µg/hr

$S_{ns0}(t)$ is generation rate of other indoor sources in the nonsmoking sections, µg/hr

λ_{air} is ventilatory air change rate, hr^{-1}

k is removal rate due to other mechanism, like deposition, adsorption, etc., hr^{-1}

Qis air flow rate between the smoking and nonsmoking section, m^3/hr

V_s *is* volume of the smoking section, m^3

V_{ns} is volume of the nonsmoking section, m^3

p is penetration factor, dimensionless

Assuming a steady state and equilibrium state for both sections, and that $C_{ns}/C_s=f_1$, $V_{ns}/V_s=f_2$, solve equation 3.4 and 3.5, the steady state concentration in the smoking section, that is, C_{s_ss}, can be estimated by equation 3.6

$$C_{s\_ss} = [p\lambda_{air}(f_2+1)C_{out} + S/V_s + (S_{s0}+S_{ns0})/V_s]/[(\lambda_{air}+k)(1+f_1\cdot f_2)] \qquad [3.6]$$

Again, since we are interested in predicting indoor concentration of SHS derived compounds for the purpose of risk assessment of SHS exposure, we ignore the outdoor sources and other indoor sources, and use the following equation 3.7 to predict the tracer concentration from SHS only

$$C_{s\_SHS}\ (\mu g/m^3) = \frac{S}{V_s \cdot (\lambda_{air}+k)(1+f_1 \cdot f_2)} = \frac{G_{SHS} \cdot (N_{occ} \cdot (P_{sm} \cdot m) \cdot r)}{V_s \cdot (\lambda_{air}+k)(1+f_1 \cdot f_2)}$$

$$C_{ns\_SHS}\ (\mu g/m^3) = f_1\, C_{s\_SHS}$$

$$V_{ns} = f_2 V_s \qquad [3.7]$$

Where C_{s_SHS} is the steady state SHS concentration in the smoking section, $\mu g/m^3$;
C_{ns_SHS} is the steady state SHS concentration in the nonsmoking section, $\mu g/m^3$;
$G_{SHS} \cdot (N_{occ} \cdot (P_{sm} \cdot m) \cdot r) = S$ in equation 3.6;
G_{SHS} is the generation rate of SHS per cigarette, µg/cig;
N_{occ} is the number of occupancy;
P_{sm} is the prevalence of current smoker of the general population;
m is the adjustment factor of current smoking prevalence among restaurant or bar patrons so that $(P_{sm} \cdot m)$ is the current smoking prevalence of restaurant or bar patrons;
r is the active smoking rate of a smoker, cig/hr;
V_S is the volume of the smoking section, m^3;
V_{nS} is the volume of the nonsmoking section, m^3;
λ_{air} is the air exchange rate, hr^{-1};
k is the combined removal rate of mechanisms like deposition, absorption, etc, hr^{-1};
f_1 is the ratio of SHS concentration in designated nonsmoking section to that in designated smoking section; and
f_2 is the ratio of the volume of the nonsmoking section to that of the smoking section.

When f_2 =0, that is, there is no designated nonsmoking section, equation 3.7 is equivalent to equation 3.3.

3.2.2 Evaluating the Models Using Field Data from Restaurants and Bars in Minnesota, United States and in Beijing, China

Before the implementation of a comprehensive smoking ban in October 2007 in Minnesota, a statistically representative sample of 65 hospitality venues in the Minneapolis/St. Paul metropolitan area was selected to assess patrons' and servers' SHS exposure in restaurants. From February 23 through September 29, 2007, 2423 short-term visits (median: 12 minutes) were made to conduct real-time area monitoring of fine particulate matter ($PM_{2.5}$) in both indoors and outdoors and to observe the number of customers, workers and lit cigarettes at three different times of day (lunch, dinner, and evening) on four different day types (Fridays, Saturdays, Sundays, and other weekdays) in each venue. Another 210 two-hour visits were conducted at dinner and in the evening to make the same observations, monitor $PM_{2.5}$, and sample multiple gas phase SHS tracers including nicotine, 3-ethenylpyridine, 3,4-picoline, pyrrole, pyridine, myosmine. etc. Carbon dioxide (CO_2) measurements in both indoors and outdoors were also performed. For each visit, SHS PM was estimated by subtracting the outdoor $PM_{2.5}$ level to the indoor $PM_{2.5}$ level and then multiplying a calibrating factor of 0.31, which was determined by gravimetric sampling of SHS. Ventilation rate was estimated for those two-hour visits using CO_2 measurements, counts of occupants and observation of activity intensity of occupants. Data collected by this study and by the study conducted in Beijing hospitality venues in 2010 described in Chapter 2 provide important information to predict SHS concentration using equation 3.3 or 3.7 in each visit, thus provide good opportunity to evaluate the mass balance models described by 3.1-3.7 with field measurements.

3.2.2.1 Estimates of ventilation rate by CO_2 measurements

Field measurement of outdoor air ventilation rates in occupied buildings is difficult, particularly when the measurements are conducted without the occupants' knowledge. Thus ventilation rates in both studies were determined using average CO_2 concentration measurements and occupancy counts. CO_2 may be generated by several sources, including occupant respiration, burning tobacco products and unvented cooking combustion products, outdoor sources, etc. In both studies, occupant respiration is assumed to be the dominant source. Changes of indoor CO_2 concentration can be estimated by the following mass balance equation:

$$\frac{dC}{dt} = \lambda_{air} C_{out}(t) + \frac{S(t)}{V} - \lambda_{air} C(t) \qquad [3.8]$$

Where *C(t)* is the indoor CO_2 concentration as a function of time, µg/m^3

$C_{out}(t)$ is the outdoor CO_2 concentration as a function of time, µg/m^3

S(t) is the source generation rate of CO_2 in the venue, µg/hr

λ_{air} is the ventilatory air change rate, hr^{-1}

V is the volume of the microenvironment, m^3

Under the assumption of steady state,

$$C = C_{out} + \frac{S}{V\lambda_{air}} \qquad [3.9]$$

That is,

$$\lambda_{air} = \frac{S}{C - C_{out}} \qquad [3.10]$$

According to Appendix C of ASHRAE 6.21 (ASHRAE 2007), the CO_2 generation rate for a worker with typical activity or a patron with light activity is about 8.6×10^{-4}L/s and 5.16×10^{-4}L/s for a seated patron. Thus, if the number of patrons and workers were counted and both the indoor and outdoor CO_2 concentrations were measured, the ventilation rate could be estimated by equation 3.10 for each visit.

3.2.2.2 Estimates of concentrations of SHS tracers based on counts of lit cigarettes

If an average of N patrons are smoking at any time, and the average time of smoking a cigarette is 10 minutes, then

$$G_{SHS} \cdot (N_{occ} \cdot (P_{sm} \cdot m) \cdot r) = G_{SHS} \cdot N_{cig}/10min \cdot 60min/hr \quad [3.11]$$

Where G_{SHS} is the generation rate of SHS per cigarette, µg/cig;
N_{occ} is the number of occupancy;
N_{cig} is the average number of cigarettes smoked at any time;
P_{sm} is the current smoking prevalence of the general population;
m is the adjustment factor of current smoking prevalence for restaurant or bar patrons;
r is the active smoking rate of a smoker, cig/smoker-hr.

That is, equation 3.7 can be re-written as below:

$$C_{est\_SHS}\ (\mu g/m^3) = \frac{G_{SHS} \cdot (N_{occ} \cdot (P_{sm} \cdot m) \cdot r)}{V_{smk} \cdot (\lambda_{air} + k)(1 + f_1 \cdot f_2)} = \frac{G_{SHS} \cdot N_{cig}/10min \cdot 60min/hr}{V_{smk} \cdot (\lambda_{air} + k)(1 + f_1 \cdot f_2)} \quad [3.12]$$

Where C_{est_SHS} is the estimated SHS concentration in steady state in smoking venues or sections, µg/m^3;
V_{smk} is the volume of the smoking venue or section, m^3;
λ_{air} is the air exchange rate, hr^{-1};
k is the combined removal rate of mechanisms of deposition, absorption, etc, hr^{-1};
f_1 is the ratio of SHS concentration in designated nonsmoking section to that in designated smoking section;
f_2 is the ratio of the volume of the nonsmoking section to that of the smoking section.

Smoking may continually occur over extended time periods and at multi-points throughout a venue like restaurant or bar, and obtaining detailed information on the time and spatial coordinates of each cigarette smoked is difficult. Thus, those multiple and overlapping SHS sources are treated as a single, continuous and constant source over the specific time period represented by the sampling time period. The generation rate (G_{SHS}) is 12500 µg/cig for SHS PM, based on the mean of emission factors (EFs) reported by six papers (Leaderer and Hammond 1991; Martin, Heavner et al. 1997; Nelson, Kelly et al. 1998; Daisey 1999; Bi, Sheng et al. 2005; Charles, Batterman et al. 2007) and 1274 µg/cig for airborne nicotine based on the mean of EFs reported by seven papers (Martin, Heavner et al. 1997; Nelson, Kelly et al. 1998; Daisey 1999; Singer, Hodgson et al. 2002; Singer, Hodgson et al. 2003; Bi, Sheng et al. 2005; Charles, Batterman et al. 2007).

The average number of cigarettes smoked at any time (N_{cig}) and the volume of the smoking venue or section (V_{smk}) or the nonsmoking section (V_{nsmk}) was counted or measured during sampling. Simultaneous measurements of SHS in designated smoking sections and nonsmoking sections in restaurants or clubs in six studies showed that the SHS PM level in designated nonsmoking sections is 28% to 78% of the level in designated smoking sections, with a mean (SD) of 54% (16%) (Lambert, Samet et al. 1993; Akbar-Khanzadeh 2003; Bohanan, Piade et al. 2003; Carrington, Watson et al. 2003; Cains, Cannata et al. 2004; Huss, Kooijman et al. 2010). For nicotine, this ratio ranges from 3% to 109%, with a mean (SD) of 40% (31%), based on 10 studies (Lambert, Samet et al. 1993; Jane, Nebot et al. 2002; Akbar-Khanzadeh 2003; Bohanan, Piade et al. 2003; Carrington, Watson et al. 2003; Cains, Cannata et al. 2004; Moshammer, Neuberger et al. 2004; Navas-Acien, Peruga et al. 2004; Kuusimaki, Peltonen et al. 2007;

Schneider, Seibold et al. 2008). For the purpose of modeling, SHS PM level in designated nonsmoking section is assumed to be 60% of the level in designated smoking sections, and 40% for nicotine.

Klepeis showed that the removal rate of RSP due to surface deposition in two smoking lounges was about 19-21% of the ventilatory removal rate (one smoking lounge had an ACH of 10.7/hr and the other 13.0/hr) (Klepeis, Ott et al. 1996). Wallace found a deposition rate of 0.3-0.5/hr for sulfate particles, based on a series of studies and an assumption of a surface to volume ratio of $3m^{-1}$, and an empirical deposition rate of 0.4/hr for $PM_{2.5}$ based on the EPA Particle Team (PTEAM) study (Wallace 1996). For airborne nicotine, the indoor concentrations depend on cigarette emission, re-emission of absorbed vapors and removal mechanisms including ventilation and sorption (Daisey 1999). During smoking periods (like peak patronage time in restaurants and bars), the adsorption process dominates the desorption process, while in the nonsmoking period (like break periods or evenings), the re-emission dominates the sorption, which maintains airborne nicotine at a non-zero plateau (Van Loy, Nazaroff et al. 1998; Van Loy, Riley et al. 2001). Van Loy, et al. reported a sorption coefficient of 5.3m/hr and a desorption coefficient of 1.2×10^{-4}/hr for nicotine on carpets, and a sorption coefficient of 1.4m/hr and a desorption coefficient of 1.2×10^{-4}/hr on painted wallboards in chamber studies (Van Loy, Riley et al. 2001). Since the desorption process is relatively slow, it is ignored in modeling nicotine concentration during peak patronage times. The sorption coefficient in m/hr is similar to a deposition velocity, thus, if the room height is known, a first-order removal rate can be estimated, which is analogous to the loss parameter for "stirred settling" as used for particle deposition. If a surface-volume ratio of $3m^2/m^3$ is assumed, which is the inverse of the room height, the average of the two sorption coefficient (3.3m/hr) corresponds to a first-order removal rate of 10/hr by surface absorption.

With all the parameters determined either from literature or from filed observation or measurements, equation 3.12 can be used to estimate the SHS concentration during each visit in the two studies. Because equation 3.12 is based on the assumption that smoking happens only in the smoking section (if there is any), while smoking was observed in designated nonsmoking sections in Beijing restaurants and bars, field data from venues with designated smoking and nonsmoking sections were not included in the evaluation. Simple linear regression analysis was used to examine the quantitative relationship between the predicted concentrations and the measured concentrations of SHS PM and airborne nicotine, respectively. Scatter plots and quantile-quantile plots were also used to visualize their relationships.

3.2.3 Evaluating the Model by Monte Carlo Simulation

A Monte Carlo simulation using equation 3.7 was performed to simulate SHS concentrations in Minnesota and U.S. restaurants and bars where smoking was permitted everywhere or in designated smoking sections. Distribution of the simulated SHS PM concentrations in Minnesota restaurants and bars was compared to the data collected from the 2633 visits to 65 statistically representative Minnesota restaurants and bars in 2007 as previously described; and distribution of simulated SHS PM levels in U.S. restaurants and bars was compared to field data reported in literature.

The equation used for the simulation is:

$$C_{s\_SHS}\ (\mu g/m^3) = \frac{G_{SHS} \cdot (N_{occ} \cdot (P_{sm} \cdot m) \cdot r)}{V_s \cdot (\lambda_{air} + k)(1 + f_1 \cdot f_2)}$$

$$C_{ns\_SHS}\ (\mu g/m^3) = f_1\ C_{s\_SHS}$$

$$V_{ns} = f_2 V_s \qquad [3.7]$$

For a venue permitting smoking everywhere, f_2 =0, and this equation is equivalent to equation 3.3, which is used to estimate SHS concentrations in smoking venues.

Definition, unit, arithmetic mean (μ), range and assumed distribution for each parameter are described below. When the standard deviation (σ) of a parameter is not reported, the covariance coefficient (CV, standard deviation/assumed mean) is assumed to be 20% to 80% depending on the expected magnitude of variance. Distribution of the parameters is based on information from literature; if no related information is available to assign a distribution to a parameter, a beta distribution is assumed. For log-normal distribution, the geometric mean (GM) and geometric standard deviation (GSD) are determined using the following equations when the arithmetic mean (μ) and the standard deviation (σ) have been assumed:

$$GSD = exp\sqrt{ln\frac{\mu^2 + \sigma^2}{\mu^2}}$$

$$GM = \frac{\mu^2}{\sqrt{\mu^2 + \sigma^2}}$$

[3.13]

For a beta distribution, the two shape parameters, α and β, are determined using the SOLVER analysis function of Excel and the following equations:

$$\mu = min + \frac{\alpha(max - min)}{\alpha + \beta}$$

$$\sigma = \frac{(max - min)}{(\alpha + \beta)}\sqrt{\frac{\alpha\beta}{\alpha + \beta + 1}}$$

[3.14]

3.2.3.1 Generation rate of secondhand smoke (G_{SHS})

The assumed mean of generation rate is 12500 μg/cigarette for SHS PM and 1274 μg/cigarette for airborne nicotine based on literature reports. Because these two generation rates are well studied, and all the CVs reported are smaller than 25%, the standard deviation (SD) is assumed to be 20% of the mean in the simulation. The minimum and maximum values reported in literature were set as the lower and upper bounds, respectively, and a beta distribution is assumed for this parameter.

3.2.3.2 Occupant density (N_{OCC}/V_S)

Field observations from Minnesota restaurants and bars showed that the mean (SD) of occupant densities was 0.06 (0.06) person/m^3 in restaurants and 0.05 (0.05) person/m^3 in bars. Travers reported SHS monitoring and observations in a total of 609 hospitality venues from July 2003 to May 2006 in 16 states, District of Columbia and Puerto Rico (Travers 2008). The average number of patrons in 67 restaurants where smoking was permitted was 30.9 and the average volume of these venues was 661 m^3, which resulted in an approximate average occupant density of 0.05 person/m^3. For the 138 bars where smoking was permitted, the average number of patrons was 53.4 and the average volume of these venues was 900 m^3, which resulted in an approximate average occupant density of 0.06 person/m^3.

According to ASHREA Standard 62.1-2007, Table 6-1, the default full occupancy density should be 70 per 100 m^2 or 1000 ft^2 for restaurant dining rooms or 100 persons per 100 m^2 or 1000 ft^2 for bars. If a 10 feet or 3 meters height for a typical restaurant or a bar is assumed, the default occupant density should be 0.25 persons/m^3 for restaurants and 0.35 persons/m^3 for bars. For the purpose of the modeling, the assumed mean of occupancy density during peak patronage time was set as 1/5 of the ASHRE default value. Because substantial variability is expected for this parameter, the SD was assumed to be 80% of the mean. The lower and upper bounds were assumed to be 0 and three times of the default full occupancy density by the ASHREA Standard, respectively. A truncated log-normal (TLN) was also assumed.

3.2.3.3 Current smoking prevalence (p_{sm})

The current smoking prevalence of adults aged 18 years and over was 20% (SD 3.2%) in the U.S., 2007 (CDC 2009), and 17% (1.4%) in Minnesota (Minnesota Department of Health 2008). These means and SDs were used as the assumed mean and SD for the U.S. and Minnesota population, respectively. The range was assumed to be 0-100%, and a normal distribution was assumed for the simulation.

3.2.3.4 Smoking prevalence adjustment factor (m) and active smoking rate and (r)

Assume that the current smoking prevalence of restaurant or bar patrons is m times of the current smoking prevalence of the general population P_{sm}, then $(P_{sm} \cdot m)$ of patrons are expected to be current smokers. If r cigarettes are smoked per hour by an average active smoker, and there are N patrons in total, then $(N \cdot [P_{sm} \cdot m] \cdot r)$ is the expected number of cigarettes smoked per hour in the restaurant or bar. This is equivalent to the total number of cigarettes per hour smoked by a population of N people with a smoking prevalence ofP_{sm}, and a smoking rate of $(m \cdot r)$ cigarettes per hour. In places where smoking is commonly allowed in restaurants and bars, the adjustment factor m probably equals 1, while in places like Minnesota, where smoking is allowed in some restaurants and bars only, m is probably greater than 1 for patrons of those smoking venues.

If a current smoker smokes each cigarette for 10 minutes, then a non-stopping smoker will smoke 6 cigarettes per hour. If the observed smoking prevalence (percentage of patrons observed smoking at anytime) is P_{ob}, then the total number of cigarettes smoked by all smoking patrons is equivalent to that by $(N \cdot P_{ob})$ non-stopping smokers, who smoke $(N \cdot P_{ob} \cdot 6)$ cigarettes per hour. Thus, the observed smoking prevalence of restaurant or bar patrons can be related to the current smoking prevalence of the general population and active smoking rate of a smoker as below:

$$N \cdot P_{sm} \cdot m \cdot r = N \cdot P_{ob} \cdot 6cig/hr$$

That is,

$$m \cdot r = 6cig/hr \cdot P_{ob}/P_{sm} \quad [3.15]$$

Travers reported that the average of number of patrons in 67 restaurants with smoking permitted was 30.9, with an average of 2.0 patrons observed smoking at any time; the average number of patrons and of observed active smokers was 53.4 and 7.1 respectively in 138 bars with smoking permitted (Travers 2008). These numbers correspond to an observed smoking prevalence of 6% in smoking restaurants and 13% in smoking bars, which in turn correspond to an equivalent active smoking rate (mr) of 2 cigarettes/hr by a smoking patron in a restaurant and 4 cigarettes/hr in a bar, assuming that the current smoking prevalence of patrons is the same as of the general population. These equivalent active smoking rates were used as the assumed means for simulation, the standard deviation was assumed to be 50% of the mean and the lower and upper bounds were assumed to be 0 and 6 cigarettes/hr, respectively. A normal distribution was also assumed.

3.2.3.5 Removing rate by ventilation (λ_{air})

The major removal mechanism of SHS PM is ventilation, though deposition can also play an important role. According to ASHREA Standard 62.1-2007, Table 6-1, the default combined outdoor air rate should be 10 cfm/person or 5.1 L/s per person for restaurants, and 9 cfm/person or 4.7 L/s per person for bars. If a typical restaurant or a bar is assumed to have a 10 feet or 3 meters height, the default outdoor ventilation rate for the default full occupancy should be 4.3/hr or 17/hr per persons/m^3 for restaurants and 5.6/hr or 15/hr per persons/m^3 for bars. Though in the real world, the occupant density is usually not as high as the default full occupancy recommended by ASHRAE, and the ventilation rate may be different with the default values, restaurant or bar workers are not likely to adjust the ventilation rate consistently with the changes of the occupant density. Thus, the default values of ventilation rates recommended by ASHREA were used as the assumed means of simulations. Because great variance of the ventilation rate is expected, the SD was assumed to be 80% of the mean. The lower and upper bounds were assumed to be 5% and 5 times of the mean, respectively and a log normal distribution was assumed.

3.2.3.6 Removing rate by other mechanism (k)

The assumed mean of removing rate was assumed to be 0.4/hr for $PM_{2.5}$ by deposition, based on the EPA Particle Team (PTEAM) study (Wallace 1996) and 10/hr for airborne nicotine by surface absorption derived from a surface-volume ratio of $3m^2/m^3$ and a sorption coefficient of 3.3m/hr reported Van Loy, et al (Van Loy, Riley et al. 2001), as described in section 3.2.2. Studies on removing rate by deposition of $PM_{2.5}$ or absorption of airborne nicotine are limited, so the SD was assumed to be 50% of the mean, and the lower and upper bounds were assumed to be 0 and 3 times of the mean, respectively. Beta distributions were assumed.

3.2.3.7 Ratio of designated-nonsmoking-section SHS level to designated-smoking-section SHS level (f_1)

Consistent with section 3.2.2, SHS PM concentration in designated nonsmoking section was assumed to be 60% of the concentration in designated smoking sections, and this ratio was assumed to be 40% for airborne nicotine. For both ratios, the CV was assumed to be 50% of the means, and the lower and upper bounds were assumed to be 10% and 100%, respectively. Beta distributions were assumed for this parameter.

3.2.3.8 Ratio of designated-nonsmoking-section volume to designated-smoking-section volume (f_2)

A wide range is expected for the ratio of designated-nonsmoking-section volume to designated-smoking-section volume, and a mean of 1.0, a CV of 50%, a range of 0.1 to 10 and a beta distribution were assumed for the simulation.

Assumptions on distribution of parameters used for the modeling and sources for these assumptions are listed in table 3.1.

Table 3.1 Definition, unit, range and distribution assumed for each parameter for the Monte Carlo simulation of SHS levels in Minnesota and in U.S. restaurants and bars

Equation used for simulating:

$$C_{s\_SHS}\ (\mu g/m^3) = \frac{G_{SHS}\cdot(N_{occ}\cdot(P_{sm}\cdot m)\cdot r)}{V_s\cdot(\lambda_{air}+k)(1+f_1\cdot f_2)}$$

symbol	definitions and units	assumed arithmetic mean	SD	lower bound	upper bound	distribution	references
G_{SHS}	Generation rate of SHS per cigarette, μg/cigarette	SHS PM: 12500	2500	8100	17000	Beta: α=1.07, β=1.10	The assumed means and ranges are the means and ranges of emission factors reported in literature; the CV is assumed to be 20%
		Airborne nicotine: 1274	255	400	3000	Beta: α=7.46, β=14.74	
N_{occ}/V	occupancy density, persons/ m^3	restaurants: 0.25/5	0.04	0	0.75	Double TLN	the assumed mean is assumed to be 1/5 of the ASHRAE default full occupancy density; the CV is assumed to be 80%, and the lower and upper bound are assumed to be 0 and 3 times of the default value, respectively
		bars: 0.35/5	0.056	0	1.05	Double TLN	
P_{sm}	current smoking prevalence	Minnesota: 0.17	0.014	0.017	1.0	Truncated normal distribution	(Minnesota Department of Health 2008), (CDC 2009); the bounds are assumed to be 0 and 100% , respectively
		U.S.: 0.20	0.032	0.02	1.0		
$m \cdot r$	the product of smoking prevalence adjustment factor and active smoking rate of a smoker	Restaurants: 2	1	0	6	Truncated normal distribution	The assumed means were based on observed smoking rate derived from Travers (2008) and Equation M12. SD was assumed to be 50% of the mean.
		Bar: 4	2	0	6		
ACH	air exchange rate, hr^{-1}	restaurants: 4.3	3.5	0.2	21	Double TLN	ASHRAE default value is used as the assumed mean; the SD and bounds are assumed to be 80%, 5% and 5 times of the mean, respectively
		bars: 5.6	4.5	0.3	28	Double TLN	
κ	combined removal rate other than ventilation, hr^{-1}	SHS PM: 0.4	0.2	0	1.2	Beta: α =2.33, β =4.67	The assumed mean is based on report by Wallace (1996) for SHS PM and by Van Loy (2001) for nicotine, and the SDs were assumed to be 50% of the mean, lower and upper bound is assumed to be 0 and 3 times of the mean, respectively
		Airborne nicotine:10	5	0	30	Beta: α =2.33, β =4.67	
f_1	nsmk_SHS/smk_SHS	SHS PM: 0.6	0.3	0	1.0	Beta: α =1.00, β =0.67	The assumed mean is the mean of reported ratios of nonsmoking-section SHS to smoking-section in literature; the CVs were assumed to be 50% and the range was assumed to be 10% to100%,
		Airborne nicotine: 0.4	0.2	0	1.0	Beta: α =2.00, β =3.00	
f_2	nsmk_vol/smk_vol	1.0	0.5	0.1	10	Beta: α=2.85, β =28	Assuming the volume of the nonsmoking section is 10% to 10 times of the smoking section, with a mean ratio of 1.0 and SD of 50% of the mean

Notes: SD: standard deviation; Beta: beta distribution; α *and* β, shape parameters of beta distribution; double TLN: double truncated log-normal distribution; CV, coefficient of variance, defined by the standard deviation divided by the arithmetic mean.

3.2.4 Simulating SHS Concentrations in Chinese Restaurants and Bars by Monte Carlo Simulation

Equation 3.7 was used to simulate SHS PM and airborne nicotine concentrations in Chinese restaurants and bars with smoking permitted everywhere or in designated sections.

$$C_{s\_SHS}\ (\mu g/m^3) = \frac{G_{SHS}\cdot(N_{occ}\cdot(P_{sm}\cdot m)\cdot r)}{V_s\cdot(\lambda_{air}+k)(1+f_1\cdot f_2)}$$

$$C_{ns\_SHS}\ (\mu g/m^3) = f_1\, C_{s\_SHS}$$

$$V_{ns} = f_2 V_s \qquad [3.7]$$

The same assumed mean and distribution as described in the last section were used for the parameter of generation rate (G_{SHS}), surface deposition rate (κ), ratio of designated-nonsmoking-section SHS level to designated-section SHS level (f_1) and ratio of designated-nonsmoking-section volume to designated-section volume (f_2). Other parameters were determined as below.

3.2.4.1 Occupant density (N_{OCC}/V_S) and removing rate by ventilation (λ_{air})

Per the national Guideline JGJ 64-1989, which is the guideline for designing eating and drinking places in China since 1989, the default full occupancy density should be 1.30 m^2 per seat or per person (77 seats per 100 m^2) for class 1 (luxury) restaurants and 1.10 m^2 per seat or per person (91 seats per 100 m^2) for class 2 (general) restaurants; the default fresh outdoor air rate should be 25 m^3/(hr person) or 20 m^3/(hr person) for class 1 and class 2 restaurants, respectively.

Assuming a restaurant with a dining area of 100 m^2 and height of 3 m, the default full occupancy density is about 0.3 person/m^3 and the default air exchange rate should be 6.0 hr^{-1} (estimated with 90 persons/100m^2 and 20 m^3/hr person because the number of class 1 restaurants is expected to be much smaller than the class 2 restaurants). The Guideline recommends the same full occupancy density for bars as for restaurants and it does not recommend ventilation rate for bars, thus the default ventilation rate for bars is assumed to be the same as the default value for restaurants. Due to great variance of ventilation rates, the CV was assumed to be 80%, and the lower and upper bounds were assumed to be 5% and 5 times of the default value, respectively. A beta distribution was also assumed for the simulation.

Observations on occupancy of 405 restaurants and bars in five Chinese cities in 2007 showed that the mean (SD) of actual occupancy density was 0.11 (0.11) person/m^3 and the median (interquartile) was 0.08 (0.04-0.26) person/m^3. For the purpose of simulation, 1/3 of the default full occupancy density by the Guideline JGJ 64-1989 was used as the assumed mean, and the SD was assumed to be 80% of the mean. The lower and upper bounds were assumed to be 0 and three times of the default full occupancy density by the Guideline, respectively. A truncated log normal (TLN) was assumed for this parameter.

3.2.4.2 Current smoking prevalence (p_{sm})

The prevalence of adult current smokers in China was 31.4% in 2002 (Yang GH., Ma JM. et al. 2005) and 28.1% in 2010 (Li, Hsia et al. 2011). The mean for the simulation is assumed to be 30%, with a CV of 20%, a range of 0-100% and a normal distribution.

3.2.4.3 Smoking prevalence adjustment factor (m) and active smoking rate and (r)

Observations of the number of active smokers and occupants from restaurants and bars in five Chinese cities in 2007 when smoking was generally not regulated showed that the mean (SD) of observed smoking prevalence was 7% (7%) in restaurants and 14% (11%) in bars. Based on equation 3.13, these observed smoking prevalence (P_{ob}) corresponded to an equivalent active smoking rate (*mr*) of about 1.5 cigarettes/hr by a smoking patron in a restaurant and about 3 cigarettes/hr in a bar, assuming that the current smoking prevalence of patrons was the same as that of the general population, which was about 30%. These equivalent active smoking rates were used as the assumed means for simulation and the SD was assumed to be 50% of the mean. The lower and upper bounds were assumed to be 0 and 6 cigarettes/hr, respectively, and a normal distribution was assumed for the equivalent active smoking rate (*mr*).

The definition and distribution of parameters used for simulating SHS PM in Chinese restaurants and bars are listed in Table 3.2. Simulation is conducted separately for restaurants and bars with different smoking policies (with smoking permitted everywhere or in designated sections only).

Table 3.2 Definition, unit, range and assumed distribution for each parameter for Monte Carlo simulation of SHS PM levels in Chinese restaurants and bars

Equation used for simulating :

$$C_{s\_SHS}\ (\mu g/m^3) = \frac{G_{SHS} \cdot (N_{occ} \cdot (P_{sm} \cdot m) \cdot r)}{V_s \cdot (\lambda_{air} + k)(1 + f_1 \cdot f_2)}$$

symbol	definitions and units	assumed arithmetic mean	SD	lower bound	upper bound	distribution	references
G_{SHS}	Generation rate of SHS per cigarette, μg/cigarette	SHS PM: 12500	2500	8100	17000	Beta: α=1.07, β=1.10	The assumed means and ranges were the means and ranges of emission factors reported in literature; the CV is assumed to be 20%
		Airborne nicotine: 1274	255	400	3000	Beta: α =7.46, β=14.74	
N_{occ}/V	occupancy density, persons/ m^3	Restaurants and bars: 0.3/3	0.08	0	0.9	Double TLN	the assumed mean was assumed to be 1/3 of the default full occupancy density by the national Guideline JGJ 64-1989; the CV was assumed to be 80%; the range was assumed to be 0 - 3 times of the default value
P_{sm}	current smoking prevalence	0.30	0.06	0	1.0	Truncated normal distribution	The assumed mean was the average of current smoking prevalence in 2002 and 2010; the CV was assumed to be 20% and the range was assumed to be 0 - 100%
$m \cdot r$	the product of smoking prevalence adjustment factor and active smoking rate of a smoker	Restaurants: 1.5	0.75	0	6	Truncated normal distribution	The assumed means were based on observed smoking rates in some Chinese restaurants and bars in 2007 and Equation 3.12; The CV was assumed to be 50%.
		Bar: 3	1.5	0	6		
ACH	air exchange rate, hr^{-1}	6.0	4.8	0.3	30	Double TLN	The default value by the Guideline JGJ 64-1989 was used as the assumed mean; the CV was assumed 80%, and rang were assumed to be 5% - 5 times of the mean.
κ	combined removal rate other than ventilation, hr^{-1}	SHS PM: 0.4	0.2	0	1.2	Beta: α =2.33, β=4.67	The assumed mean was based on report by Wallace (1996) for SHS PM and by Van Loy (2001) for airborne nicotine and the SDs were assumed to be 50% of the mean, upper bound is assumed to be 0 and 3 times of the mean, respectively
		Airborne nicotine :10	5	0	30	Beta: α =2.33, β=4.67	
f_1	nsmk_SHS/smk_SHS	SHS PM: 0.6	0.3	0	1.0	Beta: α =1.00, β=0.67	The assumed mean was the mean of reported ratios of nonsmoking-section SHS to smoking-section SHS level in literature; the CVs were assumed to be 50% and the range was assumed to be 10% to100%,
		Airborne nicotine: 0.4	0.2	0	1.0	Beta: α =2.00, β=3.00	
f_2	nsmk_vol/smk_vol	1.0	0.5	0.1	10	Beta: α =2.85, β=28	The volume of the nonsmoking section was assumed 10% to 10 times of the smoking section, with a mean ratio of 1.0 and SD of 50% of the mean

Notes: SD: standard deviation; Beta: beta distribution; *α and β*, shape parameters of beta distribution; double TLN: double truncated log-normal distribution; CV, coefficient of variance, defined by the standard deviation divided by the arithmetic mean.

3.2.5 Sensitivity Analysis

To examine the sensitivity of simulated results to the assumed distribution of each parameter, one parameter was varied within its distribution each time and all others were set as their means as assumed in Table 3.2. Then the simulated outcomes were plotted with the parameter with variations, together with the Kernel density plot of the parameter in the same graph. These graphs were used to examine how the changes of simulated outcomes were related to the variations in each parameter.

3.3 Results

3.3.1 Evaluating the Models Using Field Data from Restaurants and Bars in Minnesota, United States and in Beijing, China

Based on equation 3.12, field observations of patrons' smoking activities and measurements of space volume and CO_2 concentrations (to estimate ventilation rate), the means or medians of the predicted SHS concentrations indicated by $PM_{2.5}$ were 66% to 124% of those based on field measurement. The means and medians of predicted airborne nicotine concentrations were 39% to 136% of those based on measurements (Table 3.3). Comparing the predicted to measured concentrations, predicted values were statistically related to field measurements, but they were not perfect predictors. The coefficient of determination (R^2) of simple linear regression analysis was more than 50% for SHS PM and only 35% for airborne nicotine (Table 3.4). However, for both Minnesota and Beijing restaurants and bars, the marginal distribution of predicted SHS PM concentrations were similar to the marginal distribution of field measurements; for airborne nicotine, these predicted versus observed marginal distributions were not as similar, with field measurements of airborne nicotine concentration more dispersed and higher than corresponding predicted results (Figure 3.3-3.6).

Table 3.3 Distribution of SHS PM and airborne nicotine concentrations in Minnesota and Beijing restaurants and bars by measurements and by prediction

	SHS PM		airborne nicotine	
stats	measured	predicted	measured	predicted
Minnesota				
N	202	202	187	187
mean	**110**	**127**	**3.34**	**3.30**
SD	115	133	4.03	3.52
p5	3	0	0.15	0.21
p25	32	35	0.61	1.17
p50	**72**	**89**	**1.75**	**2.38**
p75	149	166	4.54	4.37
p95	358	382	12.21	8.91
Beijing				
N	52	52	53	53
mean	**95**	**63**	**2.83**	**1.84**
SD	165	115	2.59	2.60
p5	0	0	0.10	0.00
p25	9	0	1.11	0.00
p50	**33**	**23**	**1.98**	**0.77**
p75	118	79	4.21	2.31
p95	434	206	7.96	8.52

Table 3.4 Simple regression analysis of measured SHS concentrations and predicted SHS concentrations based on field observations in restaurants and bars in Minnesota and Beijing

	Dependent variable	Independent variable	n[c]	constant (95%CI)	coefficient (95%CI)	P value	R^2
Minnesota [a]							
SHS PM	measurements	estimates	202	27 (13,42)	0.66 (0.58, 0.73)	0.000	0.58
nicotine	measurements	estimates	187	1.97 (1.23, 2.72)	0.41 (0.26.0.57)	0.000	0.13
Beijing [b]							
SHS PM	measurements	estimates	52	35 (10, 60)	0.66 (0.47, 0.85)	0.000	0.50
nicotine	measurements	estimates	53	1.75 (1.03, 2.47)	0.58 (0.36, 0.81)	0.000	0.34

[a] only including smoking venues (smoking permitted everywhere) and designated smoking sections;
[b] only including smoking venues (smoking permitted everywhere) and nonsmoking venues (smoking not permitted anywhere nominally, but in many of these venues, smoking was observed); SHS concentration in designated smoking sections were not modeled because the equation used for modeling (equation 3.12) was based on the assumption that no smoking happened in the designated nonsmoking sections, which was not the case in Beijing restaurants and bars.
[c] only those venues with estimated ventilation rate between 0 to 30 hr^{-1} based on CO_2 measurements were included; Eight visits with ventilation rate >30 hr^{-1} to Minnesota restaurants and bars and five visits with ventilation rate >30 hr^{-1} to Beijing restaurants and bars were not included in the modeling.

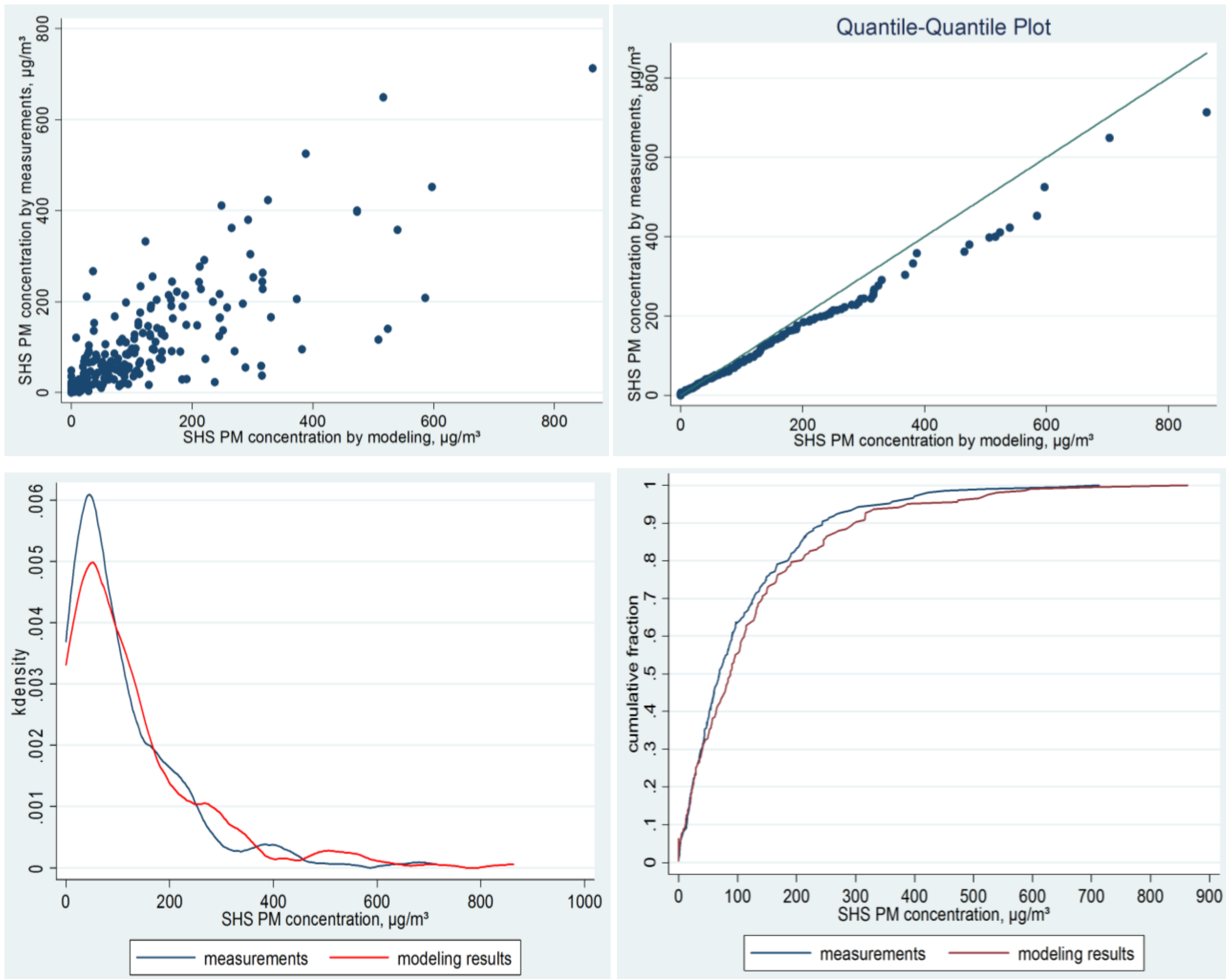


Figure 3.3 Scatter plot (upper left panel), quantile-quantile plot (upper right panel), kernel density plot (lower left panel) and cumulative probability plot (lower right panel) of field measurements and modeled SHS PM concentrations in Minnesota restaurants and bars

Notes: the scatter plot showed that SHS PM concentrations estimated by modeling were linearly related to the field measurements;

A quantile-quantile (q-q) plot compares two probability distributions by plotting their quantiles against each other. This q-q plot showed that the marginal distribution of SHS PM concentrations estimated by modeling was similar to that of the field measurements, but modeling results were more dispersed than field measurements, and were higher than corresponding field measurements, especially for values higher than 200 $\mu g/m^3$;

A kernel density plot can be considered a refinement of a histogram or frequency plot with smoothness or continuity by using a suitable kernel. This kernel plot showed that both the modeling results and field measurements were right skewed and that more values by field measurements were lower than 200 $\mu g/m^3$ while more values by modeling were higher than 700 $\mu g/m^3$;

A cumulative probability plot shows the probability that a variable X with a given probability distribution will be found at a value less than or equal to x. The cumulative plot here also showed similar marginal distribution of modeling results versus field measurements.

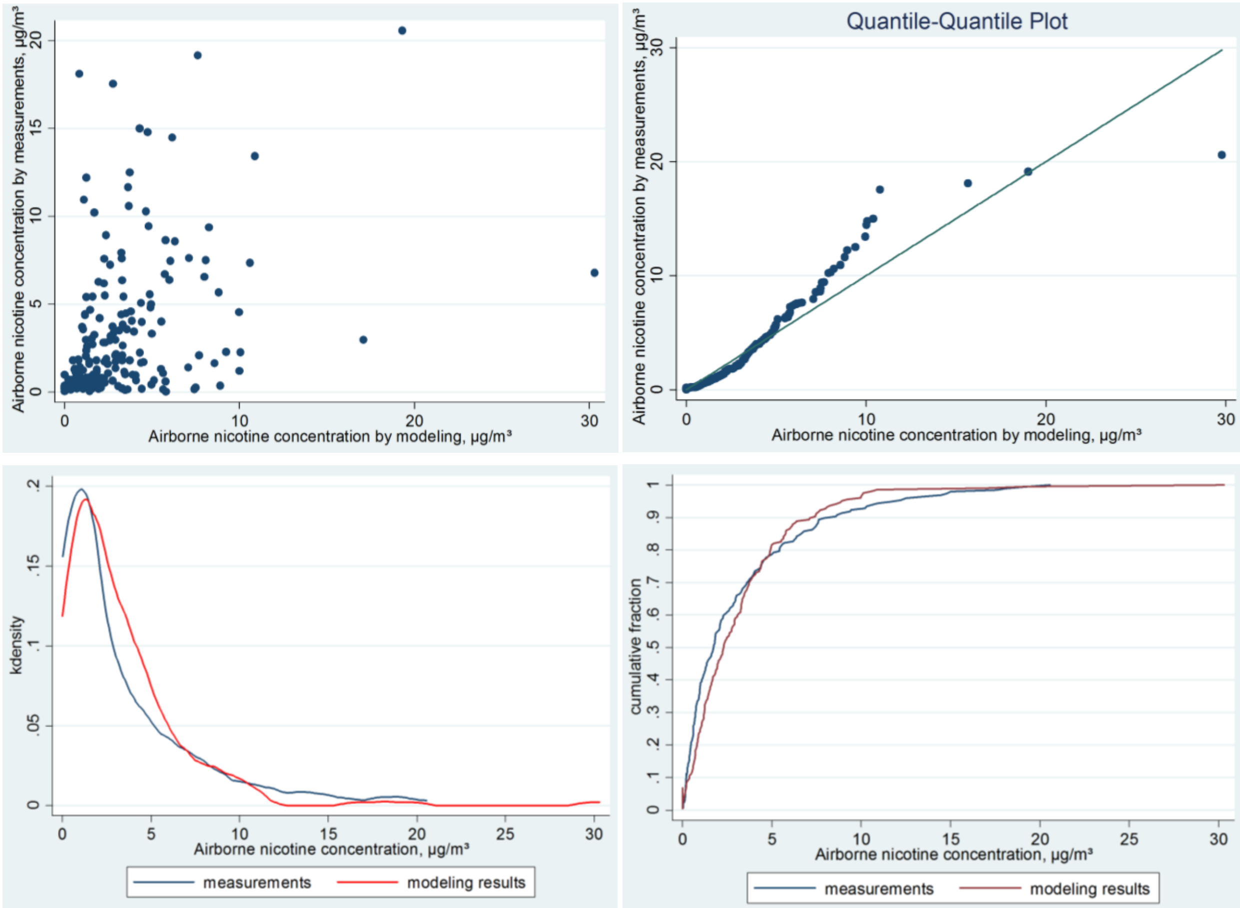


Figure 3.4 Scatter plot (upper left panel), quantile-quantile plot (upper right panel), kernel density plot (lower left panel) and cumulative probability plot (lower right panel) of field measurements and modeled airborne nicotine concentrations in Minnesota restaurants and bars

Notes: the scatter plot did not show an obvious linear relationship between airborne nicotine concentrations predicted by modeling and by field measurements;

The q-q plot showed that the marginal distribution of airborne concentrations estimated by modeling was different to that of the field measurements, with field measurements more dispersed than modeling results. The predicted concentrations tended to be lower than corresponding field measurements for values from 5 to 20 μg/m^3 and had a tail with higher value than measurement;

The kernel density plot showed that both the modeling results and field measurements were right skewed and that the modeling results have a tail with higher values;

The cumulative probability plot showed that modeling results are higher than measurements below the 70% percentile while lower above the 70%.

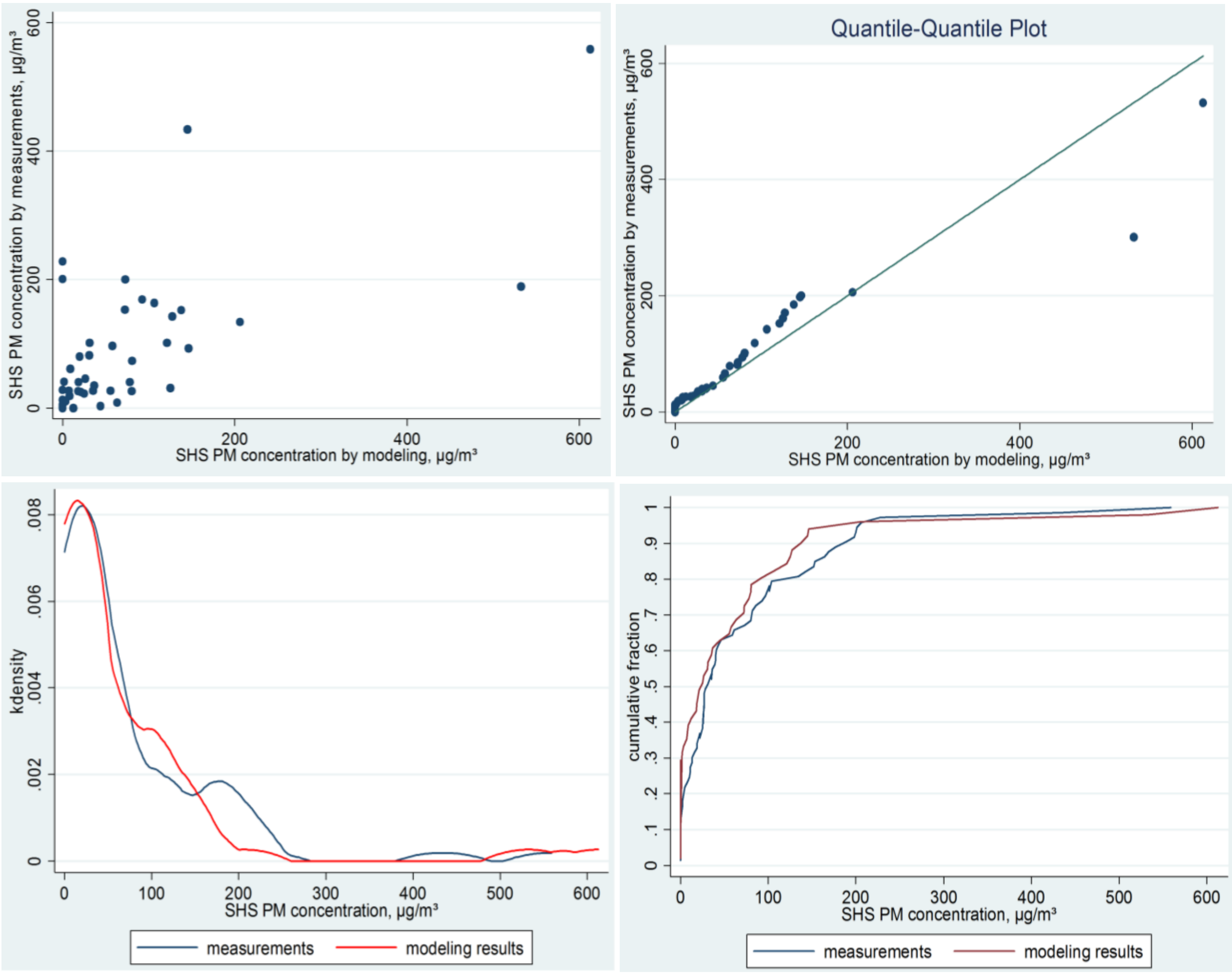


Figure 3.5 Scatter plot (upper left panel), quantile-quantile plot (upper right panel), kernel density plot (lower left panel) and cumulative probability plot (lower right panel) of field measurements and modeled SHS PM concentrations in Beijing restaurants and bars

Notes: the scatter plot showed that SHS PM concentrations estimated by modeling were approximately linearly related to the field measurements;

The q-q plot showed that the marginal distribution of SHS PM concentrations estimated by modeling was similar to that of the field measurements, but field measurements were more dispersed than modeling results when SHS PM concentrations were lower than 200 μg/m^3; the modeling results had a tail with higher values;

The kernel density plot showed that both the modeling results and field measurements were right skewed and that the marginal distribution of modeling results was similar to that of field measurements, especially when SHS PM concentrations were lower than 200 μg/m^3;;

The cumulative plot here also showed similar marginal distribution of modeling results and of field measurements; it also showed that modeling results were slightly lower than field measurements between the percentile of 2% and 95%.

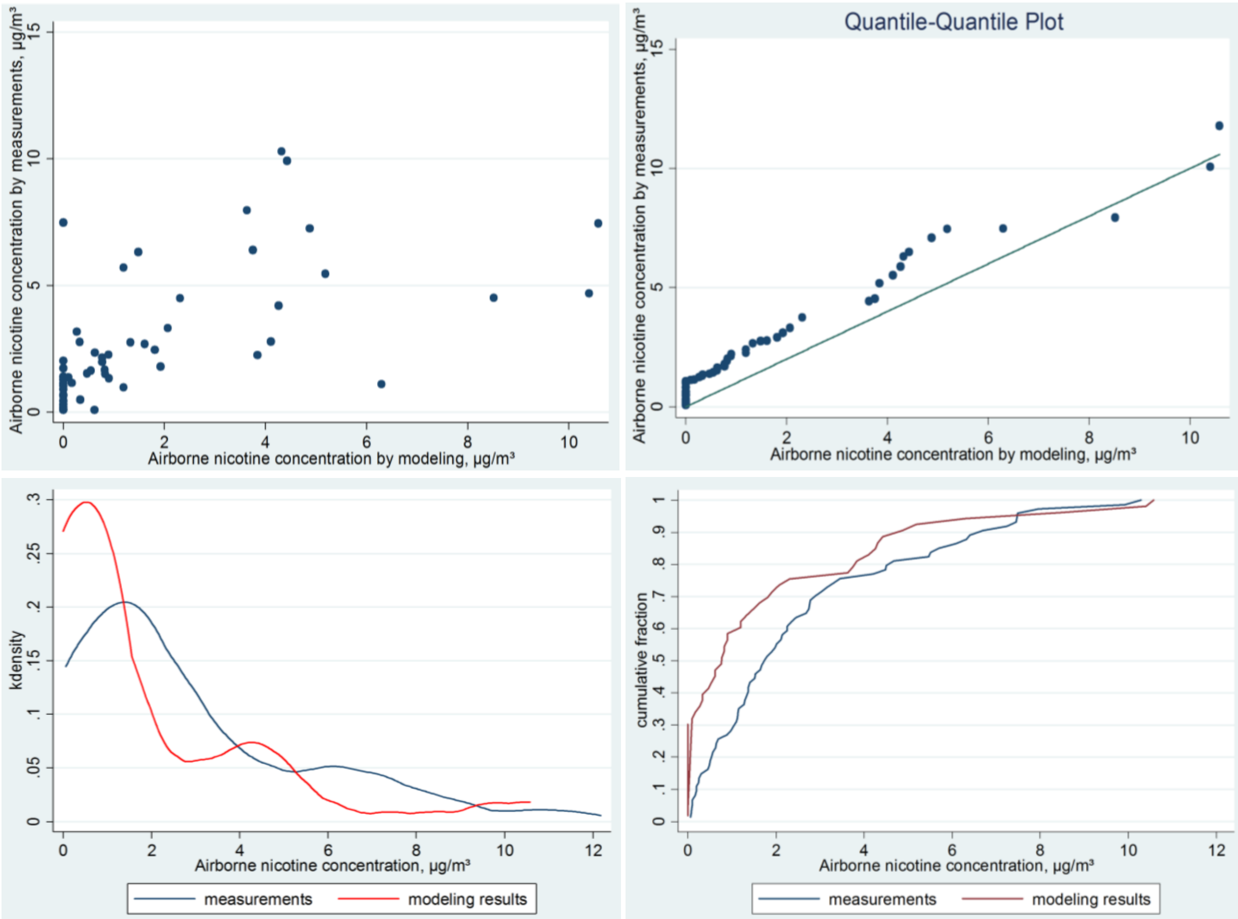


Figure 3.6 Scatter plot (upper left panel), quantile-quantile plot (upper right panel), kernel density plot (lower left panel) and cumulative probability plot (lower right panel) of field measurements and modeled airborne nicotine concentrations in Beijing restaurants and bars

Notes: the scatter plot did not show an approximately linear relationship between airborne nicotine concentrations estimated by modeling and by field measurements;

The q-q plot showed that the marginal distribution of airborne concentrations estimated by modeling was different to that of the field measurements to some extent, with field measurements more dispersed than modeling results and higher than corresponding modeling results;

The kernel density plot showed that both the modeling results and field measurements were right skewed and that more values by modeling were lower than 2 $\mu g/m^3$;

The cumulative plot showed that the marginal distribution of modeling results was different with the distribution of field measurements, and modeling results were lower than filed measurements at all cumulative probability below 95 percentile.

3.3.2 Evaluating the Models by Monte Carlo Simulation

Distribution of SHS PM concentrations measured during short time visits, 2-hour visits and all the 2633 visits to the 65 representative Minnesota restaurants and bars before the implementation of the smoking ban were shown separately in Table 3.5. Distribution of airborne nicotine concentrations measured during two-hour visits was shown in Table 3.6. Simulated SHS PM concentrations using equation 3.7 and assumptions listed in Table 3.1 were quite close to field measurements during all the short time visits or 2633 visits in terms of mean, quartiles and coefficient of variation (CV), but they tended to underestimate high observed values (Table 3.4), which might be due to indoor PM sources other than SHS. However, simulated nicotine concentrations underestimated the mean, median and high observed values, except the simulated results for designated smoking-sections of bars. Both simulated SHS PM concentrations and airborne nicotine concentrations were lower than measurements taken during the 210 two-hour visits (Table 3.4, 3.5). This was not surprising because SHS levels at dinners and on Friday and Saturday evenings were higher than the average SHS levels during peak-patronage times of other days according to measurements in Minnesota restaurants and bars (data not shown).

Table 3.5 Distribution of SHS PM concentrations in Minnesota restaurants and bars by measurements and by Monte Carlo simulation

	smoking-permitted venue				designated smoking-section			
	measured			simulated	measured			simulated
stats	12-min	2-hour	all		12-min	2-hour	all	
restaurants								
N	465	37	502	10000	1239	114	1353	10000
mean	**86**	**145**	**90**	**69**	**50**	**68**	**52**	**46**
SD	104	145	108	90	69	69	70	64
CV	121%	100%	120%	131%	139%	101%	135%	138%
p5	0	4	0	5	0	2	0	3
p25	15	38	16	19	5	20	5	12
p50	**49**	**125**	**51**	**40**	**26**	**49**	**28**	**26**
p75	121	205	126	84	69	90	71	55
p95	298	452	306	229	184	214	188	154
bars								
N	481	41	522	10000	238	18	256	10000
mean	**112**	**180**	**117**	**130**	**78**	**128**	**82**	**87**
SD	151	152	152	174	91	72	91	122
CV	136%	84%	130%	134%	116%	57%	111%	139%
p5	0	23	1	10	0	1	0	6
p25	24	59	26	35	13	78	15	22
p50	**65**	**142**	**68**	**75**	**44**	**126**	**50**	**49**
p75	136	255	144	157	111	167	119	103
p95	398	400	400	437	282	304	282	298

Notes: SHS PM concentrations were measured during 2633 visits, including 210 two-hour visits and 2423 12-minute visits during three different times of day (lunch, dinner, and evening) on four different day types (Fridays, Saturdays, Sundays, and other weekdays) in each venue; most of the 2-hour measurements (186 of 210) were conducted on Fridays and Saturdays.

Table 3.6 Distribution of airborne nicotine concentrations in Minnesota restaurants and bars by two-hour measurements and by Monte Carlo simulation

	smoking-permitted venue		designated smoking-section	
	measured	simulated	measured	simulated
restaurants				
N	38	10000	18	10000
mean	**4.01**	**1.94**	**2.74**	**1.43**
SD	4.57	2.53	2.50	1.90
CV	114%	131%	91%	133%
p5	0.15	0.19	0.01	0.13
p25	0.61	0.58	0.43	0.41
p50	**2.59**	**1.18**	**2.26**	**0.86**
p75	6.18	2.33	4.41	1.71
p95	18.09	6.10	8.58	4.57
bars				
N	35	10000	106	10000
mean	**5.15**	**4.20**	**2.43**	**3.11**
SD	4.99	5.74	3.27	4.33
CV	97%	137%	135%	139%
p5	0.19	0.43	0.15	0.30
p25	1.67	1.31	0.49	0.94
p50	**3.59**	**2.57**	**1.03**	**1.86**
p75	7.37	5.08	2.82	3.70
p95	15.00	13.07	10.29	9.70

Notes: measured airborne nicotine concentrations were during 210 two-hour visits at dinners and in the evenings, most (n=186) of which were on Fridays and Saturday

The mean (SD) of SHS PM concentrations predicted by 10000 Monte Carlo simulations using equation 3.7 and assumptions listed in Table 3.2 was 81 (108) $\mu g/m^3$ for U.S. smoking restaurants, 54 (76) $\mu g/m^3$ for U.S. designated smoking sections of restaurants, 153 (209) $\mu g/m^3$ for U.S. smoking bars and 103 (146) $\mu g/m^3$ for U.S. designated smoking sections of bars (Table 3.6). The mean (SD) of airborne nicotine concentrations predicted in these types of venues is 2.31 (3.00) $\mu g/m^3$, 1.70 (2.28) $\mu g/m^3$, 4.96 (6.45) $\mu g/m^3$ and 3.67 (5.04) $\mu g/m^3$, respectively (Table 3.6).

Siegel et al. reviewed studies published before 1993 and found that the weighted mean particulate concentration (weights used were number of restaurants or bars sampled) of 211 restaurants samples from 12 studies was 117 $\mu g/m^3$ (range 27-690 $\mu g/m^3$) and of 16 bar samples from 10 studies 348 $\mu g/m^3$ (range 75-1320 $\mu g/m^3$); for airborne nicotine, the weighted mean of 402 restaurants samples from 17 studies was 6.5 $\mu g/m^3$ (range 3.4-34 $\mu g/m^3$), and of 25 bar samples from 10 studies 19.7 $\mu g/m^3$ (range 7.4-65.5 $\mu g/m^3$) (Siegel 1993). These aggregated measurements were higher than simulated concentrations for U.S. restaurants and bars The reasons might be that restaurants and bars included in studies reviewed by Siegel et al. were not representative of U.S. restaurants and bars, and patrons' smoking prevalence and smoking rate in cigarettes/hour before 1993 were different from recent years', which the models were based upon.

Travers reported a mean (SD) of 97 (85) $\mu g/m^3$ and a median of 68 $\mu g/m^3$ SHS PM in 67 smoking-permitted restaurants and a mean (SD) of 406 (382) $\mu g/m^3$ and a median of 320 $\mu g/m^3$ SHS PM in 138 smoking-permitted bars in 16 states of the US in 2008 (Travers 2008). Waring and Siegel reported a mean (SD) of 151 (67) $\mu g/m^3$ SHS PM in 16 bars before smoking was banned in 2005 in Austin (Waring and Siegel 2007). Simulated SHS PM levels in US restaurants were similar to those reported by Travers. As for simulated SHS PM in bars, they are much lower than those measurements in bars reported by Travers, while similar to those reported Waring and Siegel (Waring and Siegel 2007).

Table 3.7 SHS PM concentrations in U.S. restaurants and bars by Monte Carlo simulation, μg/m³

	smoking-permitted restaurants		smoking-permitted bars	
stats	smoking venues	designated sections	smoking venues	designated sections
SHS PM				
N	10000	10000	10000	10000
mean	**81**	**54**	**153**	**103**
SD	108	76	209	146
p5	6	4	12	7
p25	21	13	41	26
p50	**47**	**30**	**88**	**57**
p75	98	65	184	119
p95	268	184	510	353
airborne nicotine				
N	10000	10000	10000	10000
mean	**2.31**	**1.70**	**4.96**	**3.67**
SD	3.00	2.28	6.45	5.04
p5	0.22	0.15	0.49	0.35
p25	0.67	0.49	1.51	1.08
p50	**1.37**	**1.00**	**3.02**	**2.20**
p75	2.83	2.08	6.09	4.41
p95	7.53	5.39	15.51	11.69

3.3.3 Simulating SHS Concentrations in Chinese Restaurants and Bars by Monte Carlo Simulation

SHSP PM concentrations and airborne nicotine concentrations were simulated 10000 times for Chinese restaurants and bars by Monte Carlo simulation. Results are shown in Table 3.8 and Figure 3.7–3.8. Simulated SHS concentrations, indicated by either $PM_{2.5}$ or airborne nicotine, were log-normally distributed. Simulated SHS concentrations in smoking restaurants or bars were higher than in designated smoking sections, which were in turn higher than in designated nonsmoking sections.

The means (SD) of simulated SHS PM concentrations were 135 (182) μg/m³, 90(129) μg/m³, 49(79) μg/m³ in restaurants with smoking allowed everywhere, designated smoking sections of restaurants and designated nonsmoking restaurants, respectively. The means (SD) of predicted airborne nicotine concentrations in restaurants with different smoking policies were 4.58 (6.18) μg/m³, 3.38 (4.70) μg/m³ and 1.27 (1.93) μg/m³, respectively. Predicted SHS concentrations indicated by either $PM_{2.5}$ or airborne nicotine in bars were about two times of that in restaurants with the same smoking policy, because patrons' smoking rate in bars (3 cigarettes/hour per smoker) was assumed to be twice that in restaurants (1.5 cigarettes/hour per smoker), while assumptions on other parameters were the same.

Table 3.8 SHS concentrations in Chinese restaurants and bars by smoking policy by Monte Carlo simulation, μg/m^3

	smoking-permitted restaurants			smoking-permitted bars		
stats	smoking venues	designated sections	designated nonsmoking sections	smoking venues	designated sections	designated nonsmoking sections
SHS PM						
N	10000	10000	10000	10000	10000	10000
mean	**135**	**90**	**49**	**261**	**175**	**93**
SD	182	129	79	365	254	148
CV	135%	142%	161%	140%	145%	159%
p5	10	6	2	20	12	4
p25	35	22	10	67	42	19
p50	**76**	**49**	**24**	**147**	**94**	**46**
p75	162	108	57	309	201	107
p95	451	306	175	872	606	333
airborne nicotine						
N	10000	10000	10000	10000	10000	10000
mean	**4.58**	**3.38**	**1.27**	**8.59**	**6.34**	**2.38**
SD	6.18	4.70	1.93	11.57	8.58	3.66
CV	135%	139%	152%	135%	135%	154%
p5	0.43	0.30	0.08	0.82	0.59	0.15
p25	1.32	0.94	0.30	2.57	1.83	0.58
p50	**2.75**	**2.00**	**0.68**	**5.21**	**3.79**	**1.31**
p75	5.49	4.03	1.49	10.43	7.66	2.85
p95	14.54	10.85	4.29	27.44	20.48	7.88

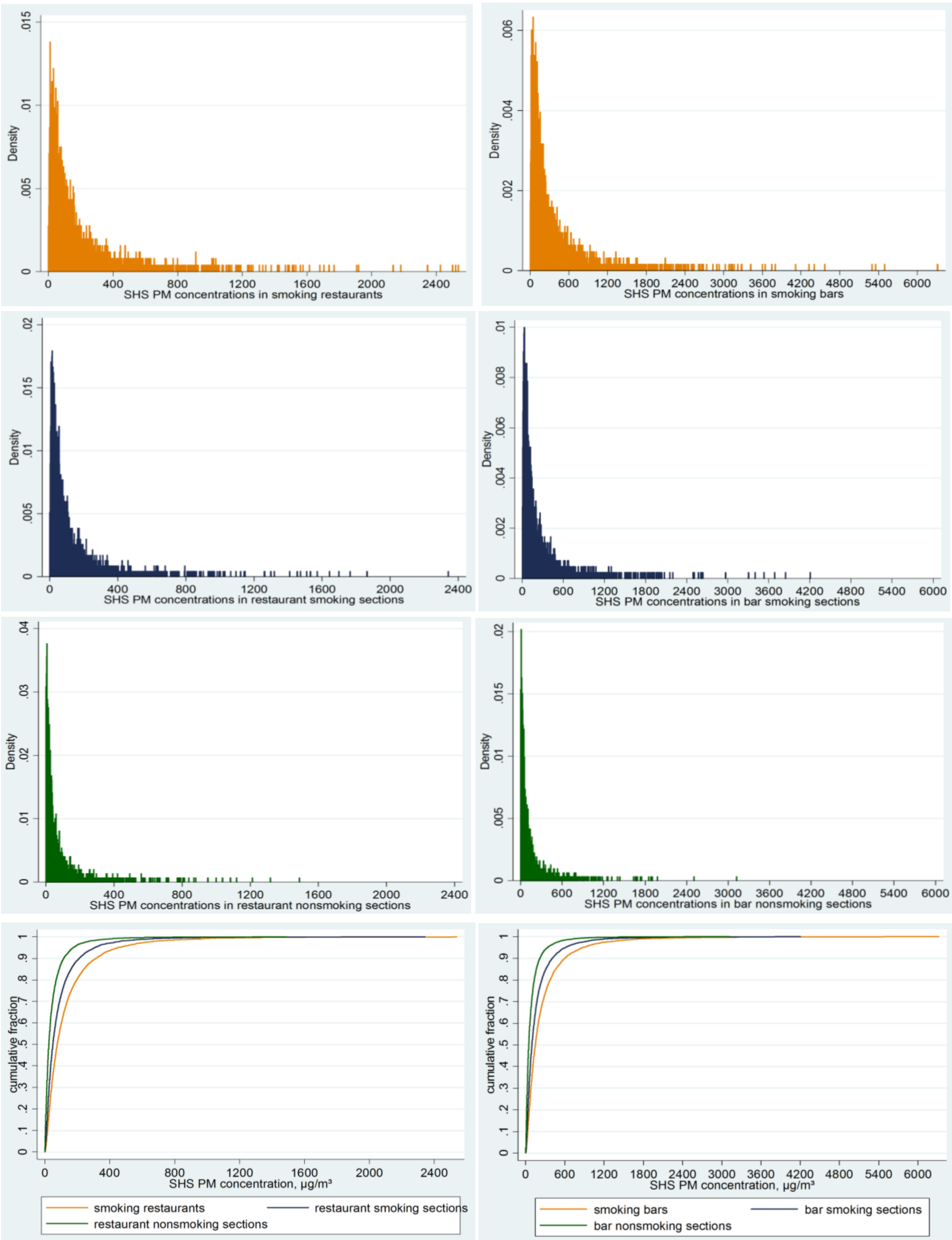


Figure 3.7 SHS PM concentrations by Monte Carlo simulation (n=10000) in Chinese restaurants (left panel) and bars (right panel) by smoking policies (orange: smoking allowed everywhere; navy: designated smoking sections; green: designated nonsmoking sections)

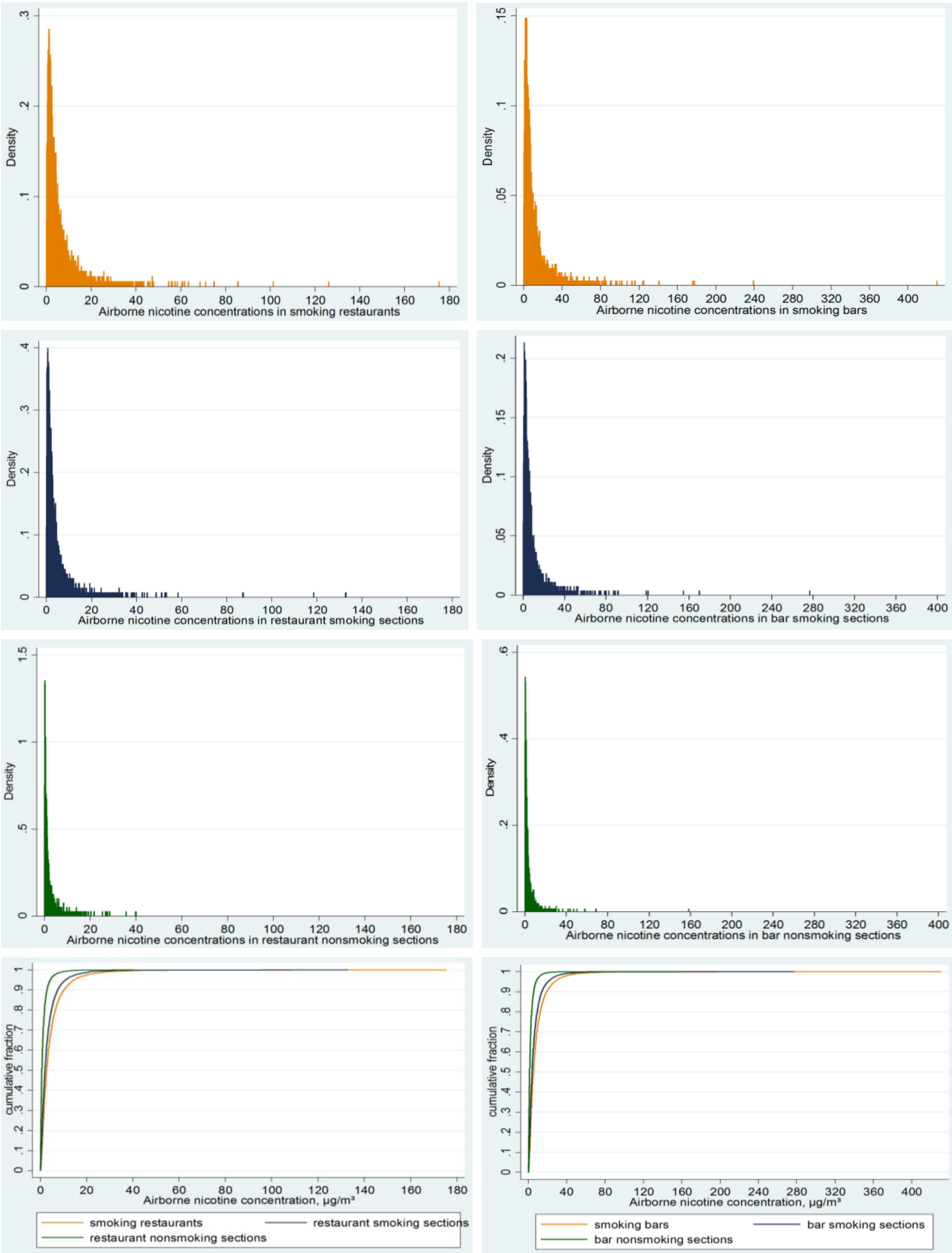


Figure 3.8 Airborne nicotine concentrations by Monte Carlo simulation (n=10000) in Chinese restaurants (left panel) and bars (right panel) by smoking policies (orange: smoking allowed everywhere; navy: designated smoking sections; green: designated nonsmoking sections)

3.3.4 Sensitivity Analysis

Both simulated SHS PM concentrations and airborne nicotine concentrations increase linearly with the increase of values of parameters of generation rate, occupancy density, current smoking prevalence and patrons' active smoking rate; they were inversely proportional to values of air exchange rate, other removal rate, ratio of nonsmoking-area concentrations to smoking-area concentrations, and the ratio of nonsmoking-area volume to smoking-area volume. Simulated SHS PM concentrations were very sensitive to occupancy density air exchange rate in the range of 0-480 $\mu g/m^3$; they were mildly sensitive to the patrons' active smoking rate in the range of 0-180 $\mu g/m^3$; and they were not so sensitive to variations of other parameters. Similarly, simulated airborne nicotine concentrations were very sensitive to occupancy density in the range of 0-22 $\mu g/m^3$; they were mildly sensitive to patrons' active smoking rate and nicotine surface absorption rate in the range of 0-8 $\mu g/m^3$; and they were not so sensitive to changes of the rest parameters. See figure 3.9 and 3.10 for details.

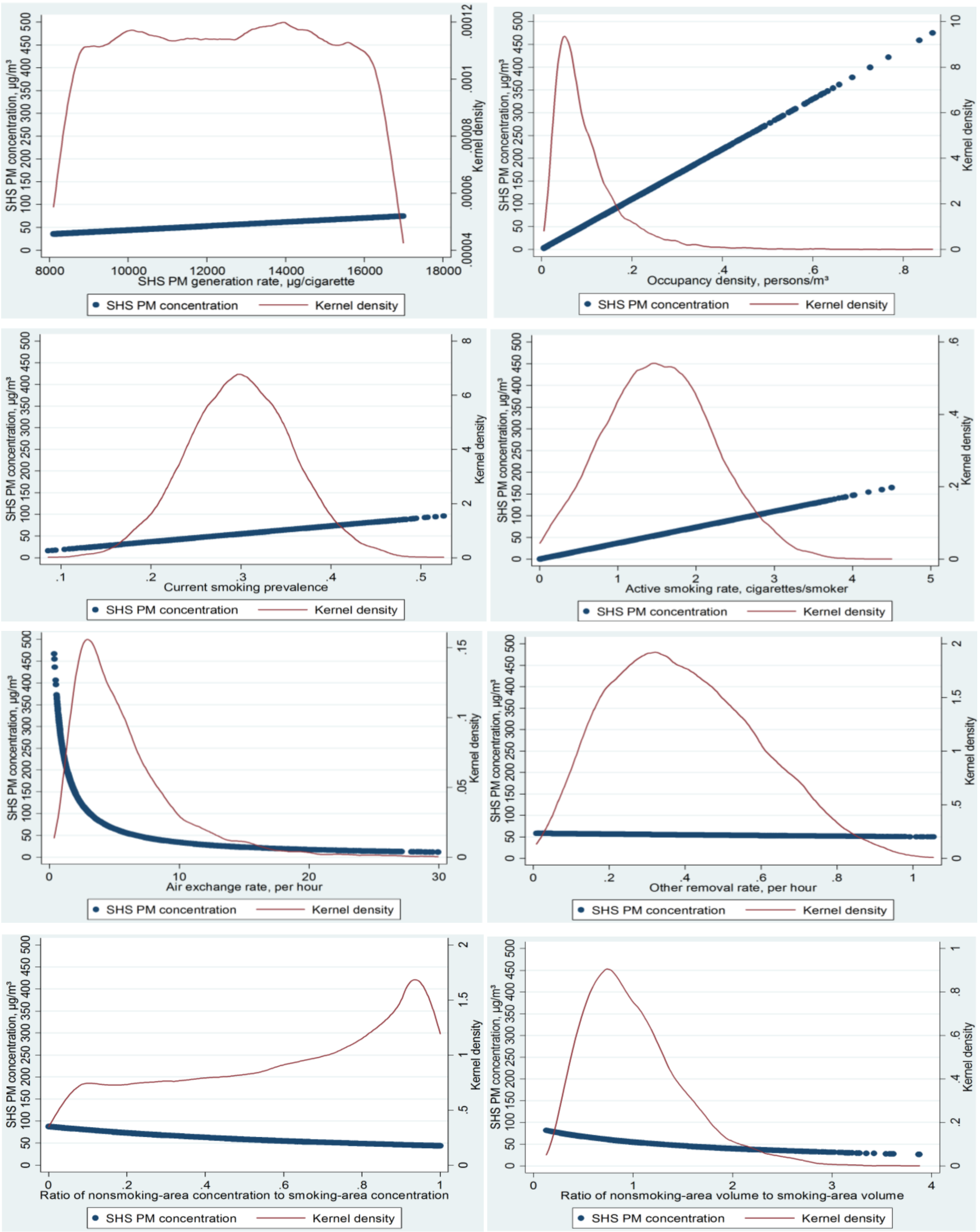


Figure 3.9 Sensitivity of simulated SHS PM concentrations to different parameters
Note: in each plot, the independent variable has a distribution as assumed in Table 3.2 and plotted in Kernel density in this figure; all other parameters are set to their means as assumed in Table 3.2

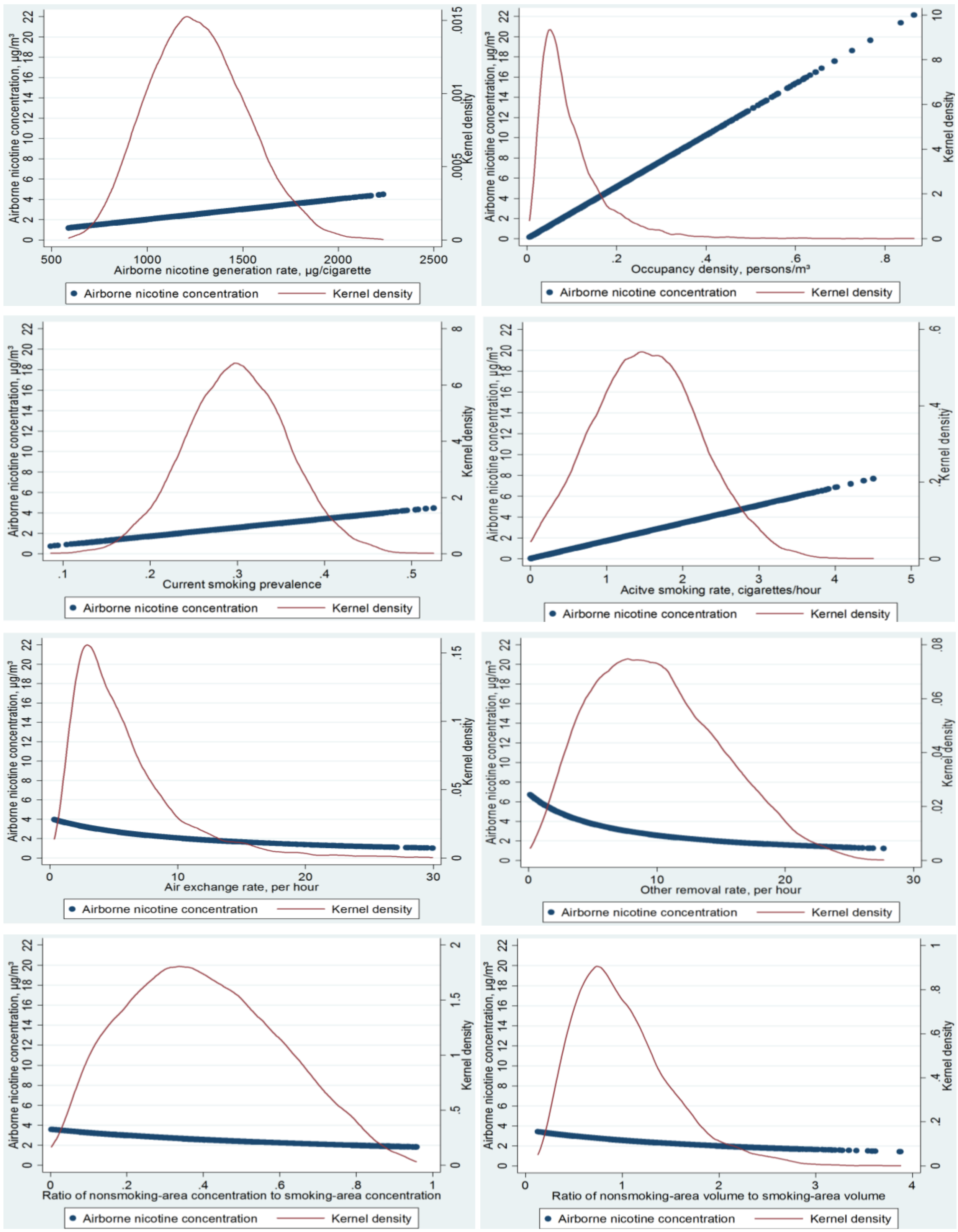


Figure 3.10 Sensitivity of simulated airborne nicotine concentrations to different parameters
Note: in each plot, the independent variable has a distribution as assumed in Table 3.2 and plotted in Kernel density in this figure; all other parameters are set to their means as assumed in Table 3.2

3.4 Discussion

Predicted SHS concentrations using mass balance equation 3.12 and field observations in Minnesota and Beijing restaurants and bars fitted reasonably well with field measurements, especially for SHS PM. Both their means and medians were quite comparable, with predicted SHS PM 66% to 124% of field measurements. Monte Carlo simulations of SHS PM concentrations in Minnesota smoking venues and designated smoking sections of restaurants and bars, respectively, also resulted in close estimate to field measurements conducted during representative patronage peak times in 65 representative restaurants and bars in Minnesota. Though simulated SHS concentrations based on information of U.S. restaurants and bars (and thus were intended to be representative of SHS concentrations across these venues) were comparable to field measurements reported in some studies while lower than field measurements in some other studies, those studies were not intended to measure SHS concentration in a representative sample of U.S. restaurants and bars. Any significant deviation of the actual parameter in those venues monitored in published studies from the parameter assumptions made for the simulation can result in significant differences. For example, the actual active smoking rates might be higher than assumed, or the ventilation rates might be lower that assumed. In all, it is reasonable to use the mass balance equations described in this chapter to estimate SHS PM concentrations in the specific type of microenvironment of restaurants and bars.

However, for airborne nicotine, the predicted concentrations did not fit so well with field measurements and their distributions were different from each other. This might be due to inappropriate assumptions for the surface absorption coefficient, for which information is limited in the literature; it might also be due to the complex physiochemical behavior of nicotine so that the mass balance equations described in this chapter might not be good enough to represent its emission and removal. There will be less confidence in the use of the mass balance equations to estimate airborne nicotine concentrations in the specific microenvironments of restaurants and bars.

Predicted SHS PM concentrations using mass balance equations and observed active smoking rates and estimated ventilation rates fitted reasonably well with field measurements in both Minnesota and Beijing restaurants and bars. Simulated SHS PM concentrations by Monte Carlo simulation using assumptions listed in table 3.1 were also distributed similarly with field measurements. These indicate that the models developed are valid in predicting SHS PM concentrations. These models can be useful for estimating short-term concentrations in restaurants and bars in regions or countries like China with limited field measurements, so as to advance exposure assessment and risk assessment and to provide important information for decision makers.

Field measurements of SHS PM in five Chinese cities in 2006 and 2007 (Table 3.9) showed that the mean SHS PM concentrations ranged from 71 to 178 μg/m^3 in smoking restaurants, comparable with simulated concentrations using equation 3.7 and assumptions listed in Table 3.2. The mean SHS PM was estimated to be 135 μg/m^3 for smoking restaurants. The mean concentrations of measured SHS PM in Beijing smoking bars in 2006 and 2007 and in Guiyang smoking bars in 2007 were also comparable with simulated concentrations, which mean was 261 μg/m^3, but concentrations measured in smoking bars in Wuhan, Xi'an and Kunming in 2007 were higher than predicted levels. Simulated results were higher than field measurements of SHS concentration indicated either by $PM_{2.5}$ or by airborne nicotine in 2008 and/or 2010 in Beijing when a partial smoking ban was implemented, which might lead to changed smoking behaviors among patrons.

Table 3.9 SHS PM and airborne nicotine concentrations in restaurants and bars with smoking permitted everywhere in Chinese cities by field measurements , μg/m^3

		city	year	N	mean	SD	median
SHS PM	Restaurants	Beijing	2006	65	144	175	68
			2007	62	178	210	111
			2008*	10	57	62	33
			2010*	34	82	80	38
		Wuhan	2007	59	136	166	74
		Xi'an	2007	58	157	179	90
		Guiyang	2007	63	102	126	72
		Kunming	2007	61	71	104	45
		China (by simulation)		10000	135	182	76
	Bars	Beijing	2006	10	223	252	109
			2007	14	195	269	44
			2008*	6	50	44	34
			2010*	15	83	83	61
		Wuhan	2007	14	664	469	777
		Xi'an	2007	14	470	390	320
		Guiyang	2007	14	181	172	140
		Kunming	2007	13	348	288	377
		China (by simulation)		10000	261	365	147
Nicotine	Restaurants	Beijing	2010*	34	3.48	3.18	2.25
		China (by simulation)		10000	4.58	6.18	2.75
	Bars	Beijing	2010*	15	4.23	4.82	2.78
		China (by simulation)		10000	8.59	11.57	5.21

* Since May 2008, the Beijing government implemented a smoking regulation requiring big restaurants (size not specified) ban or restrict smoking. Results of Beijing in 2008 and 2010 shown in this table were based on measurements in restaurants or bars without any nonsmoking sign observed.

The mass balance models described in this chapter can be used to estimate SHS concentrations in restaurants and bars, which can be used to assess servers and patrons’ exposure to SHS and related health risks due to their SHS exposure. Chapter 5 will present the work of assessing servers’ and patrons’ health risks due to SHS exposure in Chinese restaurants and bars, using SHS concentrations simulated in this chapter, together with related demographic and epidemiological information.

The mass balance models can also be used to explore strategies to control SHS exposure in restaurants and bars. There is no safe level of SHS exposure (USDHHS 2006; WHO 2009). The tobacco industry has advocated for designated nonsmoking sections for a long time. However, if the smoking sections and the nonsmoking sections are not completely separated (with some air changes between the two sections), the median SHS PM concentrations during peak patronage time is 49 μg/m^3 in restaurant nonsmoking sections in China, almost two times of the limit of 24-hour mean, 25 μg/m^3, as recommended by WHO (WHO 2005), and the estimated SHS PM concentrations are even higher in bar nonsmoking sections according to the Monte Carlo simulation. According to the uncertainty analysis, the models are sensitive to occupants' active smoking rate and venue ventilation rates. Only when smoking was eliminated in a venue, that is the active smoking rate becomes 0, can SHS exposure be completely eliminated. The American Society of Heating, Refrigerating and Air Conditioning Engineers states that ventilation is ineffective in protecting people from SHS exposure (ASHRAE 2008) and this can be easily illustrated by applying the mass balance models. Assuming that all the parameters are the same as the mean listed in Table 3.2, to control SHS PM level during peak patronage time in a restaurant no more than the 24-hour limit of 25 μg/m^3 recommended by WHO, the air change rate should be no less than 25/hr, more than 4 times of the default air change rate by the national Guideline JGJ 64-1989. It will be extremely expensive and thus unrealistic for a restaurant to maintain such a high air changing rate, while simply banning smoking is much more cost effective.

They are some limitations when using the models. First, the models are based on well-mixing and steady-state conditions, and an equilibrium between designated smoking section and nonsmoking section, which conditions may be difficult to met. Continuous monitoring of SHS concentrations for more than 20 hours in two Beijing restaurants (as described in Chapter 2) showed that though a well mixing condition was rarely met during any short time period of patronage peak times, it was almost met during relatively longer time periods, e.g., during a whole patronage peak time. Ott et al. showed that when the sampling time is relatively large compared to the pollutant detention time in a space, a trend correction can be neglected and a steady state may be assumed (Ott, Switzer et al. 1996). The average ventilation rate was assumed to be 4-6/hr^{-1}, which corresponded to a detention time of 10-15 minutes, is much smaller than a peak patronage time period, which averages about 2 hours. Thus, it is reasonable to assume a steady state if the models are used to estimate average exposure concentrations during a whole peak patronage time. Second, input parameters, including the smoking prevalence of restaurant or bar patrons and ventilation rate, were based on extrapolation from existing studies, rather than direct observations or measurements from representative field studies. This may introduce large uncertainties to the results. These input parameters are variables for which direct observation or measurements should be made in future studies. Third, it is difficult to explain simulated results by modeling to the general population, which may limit the use of simulated results for purpose of public health education campaigns.

3.5 Conclusions

It is reasonable to use the mass balance models described in this chapter to predict SHS PM concentrations in restaurants and bars; the models can be used in different regions or countries, with adjustment of assumptions of parameters to be related to the specific regions or countries. The models are also of potential use in the exploration of strategies on control SHS exposure in restaurants and bars, and they support the hypothesis that banning smoking is the only cost effective way to eliminate SHS exposure, while setting designated nonsmoking sections and improving ventilation rate is not cost effective.

Chapter 4 Evaluation of the Efficacy of Smoking Restrictions in Restaurants and Bars

4.1 Background

Smoking restrictions to prevent people from SHS exposure have evolved over time. In the 1960s, there was already strong evidence that smoking could cause lung cancer, which gave rise to the suspicion that SHS exposure could cause similar dangers; in the late 1960s and 1970s, Bulgaria, Singapore and Norway initiated restrictions on smoking in some public places; as evidence of the health hazards of SHS exposure became stronger in the 1980s, more countries or jurisdictions started to restrict smoking in workplaces and public places. New Zealand was the first country to restrict smoking to designated areas in restaurants or other licensed venues serving food in 1990. In 1998, California became the first jurisdiction in the world to implement comprehensive smoking bans in all workplaces, including restaurants and bars (IARC 2009). In 2003, WHO adopted the Framework Convention of Tobacco Control (WHO FCTC); many countries ratified the treaty, agreeing to reduce SHS exposure as recommended by Article 8 of the treaty. Based on best practice worldwide in the implementation of smoke-free measures, the Conference of the Parties to the WHO FCTC unanimously approved the guidelines of implementing Article 8 in 2007. These guidelines identified seven principles of effective legislation protecting people from SHS exposure:

Principle 1. Effective measures to provide protection from exposure to tobacco smoke, as envisioned by Article 8 of the WHO Framework Convention, require the total elimination of smoking and tobacco smoke in a particular space or environment in order to create a 100% smoke free environment. There is no safe level of exposure to tobacco smoke, and notions such as a threshold value for toxicity from second-hand smoke should be rejected, as they are contradicted by scientific evidence. Approaches other than 100% smoke free environments, including ventilation, air filtration and the use of designated smoking areas (whether with separate ventilation systems or not), have repeatedly been shown to be ineffective and there is conclusive evidence, scientific and otherwise, that engineering approaches do not protect against exposure to tobacco smoke.

Principle 2. All people should be protected from exposure to tobacco smoke. All indoor workplaces and indoor public places should be smoke free.

Principle 3. Legislation is necessary to protect people from exposure to tobacco smoke. Voluntary smoke free policies have repeatedly been shown to be ineffective and do not provide adequate protection. In order to be effective, legislation should be simple, clear and enforceable.

Principle 4. Good planning and adequate resources are essential for successful implementation and enforcement of smoke free legislation.

Principle 5. Civil society has a central role in building support for and ensuring compliance with smoke free measures, and should be included as an active partner in the process of developing, implementing and enforcing legislation.

Principle 6. The implementation of smoke free legislation, its enforcement and its impact should all be monitored and evaluated. This should include monitoring and responding to tobacco industry activities that undermine the implementation and enforcement of the legislation.

Principle 7. The protection of people from exposure to tobacco smoke should be strengthened and expanded, if necessary. Such action may include new or amended legislation, improved enforcement and other measures to reflect new scientific evidence and case-study experiences.

The adoption of the WHO FCTC and the availability of technical support from WHO resulted in the rapid diffusion of smoke-free legislation around the world (IARC 2009). As of January 2012, a total of 66 nations worldwide have enacted 100% smoke-free law in workplaces and hospitality venues, 46 of the 66 including both restaurants and bars (ANRF 2012). Though restaurants and bars are important workplaces and public places, they are often exempted from smoking bans. Table A1 in Appendix lists the 100% smoking policies in restaurants and bars in different countries. Smoke-free legislations in some countries or jurisdictions have been very successful and completely adhere to the guidelines, such as those in California, Ireland, New Zealand, Scotland, Uruguay, etc., while some others have implemented legislation with looser standards, including Cuba, Denmark, Germany, and Switzerland, etc.

Eisner et al. published a paper on evaluating the effect of the California smoking ban in bars and taverns on bartenders' exposure to SHS and their symptoms of respiratory and sensory irritation in 1998 (Eisner, Smith et al. 1998). Since then, with the increasing number of smoking bans, the studies on evaluating the effect of smoking restrictions have been increasing. WHO International Agency for Research on Cancer (IARC) reviewed 27 papers published from 1998 to 2007 on reductions in SHS exposure and effects on health due to smoking restrictions around the world (IARC 2009). Polanska et al. reviewed 12 papers published from 2000 to 2009 on hospitality workers' SHS exposure before and after implementation of smoking bans in public places (Polanska, Hanke et al. 2011). At least 10 studies on this topic have been published since 2009.

In China, 63% of adult males were current smokers in 1996, 57% in 2002 and 54 % in 2010, while current smoking rate of females were lower than 4%. The huge difference of current smoking rate between genders indicates that SHS exposure is a serious issue for both females and children. A total of 740 million nonsmokers were potentially exposed in 2010, including 182 million children exposed. Of those nonsmoking adults exposed to SHS, 72% were in public places, compared to 67% at homes and 63% in work places in 2010 (Xiao, Yang et al. 2010). SHS was estimated to cause 22,000 lung cancer deaths and 33 800 ischaemic heart disease deaths in 2002, with women bearing 80% of the total burden (Gan, Smith et al. 2007). However, smoke-free legislation in China is quite limited.

In 1979, the Chinese Ministry of Health and the ministries of Finance, Agriculture and Light Industry issued a notice named *Circular on the Publicity of the Harms of Smoking and Tobacco Control* (关于吸烟有害与控制吸烟的通知), the first official document on tobacco control in China (Kinglun Ngok and Dian Li 2010). Since then the Central Patriotic Public Health Campaign Committee, the Ministry of Railways and the Civil Aviation Administration of China have also made their own separate announcements of prohibiting smoking in public transportation and restricting smoking in public places. The first anti-tobacco legislation in China, the *People's Republic of China Tobacco Monopoly Law* (中华人民共和国烟草专卖法), was passed in 1991 and took effect in 1992. As well as mandating scientific research and technological development of tobacco monopoly commodities to improve the quality of tobacco products and reduce tar and other hazardous materials in these products, the law also prohibits or restricts smoking on public transports and in public places and bans smoking by students. The *Law on the Protection of Minors* (未成年人保护法), also passed in 1991, prohibits smoking in classrooms, dorms and activity halls of middle or elementary schools, kindergartens, daycare centers and other social venues for minors.

Since the 1980s, the government has issued regulations to restrict smoking in public places. In 1987, the State Council promulgated the *Health Regulations in Public Places* (公共场所卫生管理条例); in 1991, the Ministry of Health issued implementation details for these regulations, which banned smoking in sports stadiums, libraries, museums, art galleries/museums, shopping malls, book stores, waiting rooms of public transportation and trains, ferries and passenger planes. In 1997, the *Smoking Ban in Public Transports and Waiting Rooms* (关于在公共交通及其等候室禁止吸烟的条例) was passed, prohibiting or restricting smoking in airplanes, trains, ships, buses, subways, etc. Some provinces and cities also passed their own regulations restricting smoking in public places. By October 2006, about 46% of the cities in China had some kind of smoking restrictions, mostly including hospitals, schools, post offices, financial business halls and public places listed by the national regulations listed above. However, smoking in hospitality venues is generally not regulated (Yang, Jiang et al. 2008).

In 2006, the WHO FCTC became effective in mainland China (WHO 2011). Since then, smoking policies changed rapidly in public places, especially in restaurants. In January 2007, the Beijing Health Bureau and the Chinese Center for Disease Control and Prevention (CDC) called for voluntary smoking bans in restaurants in Beijing. On May 1st 2008, the Beijing government passed a regulation requiring large restaurants (the dimensions were not specified) within the city to prohibit or restrict smoking. Several other big cities, including Shanghai, Guangzhou, Hangzhou, and Yinchuan, have followed Beijing in the regulation of smoking in public places. Because the government is commited to the WHO FCTC, China must provide universal protection against SHS exposure within five years of the treaty's entry into force in China (WHO 2011). On May 1st 2011, the Chinese Ministry of Health implemented the revised implementation guidelines of the *Health Regulations in Public Places* (公共场所卫生管理条例) issued in 1987 to tighten its rules ofrestricting smoking in all indoor public places including restaurants and bars. See Figure 4.1 for the changes of smoking policies in Beijing from 2006 to 2011.

However, because the State Tobacco Monopoly Administration (STMA) plays an important role in developing, passing and enacting tobacco control policies, and tax revenue is an important part of local governmental revenues (Kinglun Ngok and Dian Li 2010), both national and local smoke-free legislations do not meet the recommendations outlined by the guidelines of implementing Article 8 of WHO FCTC.

Since smoke-free policies in restaurants and bars have just recently come to the attention of the Chinese population, there is little evidence on evaluating their efficacy. Given that China has about one-third of the world's total smokers (CDC 2010), it is important to add the evidence from China to the existing pool of scientific literature on smoking policy evaluation. The rapid changes of smoking policies in Beijing restaurants and bars provide a good opportunity to evaluate the efficacy of different policies. Environmental SHS concentrations in restaurants and bars have been monitored in the years 2006, 2007, 2008 and 2010 (Figure 4.2), with overlaps of venues in each two years (Figure 4.3). This chapter will compare the smoking restrictions in restaurants and bars to the guidelines of Article 8 of the WHO FCTC, and evaluate the efficacy of different smoking policies adopted from 2006 to 2010 in Beijing restaurants and bars using the data collected in those four years. To compare the evaluation results to other studies, a review of the literature on evaluating smoking restrictions in restaurants and bars was also conducted.

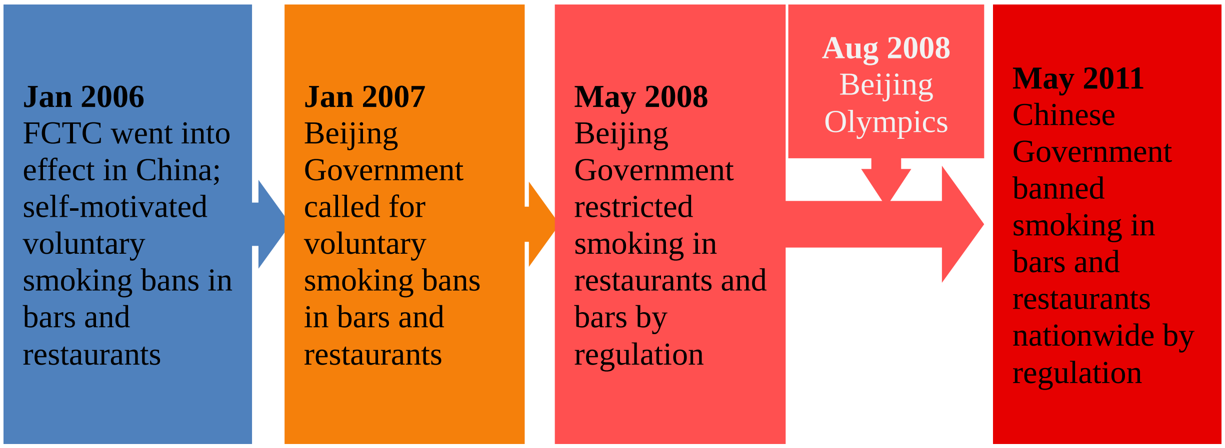


Figure 4.1 Tobacco control activities in restaurants and bars from 2006 to 2011
FCTC: Framework Convention of Tobacco Control

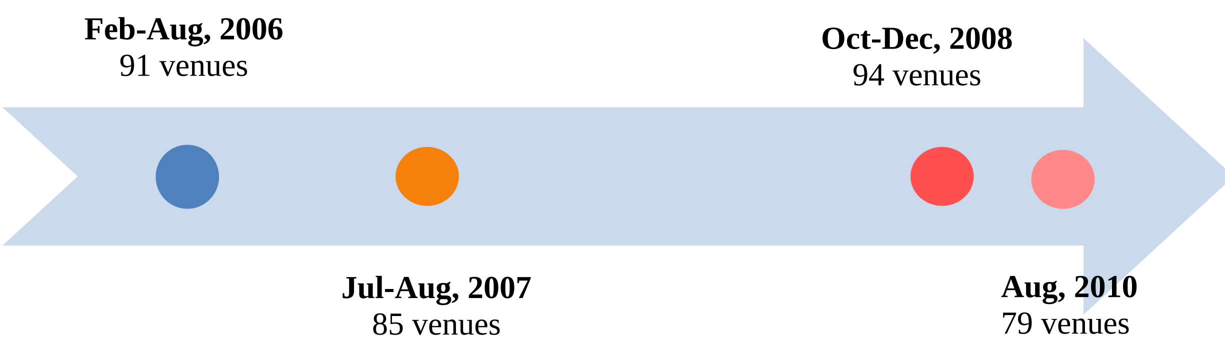


Figure 4.2 Timeline of SHS monitoring in restaurants and bars in Beijing from 2006 to 2010

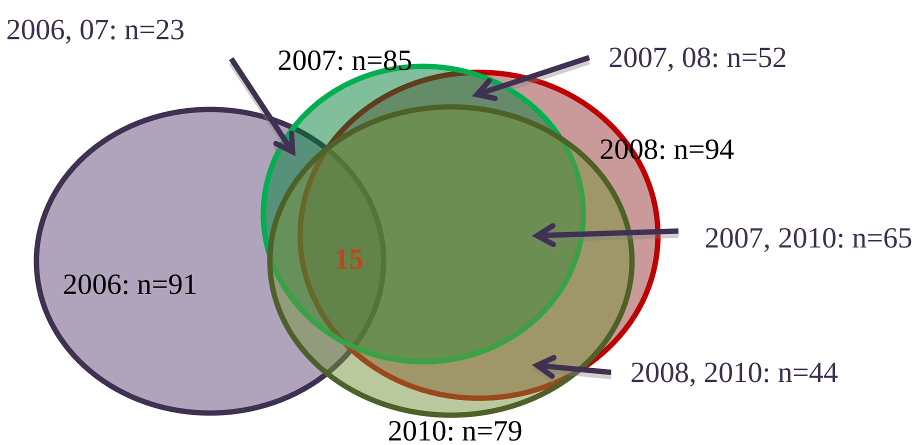


Figure 4.3 Sample size and sample overlaps of venues of the four studies from 2006 to 2010

4.2 Methods

4.2.1 Comparing Smoking Restrictions in China to the Implementation of Guidelines of the WHO FCTC Article 8

Regulations restricting smoking in China were compared with the key principles of effective legislation protecting people from SHS exposure, as identified by the guidelines of implementing Article 8 of the WHO FCTC.

4.2.2 Evaluating the Efficacy of Different Smoking Policies in Beijing Restaurants and Bars

Data collected by four studies conducted from 2006 to 2010 were used to evaluate the efficacy of different smoking policies in Beijing Restaurants and Bars: self-motivated voluntary smoking bans by restaurant and bar owners, government-encouraged voluntary smoking bans, and governmental regulatory smoking restrictions (Figure 4.1).

4.2.2.1 SHS monitoring from 2006 to 2008

According to the Standards of Industry Classification issued by the National Statistics Agency of China, hospitality venues are classified into five categories: Chinese restaurants, Chinese fast food restaurants, Western restaurants, Western fast food restaurants, and bars. In 2006, a convenience sample was selected from each of these categories in different districts of Beijing, with consideration of venue size and average expenses per patron per visit; a total of 92 venues (82 restaurants and 10 bars) were selected. In 2007, a similar sampling approach was used, except that venue selection was restricted to two of the eight districts due to logistical issues. Venues were sampled from each of the five categories in the ratio of 10:1:1:1:3 according to the number of restaurants and bars listed on website yellow page, Venues monitored in 2006 in these two districts were also included. Twenty one restaurants and two bars were followed from 2006 to 2007, and another 50 restaurants and 12 bars located in the same two districts were conveniently selected, resulting in 85 venues (71 restaurants and 14 bars) included in 2007. In 2008, the Chinese CDC released a list of the first 100 restaurants which prohibited or restricted smoking as required by the 2008 smoking regulation. Forty four venues were conveniently selected from that list and 52 from the list of venues monitored in 2007, with data from 94 venues (87 restaurants and seven bars) available for analysis.

The same standard protocol for data collection was used from 2006 to 2008. Trained staff from the Chinese CDC visited each venue during peak patronage times as patrons, sat on a table as close to the center of the dining area as possible, bought some food or drinks, placed a bag with a real-time fine particulate matters ($PM_{2.5}$) monitor (TSI SidePak AM510 Aerosol Monitor, TSI, St. Paul, Minnesota, USA) on the table or a chair, with the sampling inlet close to the breathing zone, and monitored $PM_{2.5}$ concentrations for at least 30 minutes. They asked servers about the smoking policy in the venue, examined whether there were any nonsmoking signs, and counted the number of total patrons and active smokers right after entering and before leaving the dining area and every 15 minutes during their stay there. They also measured the dimensions of the dining area with a sonic meter or estimated the dimensions when the area was irregular in shape. Outdoor $PM_{2.5}$ concentrations were also monitored for at least five minutes either right before entering or after leaving each venue. For each visit, the difference between the average indoor and outdoor $PM_{2.5}$ concentration was multiplied with an adjustment factor of 0.32, suitable for SHS (Hyland, Travers et al. 2008), and was taken as SHS related $PM_{2.5}$ (SHS PM). For venues with designated smoking and nonsmoking sections, all the measurements and observations were made in nonsmoking sections only. Field work was conducted from February to August in 2006, July to August in 2007 and October to December in 2008.

4.2.2.2 SHS monitoring in 2010

Details of venue selection and SHS monitoring in 2010 were presented in Chapter 2. A total of 79 venues were included in 2010, with 65 venues included in the 2007 study, 44 included in the 2008 study, and 15 monitored in all the four years from 2006 to 2010. See Figure 2.1 in Chapter 2 for details of venue selection. In all these venues, $PM_{2.5}$ measurements and observations during peak patronage times were conducted following the same protocol used from 2006-2008, except that they were made for one hour indoor, simultaneously in both designated smoking and nonsmoking sections whenever possible, and during both lunch and dinner times in some venues. Airborne nicotine was also sampled during peak patronage time, using filters (EMFAB, Pall part #7217) treated with sodium bisulfate and pumps with flow rate set to 2 L/min. Each team of two investigators carried one field nicotine filter blank each day. In addition, 43 volunteer nonsmoking servers who worked full daytime shifts were recruited to conduct personal airborne nicotine sampling (Chapter 2). The monitor protocol was approved by the Committee for Protection of Human Subjects at University of California, Berkeley.

4.2.2.3 Data analysis

Both cross-sectional and longitudinal comparisons of SHS concentrations and patrons' smoking behaviors were conducted by different nominal smoking policies or changes of smoking policies. SHS was indicated by SHS PM or air nicotine, and patrons' smoking behavior was indicated by active smoking rate (ASR, percentage of adult patrons that were observed smoking anytime during sampling). The nominal smoking policy in a venue was defined according to investigators' observations during peak-patronage-time sampling. If only nonsmoking signs were observed and no smoking sections were observed, it was categorized as prohibiting smoking and the venue was referred to as a nonsmoking venue; if both smoking and nonsmoking signs were observed, it was categorized as restricting smoking and the venue was referred as a venue restricting smoking; and if nonsmoking signs were not observed anywhere or no non-smoking section was observed, it was categorized as allowing smoking and the venue was referred to as a venue allowing smoking. For venues with monitoring during both lunch and dinner times in 2010, the average of these two periods were used.

Data on both SHS concentrations and patrons' smoking behaviors were skewed and nonparametric analysis were used. StataIC11 (College Station, Texas) was used for all the data analysis.

4.2.3 Literature Review of Studies on Evaluating the Efficacy of Smoking Restrictions in Restaurants and Bars

Almost all published papers on this topic have been based on pre- and post- restriction changes on one or multiple aspects of the following: self-reported SHS exposure, self-reported SHS-related health symptoms like respiratory and sensory irritation symptoms, airborne concentrations of SHS tracer(s), biomarker concentrations of SHS tracer(s), site inspection on patrons' and/or servers' smoking behavior in restaurants and bars, presence of nonsmoking signs or ashtrays, etc. Because regulations are most often based on airborne concentrations of a pollutant of interest in the environment and intended to reduce the concentration to a certain level perceived to be safe, environmental measurements provide the most relevant evidence of evaluating a regulation. Thus, the literature review in this chapter focused on changes of environmental concentrations of SHS tracers in restaurants and bars after a smoking restriction. In addition, the literature review focused on studies using the two most commonly used tracers, airborne nicotine and $PM_{2.5}$ (or respirable suspended particles [RSP] in some studies), though some studies also measured other tracers, like carbon monoxide, 3-EP, PPAH, etc.

Literature search was conducted via the Web of Knowledge website using a combination of any one of the three terms: "secondhand smoke"; "environmental tobacco smoke"; and "tobacco smoke pollution" with ("and") any one of the four terms "restaurant", "bar", "public places" or "hospitality". A total of 446 papers were identified after excluding duplicates and papers in languages other than English. Abstracts of these 446 papers were screened to identify related studies. Papers were excluded if they met any one of the following criteria: 1) did not evaluate any smoking policy; 2) did not include any restaurants or bars; 3) were reviews; 4) did not include any environmental measurements (either by area sampling or personal airborne SHS sampling); or 5) did not report any statistic metrics of mean, median or geometric mean of measurements or did not provide data to derive any of those statistic metrics. If two or more studies used the same data, the most recently published one was included.

All identified studies were summarized; SHS concentrations indicated by airborne nicotine and particulate matter before and after related smoking restrictions were contrasted by bar graphs. When multiple statistical metrics were reported, a statistical metric was chosen based on the following priority: median, geometric mean and arithmetic mean, to represent SHS concentrations of interest. These metrics were used to calculate the percentage decrease of SHS concentrations after a related smoking restriction compared to pre-ban levels (percentage change = (1-postban level/preban level) × 100%). Thus the percentage change reported in this chapter might be different from the ones reported in the original papers due to the use of different statistic metrics for the calculation.

4.3 Results

4.3.1 Comparing Smoking Restrictions in China to the Implementation Guidelines of the WHO FCTC Article 8.

Compared with the guidelines of implementing Article 8 of the WHO FCTC, smoking regulations in China, including the Beijing governmental regulation in 2008 and the tightened smoking restrictions in all indoor places national wide in 2011, are much weaker in the following aspects:

1) They do not clearly specify that 100% smoke free environments are required, and designated smoking areas are allowed (except the tightened smoking restrictions in all indoor places nationwide in 2011, which does require 100% smoke free environments).

2) In many regulations, only certain types of public places are included; restaurants and bars, especially those with small areas, are often exempted; in the tightened smoking restrictions in all

indoor places national wide in 2011, definition of public places where smoking should be banned is not clear and is limited to 13 types of places like cinemas, shopping malls, public transportations, etc.. They do not include all public places, and thus do not provide universal protection of all people.

3) They do not specify authorities responsible for enforcement.

4) They do not clarify fines or other monetary penalties for violations.

Details of comparison are listed in Table 4.1.

Table 4.1 Comparisons between local and the 2011 national smoking restriction in China and the guidelines of FCTC Article 8

FCTC Article 8 guidelines (WHO 2007)	**local and national smoke-free restrictions in China(Yang and Hu 2010; Chinese CDC 2011)**
create 100% smoke free environment	not 100% smoke free, designates smoking areas allowed (except the 2011 smoking restriction)
universal protection from SHS exposure in all indoor workplaces and all indoor public places	poor definition of public places; not including all indoor workplaces
legislation is necessary to protect people from SHS exposure; voluntary smoke free policies do not provide adequate protection; legislation should be simple, clear and enforceable	No specific regulations to restrict smoking; all smoking restrictions are just one small section of regulations of much broader issue, such as public health; the 2011 smoking restriction was just mentioned in one article of the revised implementation guidelines of *Health Regulations in Public Places*; restrictions are vague and not enforceable.
good planning and adequate resources for implementation and enforcement	Limited planning and resources for implementation and enforcement
• specify duty of compliance, including post clear signs, remove any ashtrays, supervise the observance of rules and talk reasonable specified steps to discourage smoking	• no specification on what reasonable steps should be taken to discourage smoking
• specify fines or other monetary penalties for violations	• no specification on penalties for violation
• identify the authority or authorities responsible for enforcement and include a system both for monitoring compliance and for persecuting violators	• no specification on the authority responsible for enforcement
involve civil society in the process of developing, implementing and enforcing legislation: raising awareness among the public and opinion leaders about the risks of SHS exposure, public education campaigns to pass key message on SHS hazards, effective measures to eliminate SHS and economic impacts, broad consultation with stakeholders to educate and mobilize the community and to facilitate support for legislation	limited public education and campaigns; poor public awareness of health hazards from SHS exposure; poor public awareness of the smoking restrictions; limited involvement of civil society in the process of developing, implementing and enforcing the smoking restrictions
monitor and evaluate the implementation and enforcement of smoke free legislation	limited sources and efforts on the monitoring and evaluation
strengthen and expand the protection of people from SHS exposure by including new or amended legislation, and improving enforcement and other measures	More and more public places are included, however, enforcement remains poor

4.3.2 Evaluating the Efficacy of Different Smoking Policies in Beijing Restaurants and Bars

4.3.2.1 Cross-sectional analysis of the four studies

Smoking was observed in two of the 16 nonsmoking venues/sections in 2006 and only in venues allowing smoking in 2007, while in 2008 and 2010, smoking was observed in half of the nominal nonsmoking venues or sections (Figure 4.4). The median (inter quantile range, IQR) of SHS PM concentrations in restaurants and bars was 53 (6-173), 83 (19-197), 18 (1-46), and 27 (4-93) $\mu g/m^3$ in 2006, 2007, 2008, and 2010, respectively. For the first three years, observed active smoking rate (ASR) was lowest in nonsmoking venues, followed by nonsmoking sections. In 2010, it was higher in nonsmoking venues than in nonsmoking sections. Similar trends were observed for SHS PM (Table 4.2). Kruskal-Wallis rank tests showed that in each year, both ASR and SHS PM levels were significantly different among venues or sections with different nominal policies. In all the four years, SHS PM levels were much higher in venues or sections where smoking was observed than where smoking was not observed (Table 4.2). Two-sample Kolmogorov-Smirnov tests showed no significant difference of ASR or SHS PM in restaurants and in bars each year (data not presented).

4.3.2.2 Longitudinal changes of SHS concentrations and patrons' smoking behavior

None of the 23 venues followed from 2006 to 2007 changed their smoking policies, and both ASR and SHS PM increased non-significantly ($p > 0.1$) (Table 4.3). Compared to 2007, 31 venues adopted stricter smoking policies (which changed from allowing smoking to restricting/prohibiting smoking or from restricting to prohibiting smoking) in 2008 and 33 in 2010, with the median SHS PM level decreased 79% ($p = 0.0001$) in 2008 and 72% in 2010 ($p = 0.0025$); in venues without any policy changes, SHS PM levels reduced 82% ($p=0.0009$) in 2008 and 47% in 2010 ($p=0.034$). That is, SHS PM concentrations in 2008 and 2010 all decreased significantly, compared to 2007, regardless of smoking policy changes. ASR among patrons decreased non-significantly in venues with stricter smoking policies in 2008 or 2010, but increased non-significantly in those venues without policy changes. Five of the 44 venues followed from 2008 to 2010 adopted stricter smoking policies while seven changed to less strict ones. Neither SHS PM levels nor ASR changed significantly (all $p > 0.2$) in these 44 venues, regardless of their policy changes (Table 4.3).

A total of 15 venues were followed in four years from 2006 up until 2010. Two venues restricted smoking in 2006 and 2007. Six prohibited smoking and four restricted smoking in 2008, with four of these 10 venues with smoking observed during sampling. In 2010, one restaurant changed its smoking policy from restricting to prohibiting smoking while four venues changed to less strict smoking policies or allowing smoking again. Smoking was observed in four of the seven nonsmoking venues or sections. SHS PM concentrations changed randomly from 2006 to 2007, and decreased in most venues in 2008, except in one which newly prohibited smoking in 2008 while 5% of the adult patrons were observed smoking. SHS PM concentrations in 2010 all increased to some extent compared to 2008, except in five venues (Table 4.4 and Figure 4.5). Non-parametric trend test showed no significant trend during the four years ($p = 0.15$).

4.3.2.3 Simultaneous monitoring in designated smoking sections and nonsmoking sections in 2010

Simultaneous observations and sampling were conducted in nominally designated smoking and non-smoking sections of 15 venues restricting smoking in 2010. ASR in designated smoking sections [mean (SD): 6.6% (5.5%); median (IQR): 4.7% (1.0%-12.4%)] was significantly higher than that in designated nonsmoking sections [mean (SD): 0.5% (1.0%); median (IQR): 0 (0-0.7%)]. The median airborne nicotine level in designated nonsmoking sections [mean(SD): 1.4 (1.7) μg/m^3; median (IQR): 0.6 (0.3–2.1) μg/m^3] was about 40% of that in designated smoking sections [mean(SD): 4.4 (5.4) μg/m^3; median (IQR): 1.5 (1.1–6.7) μg/m^3] and this was also true for SHS PM levels [designated nonsmoking sections: mean(SD): 27 (24) μg/m^3, median (IQR): 24 (11–39) μg/m^3; smoking sections: mean(SD): 96 (90) μg/m^3, median (IQR): 62 (16–198) μg/m^3]. Wilcoxon matched-pairs signed-rank test showed $p < 0.01$ for comparison of each of these indicators between designated smoking and nonsmoking sections.

4.3.2.4 Full-shift personal airborne nicotine sampling in 2010

For the eight volunteers working in venues allowing smoking, the mean (SD) of their time weighted average nicotine levels during their working shifts was 3.6 (2.2) μg/m^3, and the median (IQR) was 3.0 (1.7-5.9) μg/m^3. For volunteers working in venues nominally prohibiting smoking (19 subjects) or restricting smoking (13 subjects), their airborne nicotine levels were quite similar, with a mean (SD) of 3.4 (2.8) μg/m^3 and 3.4 (2.6) μg/m^3, respectively, and a median (IQR) of 2.54 (1.1, 5.4) μg/m^3 and 2.5 (1. 2, 5.7) μg/m^3, respectively. Kruskal-Wallis test showed no difference of nicotine level exposure of volunteers working in venues with different nominal smoking policies (Figure 4.6).

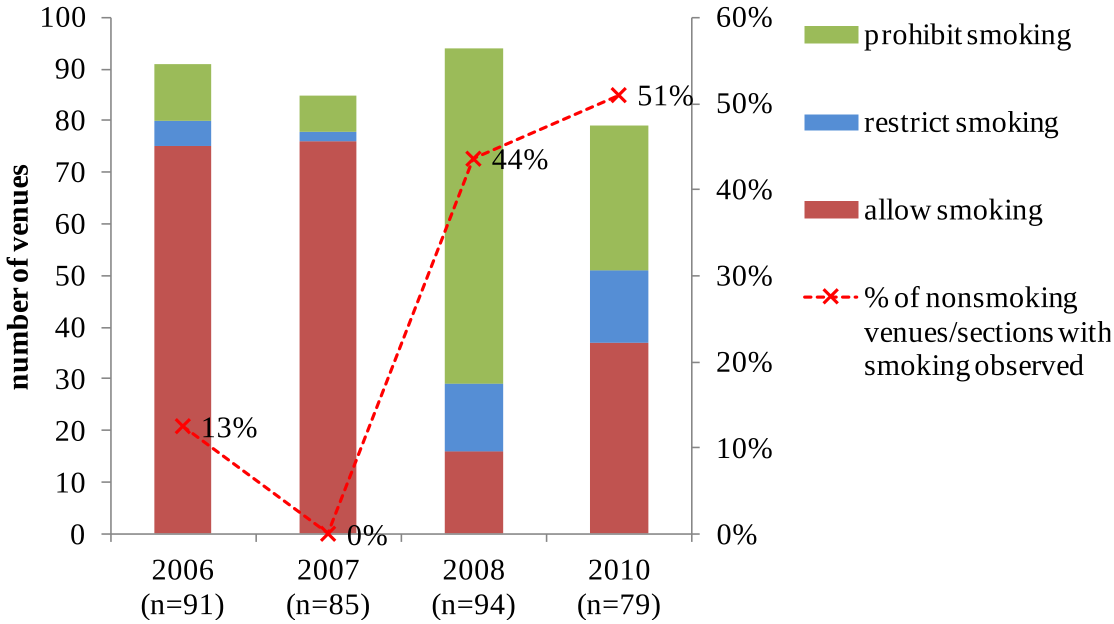


Figure 4.4 Nominal smoking polices and percentage of nominally nonsmoking venues/sections with smoking observed in each year

Notes: prohibit smoking: smoking was not allowed at all, with nonsmoking signs only in the venue; restrict smoking: smoking was allowed in designated smoking sections, with both nonsmoking signs and smoking signs in the venue; allow smoking: smoking was allowed everywhere in the venue, with no non-smoking signs at all.

Table 4.2 SHS PM concentrations and active smoking rates (ASR) in venues by smoking policies, Beijing, China, 2006-2010

	n of visits	SHS PM (μg/m³)		ASR (%)	
		mean (SD)	median (IQR)	mean (SD)	median (IQR)
2006					
Nominal Policy			***p* = 0.0001**		***p* = 0.0001**
nonsmoking venues	11	4 (7)	0 (0-9)	0.00 (0.00)	0.00 (0.00-0.00)
nonsmoking sections	5	18 (17)	22 (0-34)	2.52 (5.26)	0.00 (0.00-0.71)
smoking venues	75	154 (187)	71 (23-220)	4.65 (4.02)	3.66 (1.85-6.64)
Smoking Observed or Not			***p* <0.0001**		***p* <0.0001**
no	20	45 (120)	0 (0-20)	0.00 (0.00)	0.00 (0.00-0.00)
yes	71	152 (186)	71 (29-181)	5.09 (4.00)	3.85 (2.13-6.69)
Total	91	129 (179)	53 (6-173)	3.97 (4.11)	3.16 (0.71-6.10)
2007					
Nominal Policy			***p* = 0.0009**		***p* = 0.0003**
nonsmoking venues	7	10 (21)	0 (0-14)	0.00 (0.00)	0.00 (0.00-0.00)
nonsmoking sections	2	4 (5)	4 (1-8)	0.00 (0.00)	0.00 (0.00-0.00)
smoking venues	76	181 (221)	108 (31-234)	5.27 (5.65)	3.34 (1.45-7.65)
Smoking Observed or Not			***p* <0.0001**		***p* <0.0001**
no	23	54 (100)	14 (0-59)	0.00 (0.00)	0.00 (0.00-0.00)
yes	62	204 (232)	119 (37-267)	6.45 (5.60)	5.48 (2.17-8.82)
Total	85	163 (215)	83 (19-197)	4.71 (5.58)	2.68 (0.00-6.98)
2008					
Nominal Policy			***p* = 0.042**		***p* = 0.004**
nonsmoking venues	65	36 (65)	8 (0-38)	1.59 (2.49)	0.00 (0.00-2.94)
nonsmoking sections	13	26 (28)	14 (5-29)	2.49 (2.81)	0.91 (0.38-5.00)
smoking venues	16	55 (54)	33 (16-77)	5.08 (5.09)	4.68 (0.00-6.83)
Smoking Observed or Not			***p* <0.0001**		***p* <0.0001**
no	49	13 (22)	5 (0-19)	0.00 (0.00)	0.00 (0.00-0.00)
yes	45	64 (75)	36 (18-78)	4.82 (3.34)	4.74 (2.74-5.88)
Total	94	38 (60)	18 (1-46)	2.31 (3.34)	0.00 (0.00-4.17)
2010					
Nominal Policy			***p* = 0.046**		***p* = 0.0001**
nonsmoking venues	51	79 (171)	27 (0-72)	3.01 (4.57)	0.85 (0.00-4.27)
nonsmoking sections	21	22 (24)	15 (1-36)	0.52 (0.93)	0.00 (0.00-0.68)
smoking sections	16	90 (90)	43 (7-198)	6.47 (5.33)	4.43 (1.63-12.22)
smoking venues	33	78 (76)	40 (8-152)	5.93 (5.85)	4.66 (2.82-8.10)
Smoking Observed or Not			***p* <0.0001**		***p* <0.0001**
no	44	47 (155)	4 (0-28)	0.00 (0.00)	0.00 (0.00-0.00)
yes	77	84 (99)	44 (22-134)	5.81 (5.13)	4.17 (2.47-8.17)
Total	121	70 (124)	27 (4-93)	3.83 (5.09)	2.31 (0.00-5.56)

Notes: *p* values are based on Kruskal-Wallis rank tests for subgroups under "Nominal Policy" and two-sample Kolmogoror-Smirnov tests for subgroups under "Smoking Observed or not";

Table 4.3 Longitudinal comparison of SHS PM concentrations and active smoking rates (ASR) in venues followed in different years, Beijing, China, 2006-2010

changes of smoking policies [a]	SHS PM concentrations					ASR			
	median (IQR), μg/m^3			change (%) [b]	p [c]	median (IQR) (%)		change (%) [b]	p [c]
	n	baseline	follow-up			baseline	follow-up		
2007 vs. 2006									
no changes	23	36 (10-89)	93 (8-293)	+158	0.16	2.30 (0.00-6.69)	2.68 (0.00-6.64)	+17	0.71
2008 vs. 2007									
stricter	31	105 (29-197)	22 (8-46)	-79	0.0001	2.97 (1.68-6.62)	2.17 (0.00-5.00)	-27	0.07
no changes	21	111 (14-267)	20 (5-66)	-82	0.0009	1.71 (0.00-6.02)	1.82 (0.00-5.88)	+ 6	0.87
total	52	108 (20-234)	21 (7-50)	-81	0.0001	2.45 (1.27-6.44)	2.00 (0.00-5.22)	-18	0.14
2010 vs .2007									
stricter	33	88 (29-134)	25 (3-53)	-72	0.0025	2.88 (1.52-6.25)	1.15 (0.00-3.63)	-60	0.06
no changes	32	53 (3-184)	28 (0-101)	-47	0.034	1.76 (0.00-6.42)	2.92 (0.00-5.96)	+66	0.95
total	65	70 (14-151)	27 (1-80)	-62	0.0003	2.17 (0.00-6.25)	1.67 (0.00-4.66)	-23	0.23
2010 vs. 2008									
stricter	5	24 (19-29)	32 (20-70)	+31	0.50	0.66 (0.00-5.00)	2.83 (1.15-3.63)	+327	0.89
no changes	32	20 (5-50)	27 (2-79)	+38	0.34	1.36 (0.00-4.93)	1.43 (0.00-3.75)	+ 5	0.72
less strict	7	25 (7-85)	35 (12-101)	+40	0.74	2.17 (0.00-7.41)	3.02 (0.00-5.66)	+39	0.80
total	44	23 (7-54)	31 (8-79)	+34	0.24	1.36 (0.00-5.00)	1.85 (0.00-4.21)	+35	0.88

Notes: [a] stricter: smoking policy in the follow-up year changed from allowing smoking in the baseline year to restricting or prohibiting smoking or from restricting smoking in the baseline year to prohibiting smoking; less strict: with changes in the other way; [b] percentage of change from baseline median level to follow-up median level, + means it increased and – means it decreased; [c] p values were based on Wilcoxon matched-pairs signed-rank tests.

Table 4.4 Changes of nominal smoking policy, observed active smoking rate (ASR, %) and SHS PM (μg/m^3) in 15 venues, Beijing, China, 2006-2010

venue ID	2006 smoking policy	2006 ASR	2006 SHS PM	2007 smoking policy	2007 ASR	2007 SHS PM	2008 smoking policy	2008 ASR	2008 SHS PM	2010 smoking policy	2010 ASR	2010 SHS PM
restaurant 1	allow	1.64	44	allow	7.19	126	prohibit	5.00	306	prohibit	1.56	101
restaurant 2	allow	6.69	306	allow	2.97	93	prohibit	4.74	38	prohibit	10.84	134
restaurant 3	allow	3.16	0	allow	6.25	50	prohibit	0.00	0	prohibit	0.00	0
restaurant 4	allow	2.89	23	allow	1.28	13	restrict	0.00	1	prohibit	9.60	70
restaurant 5	allow	6.80	136	allow	6.64	293	prohibit	0.00	25	restrict	0.00	31
restaurant 6	allow	0.00	406	allow	4.35	496	prohibit	9.09	85	allow	3.02	101
restaurant 7	allow	6.67	46	allow	1.82	184	prohibit	0.00	7	allow	5.65	70
restaurant 8	allow	9.88	539	allow	14.81	298	restrict	2.17	75	allow	7.80	161
restaurant 9	allow	3.23	89	allow	14.08	493	allow	3.95	36	allow	13.79	189
restaurant 10	allow	6.64	36	allow	7.46	135	allow	6.82	0	allow	2.78	25
restaurant 11	allow	2.30	26	allow	1.82	77	allow	0.00	20	allow	0.00	13
restaurant 12	restrict	0.71	34	restrict	0.00	8	restrict	0.91	0	restrict	0.00	81
restaurant 13	restrict	11.91	35	restrict	0.00	1	restrict	0.38	0	restrict	1.11	0
bar 1	allow	2.13	10	allow	4.17	267	allow	14.29	126	allow	3.09	3
bar 2	allow	8.14	482	allow	1.67	28	allow	0.00	12	allow	12.36	27
mean		4.62	124		5.20	181		3.38	51		4.23	70
median		3.20	40		4.26	131		1.54	23		2.90	70
IQR		2.17-6.69	28-124		1.82-7.05	57-287		0-4.94	0-66		0.28-7.26	16-101

IQR: Inter quantile range

Notes: prohibit smoking: smoking was not allowed at all, with nonsmoking signs only in the venue; restrict smoking: smoking was allowed in designated smoking sections, with both nonsmoking signs and smoking signs in the venue; allow smoking: smoking was allowed everywhere in the venue, with no non-smoking signs at all.

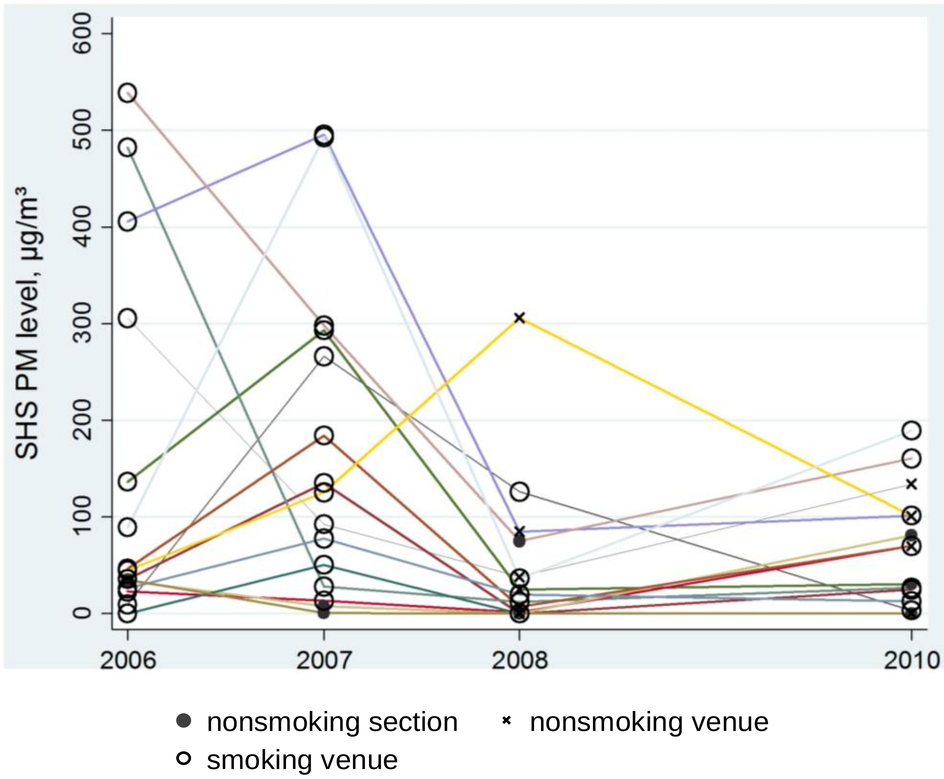


Figure 4.5 Changes of smoking policies and SHS PM levels in each of the 15 venues followed up in all the four year from 2006 to 2010

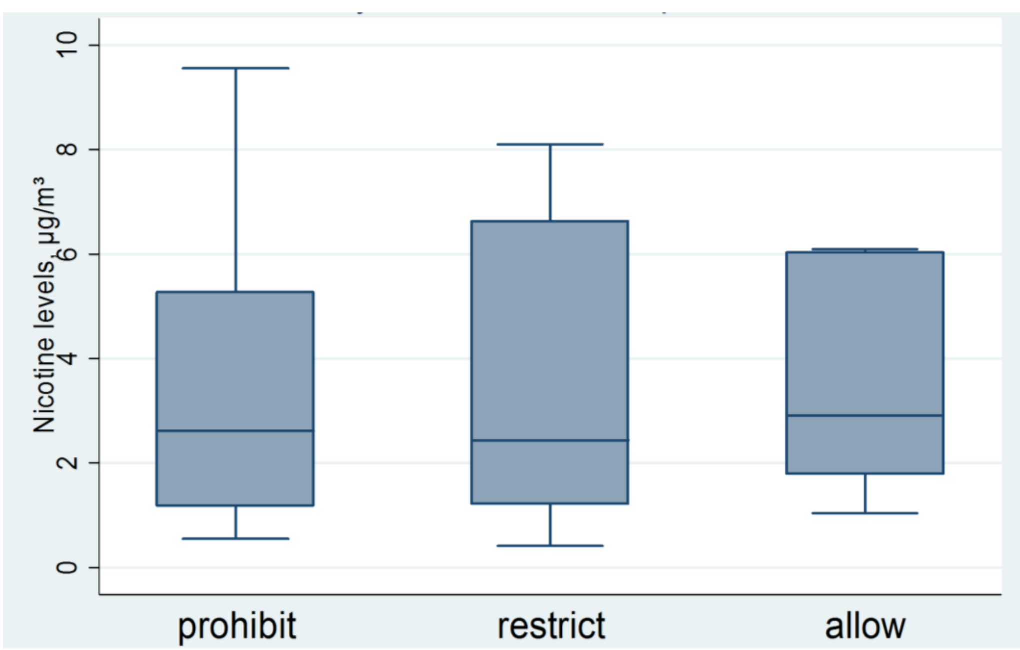


Figure 4.6 Personal airborne nicotine sampling for full shifts by different nominal smoking policies in 2010

4.3.3 Literature Review of Studies Evaluating the Efficacy of Smoking Restrictions in Restaurants and Bars

A total of 28 papers meeting all the criteria were identified. Results from one paper (Semple, Creely et al. 2007) were included in a more recent paper (Semple, van Tongeren et al. 2010) and results from two papers (Lee, Hahn et al. 2007; Lee, Hahn et al. 2008) were included in a later paper (Lee, Hahn et al. 2009). These three papers were excluded, resulting in 25 papers for the final review.

The 25 studies evaluated the efficacy of 28 national or local smoking legislations around the world on reducing SHS concentrations in restaurants and bars, five of which were partial smoking bans with some exemptions (Johnsson, Tuomi et al. 2006; Lee, Hahn et al. 2009; Nebot, Lopez et al. 2009; Erazo, Iglesias et al. 2010; Gleich, Mons et al. 2011). All studies except one (Barnoya, Arvizu et al. 2011) used repeated measurements for the evaluation. Eight studies used airborne nicotine, 19 studies used particulate matters and one used both as indicators of SHS (Ellingsen, Fladseth et al. 2006) in the environments. Seven of the nine studies including measurements of airborne nicotine used area passive nicotine sampling developed by Hammond, et al (Hammond and Leaderer 1987) and the other two used sorbent tubes. Ten of the 16 studies including particulate matters measured $PM_{2.5}$ using TSI SidePak AM510 (Minnesota, TSI Incorporated), five used other real-time measurements and one used gravimetric sampling of total dust. Table A4-A5 in the appendix summarized all the 25 studies.

For restaurants and bars which adopted complete smoking bans (prohibiting smoking everywhere), airborne nicotine concentrations decreased 94% on average (SD 6%), with a median of 96% and a range of 82% to almost 100%, compared to concentrations before the bans; air concentrations of particulate matters decreased 78% on average (SD 22%), with a median of 88% and a range of 18% to 96%. However, partial smoking restrictions, which exempted some restaurants and/or bars, did not reduce airborne nicotine concentrations significantly, with percentage changes ranging from -57% to 13%. Particulate matters did not change significantly in one study (Lee, Hahn et al. 2009) while decreased 87% in another study (Gleich, Mons et al. 2011) after partial smoking bans. See Figure 4.7 and 4.8 for details.

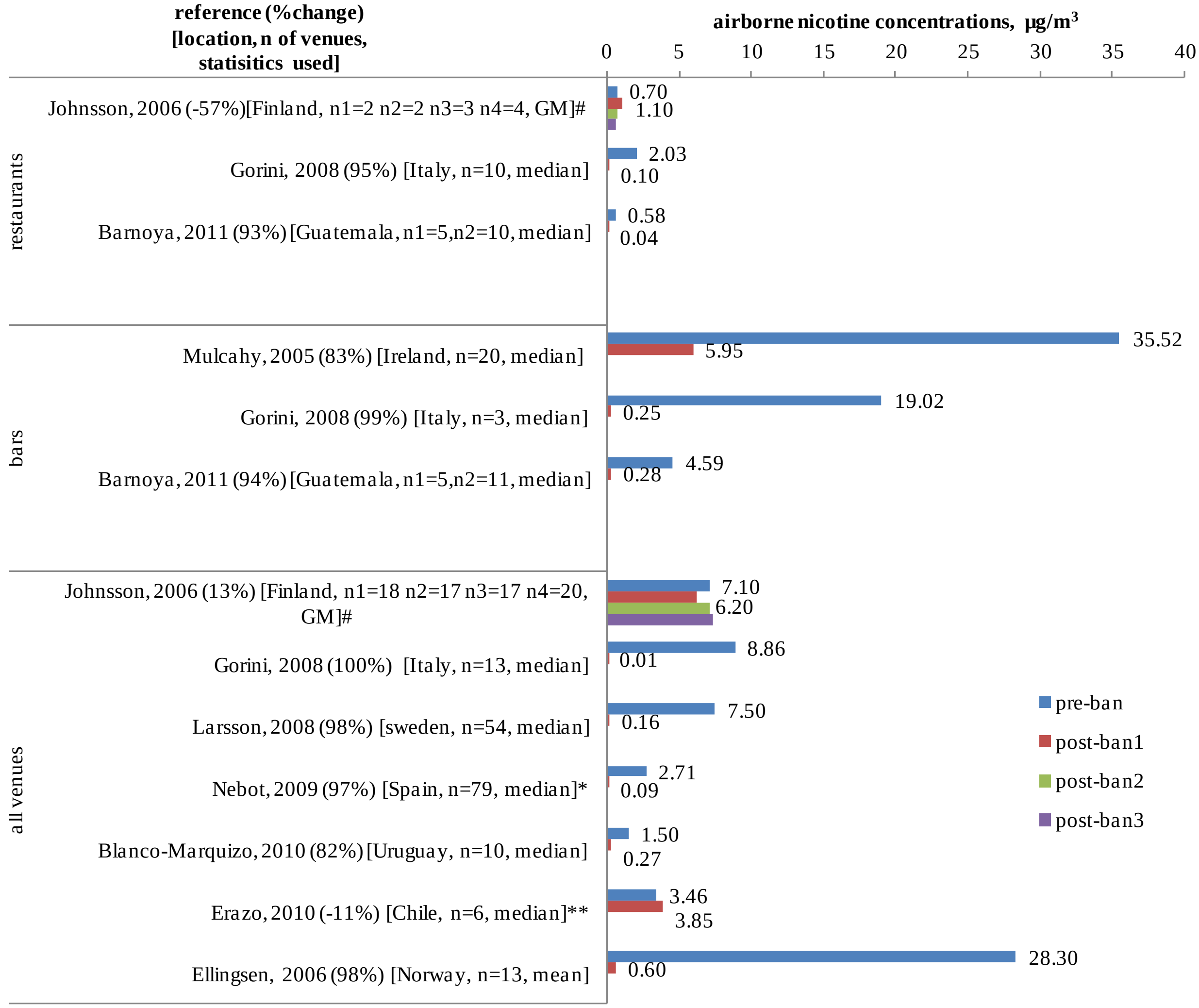


Figure 4.7 Changes of airborne nicotine concentrations before and after smoking restrictions in restaurants and bars

Notes: 1) % change=(1-post-ban1/pre-ban)×100%;

2) n: number of venues included in both pre-ban and post-ban monitoring; n1: number of venues included in the pre-ban monitoring; n2: number of venues included in the post-ban monitoring;

3) # Finland Tobacco Control Act was implemented in stages to restrict smoking in restaurants and bars: since 2000 March, smoking area ≤ 70 % for venues ≥100 m^3; since 2001 July, smoking area should ≤ 50% if a client area >50 m^2; since 2003 July the restrictions were more intensive. The three post-ban monitoring was conducted after each stage, respectively;

4) * the Spain smoking restriction was a partial smoking ban with some exemptions, only data for venues completely prohibited smoking after the restriction were included in this graph

5) ** data were for partial smoking bans with some exemptions;

6) when multiple statistics are available, the statistic used in this graph was chosen in the following order: median, geometric mean (GM), arithmetic mean.

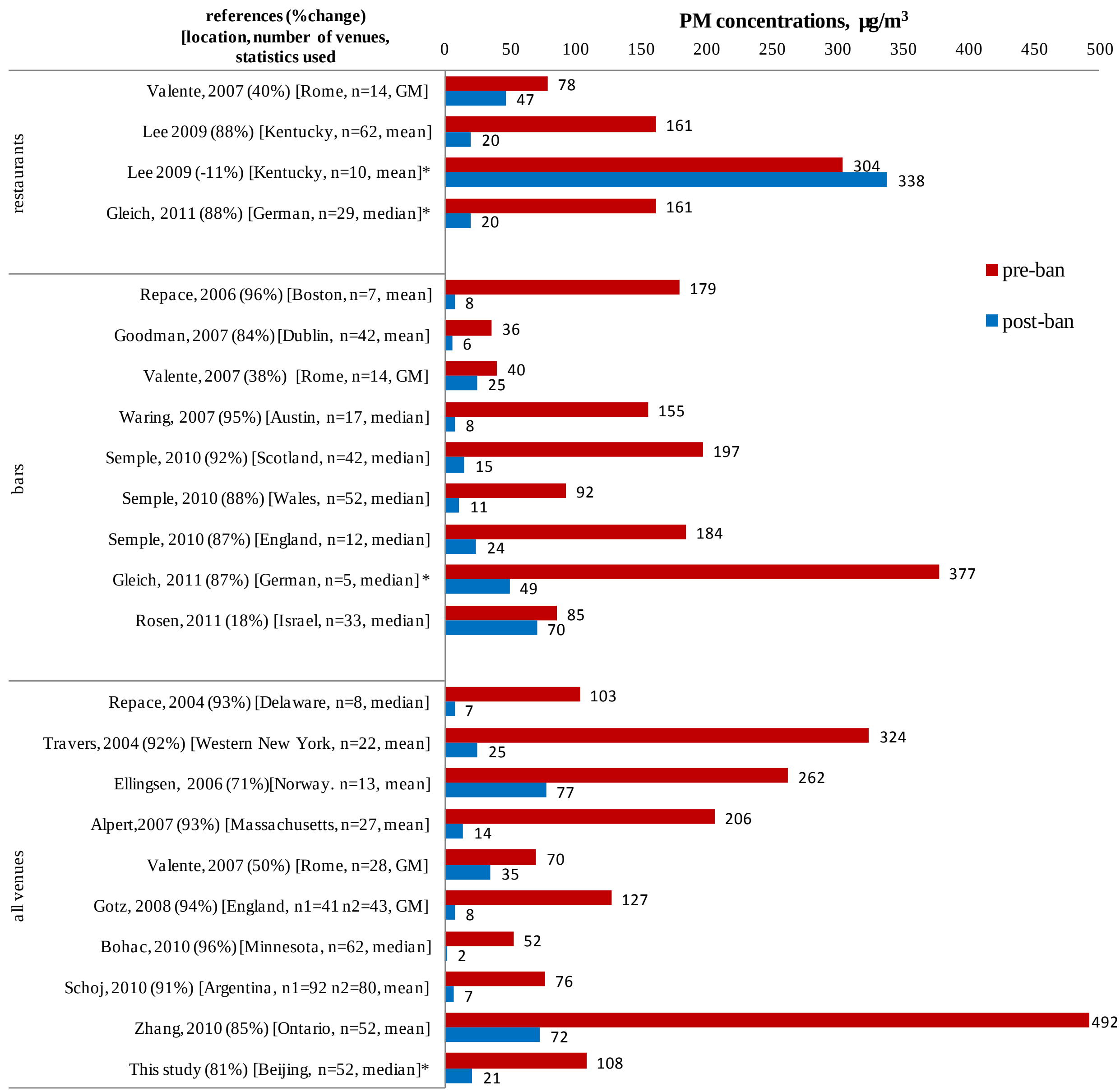


Figure 4.8 Changes of airborne concentrations of particulate matters before and after smoking restrictions in restaurants and bars

Notes: 1) * data were for partial smoking bans with some exemptions, all others were for complete smoking bans;

2) % change=(1-post-ban1/pre-ban)×100%;

3) n: number of venues included in both pre-ban and post-ban monitoring; n1: number of venues included in the pre-ban monitoring; n2: number of venues included in the post-ban monitoring;

4) when multiple statistics are available, the statistic used in this graph was chosen in the following order: median, geometric mean (GM), arithmetic mean.

4.4 Discussion

4.4.1 The Guidelines for Effective Smoke-free Legislation

The guidelines for implementing Article 8 of the WHO FCTC are based on best practices worldwide to protect people from SHS exposure. Though the implementation guidelines of the 1987 *Health Regulations in Public Places* (公共场所卫生管理条例) were revised and implemented in 2011 to tighten rules to prohibit smoking in all indoor public places, including restaurants, it is still far removed from the requirements of the treaty: it does not specify penalties for violations; and, like most other local regulations, it does not ban smoking in all indoor public places or workplaces. There are difficulties in violation reporting, law enforcement and monitoring; no specific funding has been assigned for corresponding antismoking efforts, etc. (Lv, Su et al. 2011). For these reasons, it can be expected that the enforcement of smoking restrictions, including the 2008 Beijing governmental regulation, will be poor and the efficacy limited. The evaluating study in this chapter strongly indicated that the guidelines of implementing Article 8 of the WHO FCTC should be followed wherever possible for smoke-free legislations to reach maximal effect.

4.4.2 The Efficacy of Comprehensive Smoking Bans in Restaurants and Bars Worldwide

According to the WHO guidelines for ambient air quality, the annual average $PM_{2.5}$ concentration should not exceed 10 μg/m^3 and the 24-hour average $PM_{2.5}$ concentration should not exceed 25 μg/m^3 (WHO 2005). Before the smoking ban, the average indoor $PM_{2.5}$ concentrations in restaurants and bars was sometimes more than 10 times higher than the WHO 24-hour average exposure limit, while after smoking was completely prohibited, a median 88% decrease was observed, with most of the $PM_{2.5}$ concentrations below the WHO 24-hour exposure limit. Due to other sources of indoor particulate matters, this decrease seemed to underestimate the efficacy of complete smoking bans. Studies using airborne nicotine, a specific SHS tracer, showed a median of 96% reduction of SHS after the bans.

The Chinese government just started to include $PM_{2.5}$ into the national air quality standards to regulate outdoor $PM_{2.5}$ pollutants in 2012 (Xinhua 2012). For restaurant and bar servers and patrons in China, their exposure to indoor $PM_{2.5}$ due to smoking is several times higher than the WHO 24-hour $PM_{2.5}$ exposure limit and can be more than ten times the annual exposure limits; it is also much higher than outdoor $PM_{2.5}$ levels in China, as indicated by the method that outdoor $PM_{2.5}$ levels were deducted from the indoor levels to derive the SHS PM levels, and the related health risks are expected to be much higher than the risks due to exposure to outdoor $PM_{2.5}$. However, comprehensive smoking bans are much more cost-effective than strategies to control outdoor $PM_{2.5}$ levels.

4.4.3 The Efficacy of Voluntary Smoking Policy in Restaurants and Bars in Beijing

In 2006, all the voluntary smoking bans in restaurants and bars were completely self-motivated by their owners, and in 2007, they were encouraged by the government. The differences of SHS PM concentrations in venues with different smoking policies in 2006 and 2007 were much bigger than those in 2008 and 2010. This, in addition to patrons' smoking behavior observed, shows better public compliance to and enforcement of smoking regulations in

2006 and 2007 than that in 2008 and 2010. A study showed that restaurant and bar owners who knew more about SHS related health hazards were more willing to restrict or prohibit smoking in their own venues (Liu, Hammond et al. 2011). In absence of governmental regulations, those owners who voluntarily restrict or prohibit smoking in their own venues are more likely to fully enforce the smoking policy imposed by themselves, and those patrons who prefer smoke-free dining environments are more likely to comply with the smoking policy. However, only a few voluntarily adopted smoking bans in 2006, and in venues followed from 2006 to 2007, none changed their smoking policies in response to the governmental advisory on voluntary smoking bans. In a society like China, where more than half of men smoke and where both hospitality venue owners and patrons have limited knowledge on specific hazards related to SHS (Liu, Yang et al. 2008; Liu, Hammond et al. 2011), it is extremely challenging to depend on voluntary smoking bans to protect the public from SHS exposure in hospitality venues.

4.4.4 The Efficacy of the 2008 Smoking Regulation in Beijing

The 2008 smoking regulations required restaurants larger than a certain size to prohibit smoking or at least restrict smoking to designated sections. However, no practical details on the size or penalties for non-compliance were specified in its implementation guidelines, making the regulation difficult to enforce.

In 2008 and 2010, many venues started to prohibit or restrict smoking in response to the 2008 smoking regulations. In these venues, the active smoking rate of patrons decreased, while no significant changes were observed in venues without any policy changes. In all, SHS PM decreased 78% in 2008 compared to 2007, which was close to the median decrease of 88% based on the review of other studies worldwide. However, SHS PM concentrations in Beijing restaurants and bars decreased in all the venues followed from 2007 to 2008 or 2010, regardless of policy changes. The magnitude of decrease in venues with stricter policies was similar to venues with less strict policies in 2008, while the former was larger in 2010. It indicates that the 2008 smoking regulation has positive impacts on restraining patrons' active smoking to some extent, and that in addition to the reduction of burning cigarettes density, other factors might have also attributed to the reduction of indoor $PM_{2.5}$, especially in 2008. The 2008 study was conducted shortly after the Beijing 2008 Olympic Games, which might have led to more efforts to improve both indoor and outdoor air quality in many public places, including hospitality venues.

Smoking was observed in almost half the nominal non-smoking venues or sections in both 2008 and 2010, and different nominal smoking policies made no significant difference in the airborne nicotine concentrations to which servers were exposed in full shifts. This indicates poor public compliance and governmental enforcement up to two years after the ban. No significant changes were observed on SHS concentrations or patrons' smoking behavior from 2008 to 2010 and several venues even reverted to more lenient smoking policies. This indicates that after two years' implementation of the regulation, enforcement and compliance remain poor. Some venues adopted stricter smoking policies in 2010 than in 2008, which might be a result of sporadic governmental field supervision. Alternatively, it might be attributed to their owners' increased awareness of SHS hazards or the emerging trend of smoking free environments, thanks to the implementation of smoking regulations or other tobacco control activities initiated in Beijing during these two years, but if this is the case, the effects of these activities seemed very small.

In venues included in the 2010 study, SHS PM concentrations or active smoking rates in venues prohibiting smoking were higher than that in designated sections, probably because after two years' implementation of the regulation, some patrons and owners became used to the fact that no material punishments would be imposed and thus became used to ignoring the nonsmoking signs, especially when there was no contrast of smoking and nonsmoking signs; some owners even removed the existing nonsmoking signs, switching back to more permissive smoking policies. This is consistent with WHO's finding that compliance to smoking restrictions in hospitality venues are often poor and even apparently absent in many developing countries (IARC 2009). This emphasizes WHO's recommendation that: "Passing a policy is only one part of the process of protecting a population from exposure to SHS; both public education and enforcement efforts are necessary when the smoke-free policy is implemented" (WHO 2009).

4.4.5 The Efficacy of Restricting Smoking to Designated Sections

There is no known 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). No improvement in air quality was found after legislation in March 2000 that introduced nonsmoking areas in some bars and restaurants in Finland (Johnsson, Tuomi et al. 2006). In this study, according to simultaneous monitoring in both smoking and nonsmoking sections, the median $PM_{2.5}$ or air nicotine concentration in nonsmoking sections was still 40% of that in smoking sections. Thus restricting smoking can reduce but cannot eliminate patrons' exposure to SHS in restricts. For servers, personal sampling from nonsmoking volunteers working in venues restricting smoking showed high levels of exposure to SHS. Obviously, restricting smoking cannot protect servers from exposure to SHS, as they need to serve patrons in both smoking and nonsmoking sections.

4.4.6 Strengths and Limitations of the Evaluating Study

The biggest strength of the evaluation study is that it is a follow-up study with four rounds of monitoring in five years, when smoking policies in restaurants and bars changed rapidly. It collected both cross-sectional and longitudinal data with similar protocols, offering good opportunities to evaluate the efficacy of different smoking policies. Another strength is the inclusion of personal sampling in the 2010 study, providing strong evidence of servers' exposure to SHS during their work.

There are some limitations of the study. First, longitudinal data were collected in Beijing only, and no control cities were included in the study. This makes it difficult to attribute all the changes in SHS concentrations and patrons' smoking behaviors to smoking regulations only, because other interventions like public education could also have their effects. Second, convenience samples were used for logistical reasons, which may limit the generalization of results from cross-sectional comparison in different years, but results from longitudinal comparisons may be more convincing. Third, the study used $PM_{2.5}$ as a SHS tracer for the longitudinal analysis, which is sensitive to, but not specific to, SHS. However, the results of $PM_{2.5}$ sampling, observation and air nicotine sampling are consistent with each other. Lastly, the study was conducted in different seasons of different years and not all the follow-up monitoring was scheduled for the same peak patronage times (e.g. lunch or dinner) or on the same day of a week (e.g. weekdays or weekend), so the variations due to these factors cannot be estimated.

4.5 Conclusions

Although a voluntary smoking policy may be enforced better by owners and patrons may be more compliant, adoption is rare, regardless whether it is self-motivated by owners or advised by the government, and thus voluntary smoking bans cannot protect people universally from SHS exposure in restaurants and bars. The 2008 smoking regulation in Beijing did restrain patrons' smoking to some extent, but it failed to reduce significantly SHS exposures of nonsmoking servers or patrons because of poor enforcement and compliance, unclear definition of the smoking restriction and penalties. Restricting smoking to designated areas did not protect servers from SHS exposure.

Smoke-free legislations in China still set standards below the requirements by the WHO FCTC, which results in the fact that servers and patrons in restaurants and bars in Beijing are still exposed to high levels of SHS, even after the implementation of the 2008 smoking regulation. Because similar underlying limits of the Chinese government's smoking ban in public places including restaurants and bars in May 2011, similar results can be expected until the Chinese government fully complies with the guidelines for implementation of WHO FCTC Article 8.

Chapter 5 An Assessment of Health Risks and Mortality from Exposure to Secondhand Smoke in Minnesota and United States Restaurants and Bars

5.1 Background

Secondhand smoke (SHS) has been identified as a toxic air contaminant by the California Environmental Protection Agency (EPA) (Cal/EPA 2005) and many constituents of SHS have been identified as hazard air pollutants (HAPs) by the U.S. EPA. Exposure to SHS has been linked to an increased risk of many adverse health outcomes, including cancers, acute and/or chronic respiratory illness, heart disease, etc. (USDHHS 2006). Worldwide, 40% of children and one third of nonsmoking adults were exposed to SHS in 2004 and SHS exposure caused more than 600,000 deaths in that year (Oberg, Jaakkola et al. 2011).

Studies show that smoking bans significantly reduce SHS exposure and improve public health. The smoking ban in public places in Scotland reduced respiratory symptoms not only among both smoking and nonsmoking workers in bars one year after its implementation (Ayres, Semple et al. 2009), but also among the general population in subsequent years. Hospital admissions of preschool and school-age children for asthma decreased 18% per year compared to the rate before implementation of the ban (Mackay, Haw et al. 2010). Three independent reviews on the effect of smoking bans in public places on acute myocardial infarction (AMI) consistently show that they reduce individual risk and hospitalization for AMI (Institute of Medicine 2009; Lightwood and Glantz 2009; Meyers, Neuberger et al. 2009).

Although efforts have been made in recent decades to protect people from SHS exposure in public places, worldwide, only 9% of countries mandate smoke-free restaurants and bars, covering 5% of the world population (WHO 2009). In the US, 25% of the population remains unprotected by smoke-free regulations in restaurants and 35% in bars (ANRF 2012). Tobacco companies have been fighting against smoking bans in restaurants and bars with a number of excuses and strategies, and their continuing efforts to remove existing smoking bans are sometimes successful. For example, as of October 2011, 15 U.S. municipalities that had adopted effective smoke-free laws subsequently repealed, weakened, or postponed them due to such efforts (ANRF 2012).

Minnesota became the first state to restrict smoking in indoor workplaces through the Minnesota Clean Indoor Air Act in 1975. The Act primarily covered offices and retail stores. In 2003, factories and warehouses were added with provisions for smoking rooms. However, the Act did not apply to bars and restaurants. Beginning in 2000, Minnesota cities and counties began to pass community ordinances, some of which extended smoke-free policies to include bars and restaurants. Up until June 2007, there were 15 Minnesota cities and counties that had smoke-free ordinances for restaurants and bars covering 38.1 ±1.5% of Minnesotans (Minnesota Department of Health 2008). In May 2007, the Minnesota Legislature passed the Freedom to Breathe Act of 2007, a comprehensive smoke-free law covering indoor public places and workplaces, including bars and restaurants. The law went into effect in October 2007. However, a bill has been proposed to repeal the comprehensive smoking ban to allow smoking in Minnesota bars in 2011 (Minneapolis St. Paul Business Journal 2011).

Steenland and Nurminen estimated the mortality from overall occupational exposure to SHS in the U.S. (Steenland 1999) and in Finland (Nurminen and Jaakkola 2001), respectively, based on attributable risk fraction approach using epidemiological and demographical data; Repace estimated the lifetime risk of lung cancer deaths and ischemic heart disease death (IHD) from SHS exposure by office workers (Repace, Jinot et al. 1998) and by casino workers (Repace 2009; Repace, Jiang et al. 2011), based on a dose-response relationship developed by Repace in

1985 (Repace and Lowrey 1985). Though SHS concentrations are often higher in restaurants and bars than in other indoor public places (Navas-Acien, Peruga et al. 2004; Nebot, Lopez et al. 2005; Hyland, Travers et al. 2008; Rosen, Zucker et al. 2011), limited studies have estimated the health risk and mortality from SHS exposure for restaurant and bar servers and patrons. For people living in smoke-free homes, working in or patronizing restaurants and bars may be their predominant source of SHS exposure. Health effects caused to workers and patrons of these venues by SHS exposure are listed in Table 5.1.

Jamrozik estimated that 54 deaths from lung cancer, IHD and stroke among hospitality workers were attributed to their work-place SHS exposure based on epidemiological and demographical data in the United Kingdom (Jamrozik 2005). Another four published papers assessed health risks due to SHS exposure in restaurants and/or bars (El-Hougeiri and El Fadel 2002; Siegel and Skeer 2003; Hedley, McGhee et al. 2006; Lopez, Nebot et al. 2006), which were based on non-representative exposure data and examined the risks of only cancer and/or heart disease to servers/workers only. To the best of our knowledge, no studies have estimated health risks for restaurant and bar patrons, nor have any included health risks other than cancer or IHD. A comprehensive risk assessment based on more appropriate and accurate exposure assessment is imperative for policy makers in jurisdictions or countries with these venues exempt from smoking bans.

The goal of this chapter is to use different approaches to estimate the health risk and the attendant disease burden to servers and patrons in Minnesota before the implementation of its comprehensive smoking ban and in the US due to exposure to SHS in restaurants and bars. Although children who visit restaurants are at risk for numerous health effects from SHS exposure there, including eye and nasal irritation, asthma induction or exacerbation, this chapter focuses on the health risks of nonsmoking servers and adult patrons. The health outcomes evaluated include eye and nasal irritation, cancer death, ischemic heart disease (IHD) death and asthma induction.

Table 5.1 Hazard health outcomes due to exposure to secondhand smoke

Hazard health effects with sufficient evidence reported	Source
For workers	
Eye and nasal irritation	Cal EPA, 2005[a] SGR, 2006
Asthma induction	Cal EPA, 2005[a] SGR, 2006
Asthma exacerbation	Cal EPA, 2005[a] SGR, 2006
Acute coronary events	IOM, 2009 [a]
Coronary heart disease morbidity and mortality	Cal EPA, 2005[a] SGR, 2006
Lung cancer	Cal EPA, 2005[a] SGR, 2006
Nasal sinus cancer	Cal EPA, 2005[a] SGR, 2006
Breast cancer, especially for younger, premenopausal women	Cal EPA, 2005[a] SGR, 2006
For patrons	
Eye and nasal irritation (for both adults and children)	Cal EPA, 2005[a] SGR, 2006
Asthma induction (for both adults and children)	Cal EPA, 2005[a] SGR, 2006
Asthma exacerbation (for both adults and children)	Cal EPA, 2005[a] SGR, 2006
Acute coronary events	IOM, 2009 [a]
Coronary heart disease morbidity	Cal EPA, 2005[a] SGR, 2006
Lung cancer	Cal EPA, 2005[a] SGR, 2006

[a] sufficient"; [b] suggestive";

Cal EPA, 2005: *Proposed Identification of Environmental Tobacco Smoke as a Toxic Air Contaminant* by California EPA (Cal/EPA 2005).

IOM,2009: *Secondhand Smoke Exposure and Cardiovascular Effects: Making Sense of the Evidence* by Institute of Medicine (Institute of Medicine 2009);

SGR, 2006: *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General* (USDHHS 2006).

5.2 Methods

Before the implementation of the comprehensive smoking ban in October 2007 in Minnesota, a study was conducted to collect detailed time-of-day and day-of-week SHS exposure data from restaurants and bars in Minnesota. The study selected a statistically representative sample of 65 venues that permitted smoking within a 20-mile radius of downtown Minneapolis. Venues from a commercially available database were stratified by type (venues with full service, venues with limited service and drinking places) based on codes of the North American Industry Classification System and within type by size based on employee count. Substrata were sampled in proportion to the number of employees working in smoking-permitted venues and the expected standard deviation of the SHS concentrations (Hewett, Bohac et al. 2011). From February 23 through September 29, 2007, 2423 short-term visits (median: 12 minutes) were made to conduct real-time area monitoring of fine particulate matter ($PM_{2.5}$) and observe the number of customers, workers and lit cigarettes at three different times of day (lunch, dinner, and evening) on four different day types (Fridays, Saturdays, Sundays, and other weekdays) in each venue. These peak patronage time visits are used as the basis for estimating exposures. Another 210 two-hour visits were conducted at dinner and in the evening to make the same observations, monitor $PM_{2.5}$, and sample multiple gas phase SHS tracers including nicotine, 3-ethenylpyridine, pyridine, pyrrole, picoline, quinoline and myosmine. Most (n=186) of the two-hour visits were conducted on Fridays and Saturdays, with simultaneous measurements of $PM_{2.5}$ and gas phase SHS tracers. For venues restricting smoking to designated smoking sections (n=40), most sampling was conducted in smoking sections, with observations recorded from both sections. Simultaneous measurements were made in both sections during 16 visits. Details of the study have been reported elsewhere (Bohac, Hewett et al. 2010; Bohac, Hewett et al. 2011; Hewett, Bohac et al. 2011).

Steenland described two general approaches to assess health risk due to SHS exposure (Steenland 1999). One is a unit risk or continuous approach, the other is exposed/nonexposed or a categorical approach. Both approaches are used in this paper. The intensive filed measurements in Minnesota restaurants and bars described above were used to estimate the health risks of eye and nasal irritation and the lifetime excess risk of cancer death (including deaths from lung cancer and other cancers) and IHD death for servers and patrons in Minnesota; epidemiological and demographic data were used to estimate the lifetime excess risk and excess burden of lung cancer death and IHD for the general population in both Minnesota and the U.S. and the risk of asthma initiation for servers in the U.S. due to exposure to SHS in restaurants and bars.

5.2.1 Estimate of Risk of Sensory Irritation Using a Categorical Approach Based on Field Measurements

Junker et al. reported that the median threshold for sensory irritation (eye, nasal, and throat) of respirable suspended particles from SHS (SHS PM) is 4.4 $\mu g/m^3$, based on a controlled chamber study (Junker, Danuser et al. 2001). Since almost all the SHS PM fall under $PM_{2.5}$ (Cal/EPA 2005), SHS PM concentrations were estimated by multiplying the difference between indoor and outdoor $PM_{2.5}$ concentrations during each visit to the 65 representative venues with a calibration factor of 0.31, which were determined by gravimetric measurements taken simultaneously with the real-time measurements. SHS PM concentrations estimated for the 2633 visits to Minnesota restaurants and bars were divided into two groups with a cutoff point of 4.4

μg/m^3. The sample was analyzed as a two-stage stratified cluster sample with the first stage consisting of the nine venue-type/size strata from which 65 clusters (venues) were drawn, and the second stage consisting of the 12 day-time strata from which a sample of all possible visits in a year was drawn by quasi-systematic sampling. The Complex Samples module of PASW 18.0.0 (SPSS, Inc. 2009) was used to compute the sampling weight for each visit, which was 1/(Venue Selection Probability × Visit Selection Probability) (weight1). Number of patrons counted during each visit was weighted by the sampling weight (weight1) and the percentage of weighted patrons during visits with SHS PM concentration higher than 4.4 μg/m^3 of total weighted patrons during all visits was taken as the percentage of patrons who were at risk of eye and nasal irritation. Because the number of servers was expected to be proportional to the number of patrons in general, this percentage was also taken as the percentage of servers who were at risk of eye and nasal irritation.

5.2.2 Estimate of Cancer Risk Using a Continuous Approach Based on Field Measurements

Repace and Lowrey (1985) developed a model to predict the risk of lung cancer death (LCD) due to exposure to SHS PM. The model was validated by predicting epidemiologically derived observational data to within 5%, and has been widely used (Siegel and Skeer 2003; Hedley, McGhee et al. 2006; Lopez, Nebot et al. 2006). The model estimated that, for the general U.S. population, the risk of LCD is 5×10^{-5} for exposure to 1 mg/day of SHS PM for one year and the lifetime excess risk (LER) of LCD can be estimated by equation 5.1:

$$\textit{LER of LCD} = 5 \times 10^{-5}\ (\text{mg/day-year})^{-1} \times \textit{Daily dose}\ (\text{mg/day}) \times \textit{Years}$$

$$\textit{Daily dose}\ (\text{mg/day}) = C_{SHS\text{-}PM}\ (\text{mg/m}^3) \times BR\ (\text{m}^3/\text{hr}) \times \textit{Time}\ (\text{hr/day}) \times f \qquad [5.1]$$

Where

Daily dose is the exposure dose of SHS PM in mg/day for an individual;
Years is the number of years exposed to SHS;
$C_{SHS\text{-}PM}$ is the average concentration of SHS PM in mg/m^3 during the period of exposure (here taken to be the peak patronage times);
BR is the breathing rate in m^3/hr;
Time is the average hours per day exposed to SHS;
f is the number of days exposed per week divided by 7 days.

SHS PM concentrations measured during visits to Minnesota restaurants and bars were weighted by the sampling weight (weight1) to estimate the state-wide average concentrations in the smoking sections of smoking-permitted venues before the ban went into effect. These weighted concentrations were further weighted by the number of patrons in smoking venues/sections to estimate the average concentration to which patrons were exposed in smoking venues/sections (weight2). The average SHS PM level to which all patrons in designated nonsmoking section were exposed was estimated by multiplying the SHS PM level in smoking sections by 0.525 (the ratio of average SHS PM level in nonsmoking sections to the average level in smoking sections from simultaneous side-by-side measurements during 16 visits), then weighted by weight 1 and the number of patrons in nonsmoking sections (weight 3). To estimate the average SHS PM level to which all servers were exposed, the smoking and non-smoking section concentrations were combined in proportion to the number of patrons in each section (weight 4), assuming that the time spent by servers in each section was proportional to the number of patrons. See Table 5.2 for these weighted concentrations.

To estimate the daily dose, breathing rates (BR in Eq. 5.1) recommended by U.S. EPA (1997) were used: 1.6 m^3/hr for servers at a moderate activity level and 1.0 m^3/hr for patrons at a light activity level. To avoid overestimating servers' exposure during work, their exposure time was assumed to be four hours a day during peak patronage times. A typical assumption of working five days per week for a working life of 45 years was also applied when estimating servers' LER of LCD. For patrons, the LER of LCD was estimated based on the assumption that they visit a restaurant or bar once every week, with an average time of 86 minutes or 1.4 hours each week (Tsang and Klepeis 1996) for 60 years.

The overall cancer risk due to exposure to volatile organic compounds (VOCs) from SHS regulated as HAPs by US EPA was quantified by using the cancer unit risk estimate (URE) reported by US EPA (2011) or the equivalent cancer unit risk (UR) reported by California EPA (Cal/EPA OEHHA 2009). Both URE and UR in $(\mu g/m^3)^{-1}$ describe the excess cancer risk associated with a daily inhalation exposure to 1 $\mu g/m^3$ of a given chemical for a lifetime of 70 years, assuming 20 m^3/day of inhalation. The LER of any kind of cancers due to the exposure can be estimated by equation 5.2.

$$\text{LER of cancers} = C_{SHS\text{-}VOC}\,(\mu g/m^3) \times URE \text{ or } UR\,(\mu g/m^3)^{-1}$$

$$C_{SHS\text{-}VOC}\,(\mu g/m^3) = C_{SHS\text{-}PM}\,(\mu g/m^3) \times (EF_{SHS\text{-}VOC}/EF_{SHS\text{-}PM}) \times F \qquad \text{[Eq. 5.2]}$$

Where

$C_{SHS\text{-}VOC}$ is the daily average concentration of a SHS VOC in $\mu g/m^3$ during a lifetime of 70 years;
URE is the cancer unit risk estimate in $(\mu g/m^3)^{-1}$ reported by US EPA;
UR is the cancer unit risk in $(\mu g/m^3)^{-1}$ reported by California EPA;
Years is the number of years exposed to SHS;
$C_{SHS\text{-}PM}$ is the average concentration of SHS PM in $\mu g/m^3$ during peak patronage time;
$EF_{SHS\text{-}VOC}$ and $EF_{SHS\text{-}PM}$, are the average emission factors of SHS VOC and SHS PM from the literature, respectively, μg/cigarette;
F is (4hr/day $\times$ 1.6 m^3/hr/(20m^3/day) $\times$5day/7day $\times$45years/70years) for servers and (1.3hr/day $\times$1.0m^3/hr/(20m^3/day) $\times$1day/7day $\times$60years/70years) for patrons.

The overall cancer risk from exposure to SHS VOCs is estimated by summing the cancer risk from exposure to individual SHS VOCs. The URE was used when it was available from the US EPA website; otherwise, the UR reported by California EPA was used. Since SHS PM was most intensively monitored, and the ratios of simultaneous measurements of SHS PM and SHS VOC tracers were quite similar to the ratios of their emission factors (EF) reported in literature (Leaderer and Hammond 1991; Hodgson, Daisey et al. 1996; Mahanama and Daisey 1996; Martin, Heavner et al. 1997; Nelson, Kelly et al. 1998; Daisey 1999; Singer, Hodgson et al.

2002; Singer, Hodgson et al. 2003; Bi, Sheng et al. 2005; Charles, Batterman et al. 2007), exposure to SHS VOCs was estimated from the ratios of their EFs to SHS PM EF. There were nine SHS VOCs with both URE/UR and EF available, thus the LER of cancer due to SHS VOCs exposure was estimated as the sum of cancer risk from these nine SHS VOCs. See Table 5.3 for measured SHS VOC tracers concentrations during 2-hour visits and Table 5.4 for the estimates of the nine SHS VOCs used for the cancer risk assessment.

Table 5.2 Average SHS PM concentrations by different venue types, time of day and day of week, Minnesota, 2007

			n of visit	SHS PM concentration, mean (SE), µg/m³				
				venue avg unweighted [a]	venue avg weighted1 [b]	patrons_smks weighted2 [c]	patrons_nsmks Weighted3 [d]	workers weighted4 [e]
Venues with full Service	weekday	Lunch	111	38 (6)	47 (16)	91 (43)	13 (3)	42 (18)
		Dinner	121	58 (6)	58 (11)	90 (10)	25 (4)	54 (9)
		Evening	123	55 (6)	53 (12)	90 (20)	25 (6)	50 (12)
	Friday	Lunch	110	28 (5)	35 (12)	81 (35)	14 (6)	35 (15)
		Dinner	151	79 (6)	71 (12)	110 (19)	36 (5)	66 (10)
		Evening	126	96 (9)	95 (16)	143 (13)	55 (15)	98 (11)
	Saturday	Lunch	122	24 (4)	25 (7)	46 (11)	8 (2)	27 (8)
		Dinner	156	47 (4)	59 (11)	93 (20)	31 (8)	48 (8)
		Evening	123	83 (10)	74 (16)	149 (51)	27 (5)	84 (25)
	Sunday	Lunch	108	30 (4)	34 (6)	50 (9)	10 (4)	31 (6)
		Dinner	126	48 (5)	39 (9)	63 (14)	23 (4)	38 (8)
		Evening	114	55 (7)	57 (11)	94 (18)	17 (3)	51 (10)
Venues with limited service	weekday	Lunch	31	22 (5)	13 (4)	19 (8)	20 (3)	14 (6)
		Dinner	33	120 (20)	97 (45)	153 (36)	41 (3)	108 (35)
		Evening	31	95 (17)	80 (24)	149 (31)	40 (4)	101 (25)
	Friday	Lunch	24	33 (9)	38 (16)	57 (20)	4 (1)	30 (14)
		Dinner	36	143 (23)	148 (67)	233 (69)	64 (3)	169 (58)
		Evening	34	151 (25)	108 (35)	202 (37)	49 (10)	149 (34)
	Saturday	Lunch	28	49 (16)	45 (20)	124 (64)	14 (4)	52 (23)
		Dinner	32	82 (13)	58 (14)	91 (6)	39 (10)	63 (10)
		Evening	42	111 (20)	84 (19)	160 (21)	75 (6)	105 (14)
	Sunday	Lunch	19	33 (13)	33 (14)	86 (34)	11 (1)	40 (19)
		Dinner	28	113 (27)	94 (41)	172 (37)	39 (19)	103 (40)
		Evening	26	85 (17)	60 (22)	110 (30)	21 (3)	75 (25)
Drinking places	weekday	Lunch	62	31 (6)	38 (8)	43 (13)	9 (1)	28 (6)
		Dinner	65	136 (17)	158 (51)	197 (56)	54 (10)	140 (38)
		Evening	61	155 (19)	159 (27)	181 (25)	62 (19)	156 (18)
	Friday	Lunch	63	27 (4)	29 (5)	29 (5)	24 (1)	22 (4)
		Dinner	66	180 (24)	191 (42)	217 (63)	51 (5)	164 (36)
		Evening	77	155 (19)	133 (18)	189 (32)	32 (4)	151 (21)
	Saturday	Lunch	61	45 (10)	51 (16)	88 (26)	26 (3)	38 (9)
		Dinner	70	114 (11)	124 (25)	129 (24)	49 (4)	105 (17)
		Evening	75	154 (22)	150 (27)	214 (36)	54 (3)	155 (26)
	Sunday	Lunch	56	41 (9)	56 (18)	78 (16)	4 (3)	48 (12)
		Dinner	58	91 (14)	112 (24)	145 (29)	49 (4)	95 (15)
		Evening	64	99 (11)	123 (28)	166 (47)	145 (9)	139 (33)
All	weekday	Lunch	204	34 (4)	40 (8)	63 (24)	14 (2)	33 (10)
		Dinner	219	90 (7)	98 (20)	143 (26)	31 (4)	90 (13)
		Evening	215	89 (8)	95 (12)	140 (15)	33 (7)	90 (10)
	Friday	Lunch	197	29 (3)	33 (7)	60 (21)	15 (4)	30 (9)
		Dinner	253	114 (8)	123 (18)	170 (29)	42 (4)	105 (13)
		Evening	237	123 (9)	111 (11)	172 (16)	53 (12)	120 (9)
	Saturday	Lunch	211	34 (4)	38 (7)	75 (16)	12 (3)	34 (6)
		Dinner	258	69 (5)	82 (11)	107 (13)	34 (6)	66 (7)
		Evening	240	110 (9)	103 (13)	178 (28)	35 (6)	109 (17)
	Sunday	Lunch	183	34 (4)	43 (8)	65 (9)	9 (3)	36 (5)
		Dinner	212	68 (6)	71 (11)	113 (16)	27 (5)	64 (8)
		Evening	204	73 (6)	84 (13)	130 (25)	52 (26)	84 (15)
Total			2633	72 (6)	78 (9)	134 (12)	30 (4)	78 (7)

[a] average SHS PM level by venue types without any weighting; [b] average SHS PM level weighted by the inverse of venue selection probability and sampling time period probability (weight 1); [c] average SHS PM level exposed by patrons visiting sections or venues allowing smoking, weighted by weight 1 and number of customers in these section or venues (weight 2); [d] average SHS PM level exposed by patrons visiting sections or venues prohibiting smoking, weighted by weight 1 and number of customers in these section or venues (weight 3); [e] average SHS PM level exposed by servers working in restaurants and bars allowing or restricting smoking, weighted by weight 1 and the proportion of their time working in smoking sections and nonsmoking sections(if there is any) (weight 4).

Table 5.3 Average concentrations of SHS VOC tracers measured during 2-hour sampling, unweighted, μg/m³, Minnesota, 2007

			No. of visits	SHS PM, all[a]	SHS PM, 2 hr[b]	Nicotine	3-EP	Pyridine	Pyrrole	Myosmine
Venues with full service	Friday	Dinner	35	79	96	3.34	1.88	2.63	2.16	0.45
		Evening	21	96	129	4.53	2.31	3.84	2.52	0.50
	Saturday	Dinner	29	47	39	1.08	0.86	1.44	0.93	0.19
		Evening	22	83	59	1.90	1.29	2.02	1.33	0.28
Venues with limited service	Friday	Dinner	4	143	247	7.13	4.24	6.66	4.16	0.91
		Evening	10	151	203	3.46	2.39	5.37	4.19	0.49
	Saturday	Dinner	7	82	108	3.23	1.99	3.17	2.50	0.41
		Evening	7	111	111	3.12	1.99	3.23	2.01	0.38
Drinking Places	Friday	Dinner	9	180	194	3.42	1.8	2.37	1.95	0.42
		Evening	19	155	150	4.45	2.79	3.9	2.85	0.54
	Saturday	Dinner	8	114	134	3.27	2.36	3.32	2.83	0.51
		Evening	15	154	182	5.34	3.05	6.56	3.61	0.78
All	Friday	Dinner	48	115	127	3.67	2.06	2.92	2.29	0.48
		Evening	50	123	152	4.29	2.51	4.17	2.98	0.52
	Saturday	Dinner	44	69	67	1.82	1.32	2.06	1.52	0.28
		Evening	44	110	109	3.27	2.00	3.76	2.21	0.47

Notes: all the measurements of SHS VOC tracers were conducted during dinner or evening patronage times on Fridays or Saturdays for about 2 hours.

[a] SHS PM, all: includes all the short-time (10-15 minutes) measurements and 2 hour measurements in each substratum;

[b] SHS PM, 2 hr: includes only the measurements of $PM_{2.5}$ taken side by side with SHS gas phase tracers.

Table 5.4 Emission factors (EFs) from the literature for SHS specific compounds and volatile organic compounds and ratios of EFs and side-by-side field measurements to $PM_{2.5}$ or 3-Ethenylpridine (3EP)

	mean EF [a] μg/cig	range of EF [b] μg/cig	ratio of EF_{PM}/EF_{VOC}	ratio of C_{PM}/C_{VOC} [c]	ratio of EF_{VOC}/EF_{3EP}	ratio of C_{VOC}/C_{3EP} [d]
Selected SHS tracers with field measurements						
Pyridine	348	60-530	35.8	22.4	0.83	1.50
Pyrrole	373	230-460	33.4	35.3	0.88	0.97
3,4-Picoline	312	264-350	40.0	41.3	0.74	0.60
3-Ethenylpridine	422	84-660	29.5	36.3	1.00	1.00
Nicotine	1274	396-3070	9.8	14.4	3.02	1.80
Myosmine	122	83-160	102.6	169.3	0.29	0.20
$PM_{2.5}$	12471	8100-17000	1.0	1.0	29.5	36.3
Volatile organic compounds						
Acetaldehyde	2292	2042-2496	5.4		5.4	
Acetonitrile	952	858-1069	13.1		2.3	
Acrolein	363	284-404	34.4		0.9	
Acrylonitrile	170	99-250	73.4		0.4	
Benzene	431	263-590	28.9		1.0	
1,3-Butadiene	279	157-400	44.6		0.7	
2-Butanone	323	166-540	38.6		0.8	
Cresol	109	62-148	114.1		0.3	
Ethylbenzene	131	101-170	95.3		0.3	
Formaldehyde	1101	243-1333	11.3		2.6	
Isoprene	2400	1990-2810	5.2		5.7	
Methylnaphthalene	51	41-61	244.5		0.1	
Naphthalene	45	34-55	280.3		0.1	
Phenol	157	26-360	79.3		0.4	
Styrene	160	141-210	78.1		0.4	
1,2,4-Trimethylbenzene	56	25-74	221.3		0.1	
Toluene	777	364-1270	16.0		1.8	
Xylene	400	135-571	31.2		0.9	
N-Nitrosodimethylamine	0.57	0.34-0.79	22073		0.0013	
N-Nitrosopyrrolidine	0.10	0.07-0.14	119918		0.00025	

[a] average of emission factors (EFs) reported by (Leaderer and Hammond 1991; Hodgson, Daisey et al. 1996; Mahanama and Daisey 1996; Martin, Heavner et al. 1997; Nelson, Kelly et al. 1998; Daisey 1999; Singer, Hodgson et al. 2002; Singer, Hodgson et al. 2003; Bi, Sheng et al. 2005; Charles, Batterman et al. 2007); [b] range of EFs indicates the range of means of EFs reported by different studies, except N-Nitrosodimethylamine and N-Nitrosopyrrolidine, for which ranges represent 95% confidence intervals reported in the single study by (Mahanama and Daisey 1996); [c] ratios of concentration of $PM_{2.5}$(C_{PM}) to concentration of volatile organic compound (C_{VOC}) were derived from simple liner regression analysis of 186 side-by-side 2-hour measurements of $PM_{2.5}$ and SHS VOC tracers; [d] ratios of concentration of volatile organic compound (C_{VOC}) and concentration of 3-Ethenylpridine (3EP, C_{3EP}) were from simple linear regression analysis of 186 valid side-by-side 2-hour measurements of 3EP and other SHS tracers listed on the table.

5.2.3 Estimate of Health Risk by Excess Risk Assessment Method (Exposed/Nonexposed)

This method has been used to assess disease burden due to SHS exposure worldwide (Oberg, Jaakkola et al. 2011) and in the U.S. (CDC 2008). Briefly, the burden of a specific disease due to SHS exposure was estimated from the population attributable fraction (PAF), defined as the proportional reduction in disease that would occur if the exposure was reduced to zero. The attributable burden (AB) of a disease due to SHS exposure can be estimated by equations 5.3 (CDC 2008; Oberg, Jaakkola et al. 2011) and the attributable risk (AR) of death/case can be estimated by equation 5.4 (Steenland 1999).

$$AB_{SHS} = B_{ns} \times PAF_{SHS}$$
$$B_{ns} = (B - AB_{sm}) - (B - AB_{sm}) \times p_{sm} = (B - AB_{sm}) \times (1 - p_{sm})$$
$$PAF_{SHS} = p_{SHS}\,(RR_{SHS}-1)/[p_{SHS}\,(RR_{SHS}-1)+1] \quad [5.3]$$

$$AER_{SHS} = AB_{SHS}/P_{risk}$$
$$LER_{SHS} = AER_{SHS} \times Years \quad [5.4]$$

Where

B is the total burden of a disease in number of deaths/cases per year among the whole population;
B_{ns} is the burden of a disease in number of deaths/cases per year among nonsmokers;
$AB_{sm,}$ is the attributable burden of a disease in number of deaths/cases per year among smokers due to smoking;
AB_{SHS} is the attributable burden of a disease in number of deaths/cases per year among nonsmokers due to SHS exposure;
PAF_{SHS} is the PAF of the disease burden due to SHS exposure among nonsmokers;
p_{sm} is the prevalence of current smoking;
p_{SHS} is the prevalence of SHS exposure;
RR_{SHS} is the relative risk of a disease due to SHS exposure among nonsmokers;
AER_{SHS} is the average annual excess risk of death/case due to SHS exposure among nonsmokers;
P_{risk} is the population at risk, that is, current nonsmokers aged 35 years or older;
LER_{SHS} is the life time excess risk of death/case due to SHS exposure among nonsmokers;
Years is the number of years of exposure during lifetime.

To estimate the excess number of LCD and IHD deaths due to SHS exposure among nonsmoking adults in Minnesota and the U.S., the latest (year 2004) disease burden of these two diseases among all adults aged 35 and older (B in Eq. 5.3) and that attributed to smoking (AB_{sm} in Eq.5.3) were obtained from the CDC *Smoking-Attributable Mortality, Morbidity, and Economic Costs (SAMMEC)* website (CDC 2010a); the prevalence of current smoking (p_{sm}) for the US and the Minnesota populations and the prevalence of SHS exposure (p_{SHS}) for the US population were obtained from CDC *Morbidity and Mortality Weekly Report* (MMWR) (CDC 2005a ; CDC 2005b ; CDC 2010b). The prevalence of SHS exposure (p_{SHS}) for the Minnesota population relative to the U.S. population was assumed to be proportional to the ratios of prevalence of current smoking among the Minnesota population and the US population. Relative risk of LCD or IHD due to SHS exposure (RR_{SHS}) was acquired from the meta-analysis contained in the 2006 report of *The Health Consequences of Involuntary Exposure to Tobacco Smoke* by the Surgeon General (USDHHS 2006). Using these sources, the LER_{SHS} is the lifetime excess risk due to SHS exposure in general from all sources among nonsmokers, not just from exposure in restaurants and bars.

The 1992-1994 *National Human Activity Pattern Survey* (NHAPS) for the US determined the percentage of total time exposed to SHS that occurred in different microenvironments and showed that the percentage of total time exposed that occurred in restaurants and bars was 8.5% for males and 9.1% for females (Klepeis, Tsang et al. 1996). It was not reported whether these fractions were for restaurant and bar patrons only or for the general population including restaurant and bar workers. In this study, the latter was assumed to be true. Though exposure intensity varies to a great extent in different microenvironments, with SHS levels in bars and restaurants often higher than other indoor places (Siegel 1993; Hyland, Travers et al. 2008), these fractions were applied conservatively, without adjustment for relative exposure intensities, to estimate the LCD and IHD deaths due to SHS exposure in restaurants and bars for the general population (including servers and patrons).

Similar approaches were used to estimate the risk of asthma initiation due to SHS exposure at work for never-smoking restaurant and bar servers in Minnesota as well as in the US. According to the website of CDC's *Work-Related Lung Disease Surveillance System (CDC/NIOSH 2008)*, the average prevalence of current asthma (with asthma attack in the past 12 months) among never-smoking employees aged 18 and over in eating and drinking places was 3.8% (95% CI: 3.0-4.6%) from 1997 to 2005. The asthma incidence rate was estimated to be 10% of the prevalence of current asthma (Rudd and Moorman 2007). Data on restaurant and bar server (waiter/waitress and bartender) employment in 2004 was obtained from the U.S. Bureau of Labor Statistics (2011) and the never-smoking rate for the server population was assumed to be the same as the general population, which can be obtained from CDC MMWR website (CDC 2005a ; CDC 2005b).

To estimate the population attributable fraction (PAF_{SHS}) of asthma initiation, the relative risk was taken from a case control study in Finland (Jaakkola, Piipari et al. 2003) and the prevalence of SHS exposure at work in restaurants and bars was estimated from the percentage of the population not covered by smoking bans for restaurants and/or bars in May 2007 in Minnesota and in January 2011 in the U.S. (Minnesota Department of Health 2008; ANRF 2012). No data were available on prevalence of exposure in 2004, and using 2007 or 2011 data would probably underestimate the PAF_{SHS} since more employees were exposed to SHS at work in 2004.

5.3 Results

5.3.1 Estimates of Health Risks Based on Field Measurements: Categorical or Continuous Approach

The venue-weighted average of SHS PM levels during all the 2633 visits to Minnesota restaurants and bars was 72 $\mu g/m^3$ (SE 6 $\mu g/m^3$) and the average of nicotine levels during 201 two-hour visits was 3.17 $\mu g/m^3$ (SE 0.31 $\mu g/m^3$). The patron-weighted average SHS PM concentration to which patrons were exposed during their visits to smoking venues/sections was 134 μg/m^3 (SE 12 μg/m^3), the corresponding average for patrons visiting non-smoking sections was 30 μg/m^3 (SE 4 μg/m^3), and the weighted average for servers working in smoking-permitted venues was 78 μg/m^3 (SE 7 μg/m^3). 81.9% (2157) of the visits had SHS PM concentrations above the threshold of eye and nasal irritation (4.4 μg/m^3), which accounted for 89.9% of weighted patrons.

Based on the risk model developed by Repace (1985), SHS exposure in restaurants and bars before the implementation of the Minnesota comprehensive smoking ban could cause a LER of LCD of 18×10^{-6} (95% CI 13-23$\times10^{-6}$) for patrons visiting designated nonsmoking sections only, 80×10^{-6} (95%CI 66-95$\times10^{-6}$) for patrons visiting smoking venues/sections only and a LER of 802×10^{-6} (95%CI 658-936 $\times10^{-6}$) for servers (Table 5.5). The LER of overall cancer death due to exposure to nine SHS-VOCs is 48×10^{-6} for servers, 4.8×10^{-6} for patrons visiting only smoking venues/sections, 1.1×10^{-6} for patrons visiting only designated nonsmoking sections; most of these cancer risks were non-lung cancer risks (Table 5.6).

5.3.2 Excess Risk Assessment Approach (Exposed/Nonexposed)

This approach estimated the LER to be 800×10^{-6} (95%CI 430-1,180 $\times10^{-6}$) for LCD and $7{,}670\times10^{-6}$ (95% CI 4,830-10,510$\times10^{-6}$) for IHD death for the general nonsmoking population (including both patrons and servers) due to the average SHS exposure from all sources in Minnesota, and 890×10^{-6} (95% CI 480-1,290$\times10^{-6}$) for LCD and $12{,}530\times10^{-6}$ (95% CI 8,430-16,620$\times10^{-6}$) for IHD death in the U.S. (Table 3). The LER of asthma initiation is estimated to be 7.2% (95% CI 2.4-11.9%) for nonsmoking servers due to SHS exposure in restaurants and bars in Minnesota and 4.1% (95% CI 0.7-7.5%) for nonsmoking servers in the US. These risks correspond to three LCDs and 32 IHD deaths per year among the general nonsmoking population, 53 new asthma cases per year among nonsmoking servers in Minnesota, 214 LCDs and 3001 IHD deaths per year among the general nonsmoking population and 1420 new asthma cases per year among nonsmoking servers in the US. (Table 5.7-5.8).

Table 5.5 Servers' and patrons' risk of lung cancer death due to exposure to secondhand smoke in restaurants and bars in Minnesota, 2007

	Servers	Patrons	
		Smoking venues/section	Nonsmoking sections
Weighted SHS PM levels, mean (95%CI), μg/m^3	78 (64, 91)	134 (110, 158)	30 (22, 38)
Dose response according to Repace, et al	5×10^{-5} per year for exposure to 1mg per day		
Breathing rates, m^3/hr	1.6	1.0	1.0
Average hours per day exposed to SHS, hr/day	4	1.4	1.4
Days per week exposed to SHS, day/week	5	1	1
Number of years exposed to SHS, years	45	60	60
Lifetime excess risk of lung cancer death (95%CI), 10^{-6}	802 (658, 936)	80 (66, 95)	18 (13, 23)

Note: the 95% confidence intervals (CIs) presented here indicate only the variance of the weighted SHS PM levels during peak patronage times; uncertainties from other sources are not integrated.

Table 5.6 Servers' and patrons' cancer risk due to exposure to nine SHS VOCs in restaurants and bars in Minnesota, 2007

				Servers		Patrons, smoking venues/sections		Patrons, nonsmoking sections	
	Carcinogenicity effect	URE/UR[a] (10^{-6})	EF [b] (μg/cig)	level [c] (μg/m³)	LER [d] (10^{-6})	level [c] (μg/m³)	LER [d] (10^{-6})	level [c] (μg/m³)	LER [d] (10^{-6})
$PM_{2.5}$			12471	11.5	--	1.1	--	0.2	--
Acetaldehyde	nasal cancer in rates	2.20	2292	2.11	4.6	0.20	0.5	0.04	0.1
Acrylonitrile	lung cancer in human	68.0	170	0.16	10.6	0.01	1.1	0.00	0.2
Benzene	leukemia in human	7.80	431	0.40	3.1	0.04	0.3	0.01	0.06
1,3-Butadiene	lymphohematopoietic cancer in human	30.0	279	0.26	7.7	0.02	0.78	0.01	0.2
Ethylbenzene	kidney cancer in rats	2.50	131	0.12	0.3	0.01	0.03	0.00	0.01
Formaldehyde	nasal cancer in human	13.0	1101	1.01	13.2	0.09	1.3	0.02	0.3
Naphthalene	nasal cancer in rats	34.0	45	0.04	1.4	0.00	0.1	0.0009	0.03
N-Nitrosodimethylamine	liver cancer in rats	14000	0.57	0.00052	7.3	0.00005	0.7	0.00001	0.2
N-Nitrosopyrrolidine	liver cancer in rats	600	0.10	0.00010	0.06	0.00001	0.005	0.000002	0.001
Total risk of all cancers		--	--	--	48.3	--	4.8	--	1.1
Total risk of non-lung cancers		--	--	--	37.7	--	3.8	--	0.8

[a] URE/UR: unit risk estimate reported by U.S. EPA or unit risk reported by California EPA;
[b] EF: emission factor, average of EFs reported in the literature, see table 5.4;
[c] level: daily average exposure concentration during a lifetime of 70 years, adjusted by the factor in equation 5.2;
[d] LER, lifetime excess risk of cancers;
Notes: only nine SHS-VOCs with both EF in μg/cigarette available from the literature and URE or UR available from U.S. EPA or California EPA website are included in this table. Compounds for which either EF or URE/UR is unavailable are not included even though they are known carcinogens.

Table 5.7 Attributed death and lifetime excess risk of LCD and IHD death due to SHS exposure in Minnesota and U.S., 2004 [a]

	Minnesota [b]		United States [b]	
	Lung cancer	Ischemic heart disease	Lung cancer	Ischemic heart disease
Total burden (B), 2004, deaths/year [c]	2 352	4 861	157 908	450 043
Attributable burden due to smoking (AB_{sm}), 2004, deaths/year [c]	1 838	776	125 542	72 715
Population at risk, current nonsmokers aged 35+ (P_{risk}), 2004 [c]	male 1 026 443 female 1 140 400		male 57 058 144 female 65 584 599	
Prevalence of current smoking (p_{sm}), 2004, % [d]	male 22.0 (17.7, 26.3) female 19.5 (15.8, 23.2)		male 23.4 (21.6, 25.2) female 18.5 (17.1, 19.9)	
Prevalence of SHS exposure (p_{SHS}), 2003-2004, % [e]	male 48.8 (41.6, 55.9) female 46.6 (38.8, 54.4)		male 51.9 (44.3, 59.5) female 44.2 (36.8, 51.6)	
Relative risk due to SHS exposure (RR_{SHS}) [f]	1.22 (1.12, 1.32)	1.27 (1.17, 1.37)	1.22 (1.12, 1.32)	1.27 (1.19, 1.36)
Disease burden among nonsmokers (B_{ns}), 2004, deaths/year	410 (380, 439)	3 235 (3 019, 3 450)	25 794 (24 031, 27 557)	298 365 (278 356, 318 373)
Overall mortality rate among nonsmokers aged 35+, per 10^4	1.9 (1.7, 2.1)	14.9 (13.5, 16.3)	2.1 (1.9, 2.3)	24.3 (22.0, 26.6)
PAF of disease burden among nonsmokers due to SHS exposure (PAF_{SHS}), %	9.5 (5.4, 13.6)	11.4 (7.3, 15.5)	9.5 (5.4, 13.6)	11.4 (7.9, 15.0)
Attributable burden among non-smokers due to SHS exposure (AB_{SHS}), deaths/year	39 (26, 52)	369 (273, 466)	2 412 (1 630, 3 195)	34 143 (26 281, 42 004)
Average annual excess risk due to SHS exposure (AER_{SHS}), 10^{-6}	17.8 (9.5, 26.1)	170.4 (107.3, 233.5)	19.7 (10.8, 28.6)	278.4 (187.4, 369.3)
Lifetime excess risk due to SHS exposure for 45 years (LER_{SHS}), 10^{-6}	800 (430, 1 180)	7 670 (4 830, 10 510)	890 (480, 1 290)	12 530 (8 430, 16 620)
Percentage of SHS exposure in restaurants and bars of total SHS exposure in terms of time, % [g]	male 8.5 female 9.1		male 8.5 female 9.1	
Mortality attributed to SHS exposure in restaurants and bars, deaths/year	3 (2.6, 4.3)	32 (26, 38)	214 (164, 263)	3 001 (2 512, 3 490)

[a] Assessment of disease burden was conducted separately for male and female populations, but aggregated data are presented in this table to save space; Overall mortality rate among nonsmokers aged 35+, PAF_{SHS}, AER_{SHS} and LER_{SHS} were weighted estimates by population at risk of males and females;

[b] Except [c d e f g], all the other numbers were estimated according to equation 5.3 or 5.4; the confidence intervals were estimated by propagation of uncertainties of reported parameters;

[c] Data obtained from the CDC SAMMEC website (CDC 2010a);

[d] Data obtained from CDC Morbidity and Mortality Weekly Report (MMWR)(CDC 2005a);

[e] Data from CDC MMWR, which was defined as the percentage of nonsmoking population with serum cotinine ≥ 0.05 ng/ml (CDC 2010b);

[f] Relative risks due to SHS exposure from the meta-analysis in the Surgeon General's Report (USDHHS 2006);

[g] Data from the 1992 to 1994 National Human Activity Pattern Survey (NHAPS) for the United States (Klepeis, Tsang et al. 1996).

Table 5.8 Attributed cases and lifetime excess risk of asthma initiation among never smoking servers due to SHS exposure at work in restaurants and bars in Minnesota and in U.S., 2004 [a]

	Minnesota [b]	United States [b]
Number of restaurant and bar servers employed, 2004 [c]	63 300	2 700 590
Never smoking rate, 2004, % [d]	52.5 (49.2, 55.8)	57.6
Prevalence of current asthma among never smoking restaurant and bar servers, % [e]	3.8 (3.0, 4.6)	3.8 (3.0, 4.6)
New asthma cases among never smoking restaurant and bar servers (B_{ns}), cases/year [f]	126 (104, 148)	5 911 (4 861, 6 961)
Percentage of population covered by smoke-free restaurants and/or bars ($1-p_{SHS}$), % [g]	38.1 (35.2, 41.0)	restaurants: 74.5 bars: 63.7
Relative risk of asthma initiation due to SHS exposure (RR_{SHS}) [h]	2.16 (1.26, 3.72)	2.16 (1.26, 3.72)
Population at risk, never smoking restaurant and bar servers (P_{risk})	33 233 (31 558, 34 907)	1 555 540
PAF of new asthma cases among never smoking restaurant and bar servers due to SHS exposure (PAF_{SHS}), %	41.8 (16.0, 67.6)	24.0 (4.7, 43.3)
New asthma cases attributed to SHS exposure (AR_{SHS}), cases/year	53 (25, 80)	1 420 (449, 2 390)
Average annual excess risk of asthma initiation due to SHS exposure (AER_{SHS}), 10^{-6}	1588 (542, 2635)	913 (153, 1672)
Lifetime excess risk of asthma initiation for restaurant and bar servers due to SHS exposure at work for 45 years (LER_{SHS}), %	7.2 (2.4, 11.9)	4.1 (0.7, 7.5)

[a] Assessment of disease burden was conducted separately for waiters/waitresses and bartenders, but aggregated data were presented in this table to save space; PAF_{SHS}, AER_{SHS} and LER_{SHS} were weighted estimates by population at risk;

[b] Except [c d e f g h], all the other numbers were estimated according to equation 5.3 or 5.4; the confidence intervals were estimated by propagation of uncertainties of reported parameters;

[c] Data from Occupational Employment Statistics, U.S. Bureau of Labor Statistics (2011);

[d] Data from CDC Morbidity and Mortality Weekly Report (MMWR) (CDC 2005a ; CDC 2005b). The variance for never smoking rate of the U.S. population was not reported;

[e] Current asthma was defined as having an asthma attack in past 12 months. Data are from CDC NIOSH website of Work-Related Lung Disease (WoRLD) Surveillance System, table 9-20 (CDC/NIOSH 2008); which presents the average prevalence of current asthma among never smoking employees aged 18 and over in eating and drinking places from 1997 to 2005;

[f] Estimated from [a b c] and the assumption that the incidence rate of new asthma cases is 10% of prevalence of current asthma according to Rudd and Moorman (2007);

[g] Data from Minnesota Adult Tobacco Survey report for Minnesota (Minnesota Department of Health 2008) and from American Nonsmokers' Rights Foundation websites for U.S. (2012) (no variance reported). The coverage percentage was for May2007 for MN and for January 2011 for U.S.A.;

[h] Relative risk of asthma initiation related to workplace SHS exposure reported by Jaakkola et al (2003).

5.4 Discussion

The US EPA requires that the annual average ambient $PM_{2.5}$ concentration should not exceed 15 μg/m^3 and the 24-hour average level should not exceed 35 μg/m^3 (U.S. EPA 2006); the World Health Organization has even stricter guidelines for ambient air quality (WHO 2005), with the annual mean not exceeding 10 μg/m^3 and 24h-hour mean not exceeding 25 μg/m^3. Consistent with other studies (Repace 2004; Hyland, Travers et al. 2008; Liu, Yang et al. 2010), this study found that restaurant and bar servers working in smoking-permitted venues could be exposed to SHS at work more than twice the ambient $PM_{2.5}$ 24-hour average exposure limit and more than four times the annual average exposure limits.

Though four papers (El-Hougeiri and El Fadel 2002; Siegel and Skeer 2003; Hedley, McGhee et al. 2006; Lopez, Nebot et al. 2006) have been published on assessing health risks due to SHS exposure in restaurants and/or bars, this study is the first quantitative risk assessment for patrons of bars and restaurants and for asthma and cancer other than lung cancer (Table 5.9). The quality of the underlying exposure data is vastly superior to that in any of the previous secondhand smoke risk studies, which examined risks for servers or workers only and only for cancer and heart disease. The paper by El-Hougeiri and El Fadel estimated the number of hours spent by chefs and waiters above irritant concentrations of carbon monoxide (CO) and total suspended particles (TSP) and the risk of cancer based on 16 CO and 12 TSP measurements in one restaurant and mathematical modeling (note that neither CO nor TSP are unique to SHS). The paper by Hedley et al. was based on air nicotine concentrations back-calculated from urine cotinine measurements from 184 volunteers, who were catering workers (detailed job titles not specified) from restaurants and bars in Hong Kong and used questionnaires to identify exposure sources; serious limitations in this approach include the metabolic variability in both the rate and the percentage of air nicotine metabolized to cotinine; the fact that cotinine integrates exposures from all venues, including homes and cars, the uncertainty regarding where each sample and each exposure is on the cotinine decay curve, and the concern about the quality of information from questionnaires used to identify sources. Siegel and Skeer used airborne nicotine concentrations reported in 10 studies at 27 bars in the U.S., while Lopez et al. used airborne nicotine measurements taken over one week in 26 restaurants and disco/pubs in Spain. Thus, measurements from only one US restaurant were used in any of these SHS risk assessment papers; for all of three other studies, all sample sites and subjects were of convenience, not chosen scientifically. In contrast, the 65 Minnesota bars and restaurants in this study were chosen systematically to represent venues permitting smoking, multiple SHS constituents were measured (including nicotine) and over 2,000 measurements were made methodically at different times of day and different days of the week to capture the variability in SHS concentrations.

In addition, three papers (Siegel and Skeer 2003; Hedley, McGhee et al. 2006; Lopez, Nebot et al. 2006) used a single dose-response model, that published by Repace and Lowery in 1985 (Repace and Lowrey 1985) to estimate the excess lung cancer risk and/or heart disease risk for workers; the paper by El-Hougeiri and El Fadel (2002) based its dose-response model on potency factors for diesel exhaust released by California Air Resources Board and the Office of Environmental Health Hazard Assessment in 1998. By contrast, this study used both the Repace and Lowery model and others to estimate excess lung cancer risk and/or heart disease risk for servers and patrons. See Table 9 for comparison of this study and the four studies described above.

Restaurants and bars are one of the leading employers (U.S. BLS 2011) and are important public places for the general population. According to a telephone interview with a nationally representative sample of 2250 adults, 66% of adults eat out at least weekly (Pew Research Cener 2006). However, about 30% of the U.S. population and 95% of the world population are still not covered by smoking bans for restaurants and bars (WHO 2009; ANRF 2012).

A LER of 1×10^{-6} has been considered as a *de minimis risk*, which is an acceptable level of risk that is below regulatory concern, while a LER of 3×10^{-4} has been considered as a *de manifestis risk*, a risk of obvious or evident concern and one that public agencies will almost always regulate to control or mitigate when recognized (Travis, Crouch et al. 1987). Among workers, a LER of 1×10^{-3} has been considered as a *significant risk*, an unsafe level often used as a benchmark by the U.S. Occupational Safety and Health Administration (OSHA). The results of this study indicate that SHS-induced LER of LCD for restaurant and bar servers is much higher than the *de manifestis* risk level, regardless of which dose-response model is used for the estimates. The LER of non-lung cancers due to exposure to SHS-VOCs regulated as HAPs by U.S. EPA is in addition to the LER of LCD and is probably underestimated because we included only the nine SHS-VOCs for which both emission factors and cancer unit risk estimates have been reported; the impact of particle phase or other gas phase carcinogens was omitted. We would expect that the LER of IHD death for restaurant and bar nonsmoking servers is much higher than the *significant risk* used by OSHA. Regarding other health effects, about 90% of patrons and servers visiting or working in restaurants or bars allowing smoking are at risk of eye and nasal irritation, and the lifetime excess risk of asthma initiation could be higher than 10% for nonsmoking servers.

A study in five cities in China reported that the geometric mean of indoor $PM_{2.5}$ levels in restaurants and bars with smoking observed was 208 $\mu g/m^3$ (Liu, Yang et al. 2010). Another study conducted in 10 cities of eight European countries reported that for restaurants and cafeterias with smoking not banned, the median (inter-quartile ranges, IQRs) of seven-day weighted average nicotine levels ranged from 1.18 (0.19-4.84) $\mu g/m^3$ in Paris, France, to 10.95 (6.22-17.67) $\mu g/m^3$ in Bratislava, Slovakia (Lopez, Nebot et al. 2008). These SHS levels were similar to or higher than the peak-time two-hour averaged nicotine levels in the smoking sections of restaurants and bars in this study (median 1.60 $\mu g/m^3$, IQRs 0.5-4.2 $\mu g/m^3$, data not shown). The health risks from SHS exposure in these cities/countries are expected to be similar to or higher than the risks reported in the current study. These risks can impose a significant disease burden on the population, strongly indicating that smoking in restaurants and bars should be a priority of regulatory concern to municipal, state and national governments, and that they should not be exempt from smoking bans.

To fight against comprehensive smoking bans in restaurants and bars, the tobacco industry has advocated designated nonsmoking sections in restaurants and bars. Unfortunately, this approach offers little or limited protection for nonsmokers, especially for nonsmoking servers, who must serve customers in both sections. The results of our study showed that the LER of LCD is more than ten times the *de minimis risk* even for patrons who visit only designated nonsmoking sections once a week during their lifetime, and the LER of IHD death is substantially higher than that of LCD. Thus, restricting smoking to designated areas is an ineffective way to eliminate the health risk of SHS.

The attributable risk assessment method indicated that the LER of LCD due to SHS exposure from all sources is similar for the Minnesota population and the US population, while the LER of IHD death is lower among the Minnesota population than among the U.S. population. This is because the overall mortality rate of IHD is lower among nonsmokers aged 35 and over in Minnesota. The LER of asthma initiation among nonsmoking restaurant and bar servers is higher in Minnesota than in the U.S. as a whole, because a lower percentage of the Minnesota population was covered by smoke-free restaurants and bars.

The LER of cancer due to exposure to SHS-VOCs regulated as HAPs by the US EPA is lower than that for LCD estimated with other approaches, probably because we only included nine SHS-VOCs which had both emission factors and cancer unit risk estimates available from the literature, while excluding particle phase or other gas phase carcinogens. The estimated overall IHD mortality rate among nonsmokers aged 35 and over in the U.S. in this study (24.3×10^{-4} in table 3) is quite close to the IHD mortality rate among never-smokers reported in four cohort studies (Steenland 1992) weighted by the age and gender specific nonsmoking population of 35 and over in 2004, which is 212×10^{-6}. The consistency between these indicates that the risk assessment and the underlying assumptions used in this study are reasonable and reliable.

The confidence intervals reported in this study reflect only the variations of measured SHS levels or the reported uncertainties of related parameters used in this study and do not encompass all uncertainty of this risk assessment. We believe that the variance of servers' and patrons' exposure to SHS PM in restaurants and bars in Minnesota was relatively well characterized by the selection and weighting of the venues and the inclusion of multiple measurements taken during different times of a day and on different days of the week in each venue. Bar and restaurant servers and patrons may be different from the overall general population in lifestyle, and lifestyle factors such as drinking and unhealthy diet might be synergistic with SHS exposure. It is more possible that we underestimated the health risks of SHS exposure in restaurants and bars because it is less likely that servers and patrons have a healthier lifestyle than the general population. In addition, as servers and patrons are transient populations with a high turnover, the LER estimated in this study is likely to overestimate the risk for servers and patrons who are not exposed as much as what are assumed in this study. However, regulations should protect those who do make a career of restaurant or bar work, as well as those who visit regularly. A study showed that, among those aged 17 years and over, the current cigarette smoking rate among waiters and waitresses was 44.5% (95% CI 35.9-53.1%), comparing to the overall prevalence of cigarette smoking of 28.3% (95% CI 26.9-29.8%) during the 1988-1994 period (Bang and Kim 2001). Thus by using the proportion of current nonsmokers of the general population, it may overestimate the number of new asthma cases attributed to SHS exposure by nonsmoking servers, however, the lifetime risk will be the same.

There are reasons to believe that these health risks are underestimated. In assuming that restaurant and bar servers are exposed to SHS in the workplace for only 4 hours per day and that patrons are exposed for only 86 minutes per week, the risks for servers who work full time in these venues and for patrons who visit smoking restaurants and bars more frequently are likely to be underestimated. When using the unit risk to estimate the cancer risk due to SHS exposure, only nine SHS-VOCs were included while other carcinogens were ignored. When using the attributable risk assessment approach, we assumed that SHS exposure levels in restaurants and bars were similar to the average of general SHS exposure and we used a higher percentage of population covered by smoke-free restaurants and bars than would have been the case in earlier years. Furthermore, only three of the diseases caused by SHS exposure were included, while other health outcomes, e.g., breast cancer for young nonsmoking servers, acute heart disease events, acute respiratory irritations for children, etc., were not included due to limited data to quantify these risks.

5.5 Conclusions

The health risk for patrons visiting smoking restaurants and bars is well above the acceptable level, and for servers it exceeds the "*significant risk*" level. Banning smoking in restaurants and bars should be a high priority for governments in regions which have not done so. This study provides strong evidence that smoking should be banned in hospitality venues to protect the public's health.

Table 5.9 Comparison of this study and four published studies on assessing health risks due to SHS exposure in restaurants and bars

	this study	Lopez, et al. 2006	Hedley et al. 2006	Siegel M, Skeer M. 2003	El-Hougeiri and El Fadel 2002
venue/subjects selection	65 venues selected in a very systematic and random way to represent restaurants and bars permitting smoking, with consideration of venue types and sizes and expected standard deviatioin of SHS concentrations	convenience sample	volunteers from catering places in Hongkong	27 bars from 10 studies from literature conducted in the U.S.	one restaurant in the U.S.
assessment method	based on both filed measurements and published epidemiological data	field measurements	Urine cotinine of volunteers, exposure sources identified by questionnaires	literature review	field measurements in one venue and mathematical modeling
Tracers monitored	Included PM2.5, airborne nicotine, , 3-ethenypridine, pyridine, pyrrole, myosmine, 3,4-picoline, etc.	airborne nicotine	CO to screen smokers/nonsmokers, urine cotinine from volunteers	nicotine concentrations from literature, weighted by number of venues in selected studies	carbon monoxide (CO), total suspended particles (TSP)
sampling time period	during different patronage peak time period (lunch, dinner and evening) of different days of a week	one week of passive area nicotine sampling	no limits on urine sampling time, could be during or after (no time limit) shifts	no limitations, any nicotine measurements with mean reported	CO during peak activity time, TSP right after peak activity time
n of measurements/subjects	Over 200 2-hour measurements and over 2400 10-minutes measurements	52 samples from 26 venues	151 of 184 volunteers with complete information		16 CO measurements and 12 TSP measurements
subject of risk assessment	servers, patrons	hospitality workers	catering workers, waiters and non-waiters	bar workers	servers, chefs
health outcomes	eye and nasal irritation; lung cancer, non-lung cancer, ischemic heart disease, asthma initiation	lung cancer risk	lung cancer and heart disease deaths	lung cancer death	irritation effect, cancer effect
dose-response model	Repace model based on SHS PM exposure, VOC unit risk model, and attributable risk assessment approach	Repace model based on SHS PM exposure	Repace model, adjusted to Hongkong's heart disease mortality rate	Repace model based on SHS PM exposure	CA ARB/OEHHA diesel exhaust dose-response model in 1998

	this study	Lopez, et al. 2006	Hedley et al. 2006	Siegel M, Skeer M. 2003	El-Hougeiri and El Fadel 2002
estimated health risk	90% of patrons visiting restaurants and bars allowing smoking are at risks of eye and nasal irritation; a lifetime excess risk (LER) of 18×10^{-6}(95%CI 13-23×10^{-6}) of lung cancer death (LCD) for patrons visiting only designated nonsmoking sections, 80×10^{-6}(95%CI 66-95×10^{-6}) for patrons visiting only smoking venues/sections and 802×10^{-6} (95%CI 658-936×10^{-6}) for servers in smoking-permitted venues. An attributable-risk approach estimated a similar LER of LCD and a LER of IHD death about 10^{-2} for the general nonsmoking population with averaged SHS exposure from all sources and a LER of asthma initiation about 5% for servers with SHS exposure at work only.	A LER of LCD of 1450×10^{-6} for workers from all places studied, and 220×10^{-6} for workers in from cafeterias in hospitals	LER of lung cancer death and heart disease death combined of 3% (median 1.7%, 10-90%: 1-6%)	4.1/1000 (range 0.1-140/1000)	4.74/1000 for waiter with shift from 10 AM-6 PM, 3.58/1000 for waiter with shift from 6 PM-2 AM , 2.29/1000 for chefs with shift from 10 AM- 6PM, and 1.84/1000 for chefs with shift from 6 PM-2 AM
# of cases	214 LCDs and 3001 IHD deaths among the general nonsmoking population and 1420 new asthma cases among nonsmoking servers in the U.S. each year because of SHS exposure at work.	Not estimated	150 deaths in the Hongkong catering workforce of 200,000 (this risk applied to smoking workers, too)	Not estimated	Not estimated

Chapter 6 An Assessment of Health Risks and Mortality from Exposure to Secondhand Smoke in Chinese Restaurants and Bars

6.1 Background

More than 600 000 deaths were estimated to be caused by secondhand smoke (SHS) exposure in 2004, corresponding to 1.0% of all deaths worldwide in that year (Oberg, Jaakkola et al. 2011). As described in previous chapters, China is the largest consumer of tobacco in the world, with 301 million current smokers (including 53% of men and 2.4% of women) (Li, Hsia et al. 2011) and 556 million adult passive smokers (72.4% of adult nonsmokers) in 2010 (Xiao, Yang et al. 2010). Gan et al. estimated that 130 000 lung cancer deaths and 169 600 ischaemic heart disease deaths were attributed to active smoking, and 22 200 lung cancer deaths and 33 800 ischaemeic heart disease deaths were attributed to SHS exposure among nonsmoking adults in China in 2002 (Gan, Smith et al. 2007).

In China, where the tobacco industry is owned by the government (Chinese CDC 2011), developing and implementing effective policies to reduce active and passive smoking is particularly challenging. China ratified the World Health Organization's Framework Convention on Tobacco Control (WHO FCTC) in 2006. Health departments of the Chinese government and many health organizations have been working hard to implement the Convention and have made considerable progress. For example, more and more cities have started to revise their local legislations to prohibit or restrict smoking in more public places; national legislations have been updated to regulate cigarette packaging and labeling and to adjust the consumption tax of tobacco products. However, most of these achievements are compromised results of favoring the tobacco industry's economic interests over the health of people, and there is still a huge gap between China's current state of affairs and the FCTC requirements (Yang and Hu 2010; Lv, Su et al. 2011). As presented in Chapter 4, the Beijing Government's smoking restrictions are poorly implemented and are ineffective in protecting people from the adverse health effects of SHS exposure.

Other factors challenging tobacco control efforts in China: the majority of men smoke; smoking is acceptable to the general population; SHS exposure is prevalent; and the related hazard health effects are not recognized by nearly 75% of the population (Chinese CDC 2011). Thus, information about the magnitude of the health risks and disease burden due to SHS exposure is particularly important for policy makers to plan preventive strategies and for the general population to understand their right of enjoying smoke-free air.

There were about 11 million restaurant or bar employees in 2004 (National Bureau of Statistics of China 2005), and 15% of people aged 15 years and older eat out at least every day (Ma, Hu et al. 2005). However, smoking is generally not regulated in most restaurants and bars or is not fully implemented if there are any restrictions, as shown in Chapter 4 and another study(Yang, Jiang et al. 2008). To provide necessary evidence for advancing tobacco control in this specific environment, that is, restaurants and bars, this chapter assesses the health risks and deaths of lung cancer and ischaemic heart disease (IHD) attributed to SHS exposure in this type of environments for workers and patrons, using similar approaches as Chapter 5.

6.2 Methods

6.2.1 Estimate of Lung Cancer Risk Using a Continuous Approach Based on Modeled SHS Exposure Levels

As in Chapter 5, the model developed by Repace and Lowrey (1985) was used to estimate the lifetime excess risk (LER) of lung cancer death (LCD) due to SHS exposure, indicated by SHS PM. The same equation was used, that is:

$$LER\ of\ LCD = 5 \times 10^{-5}\ (\text{mg/day-year})^{-1} \times Daily\ dose\ (\text{mg/day}) \times Years$$

$$Daily\ dose\ (\text{mg/day}) = C_{SHS\text{-}PM}\ (\text{mg/m}^3) \times BR\ (\text{m}^3\text{/hr}) \times Time\ (\text{hr/day}) \times f$$

[5.1, Chapter 5]

Where

Daily dose is the exposure dose of SHS PM in mg/day for an individual;

Years is the number of years exposed to SHS;

$C_{SHS\ PM}$ is the average concentration of SHS PM in mg/m^3 during the period of exposure (here taken to be the peak patronage times);

BR is the breathing rate in m^3/hr;

Time is the average hours per day exposed to SHS;

f is the number of days per week exposed divided by 7 days.

Because only a limited number of studies measured SHS concentrations in non-representative restaurants or bars in some cities in China (Kang J, Lin X et al. 2007; Liu, Yang et al. 2011; Liu, Lu et al. 2012), modelled SHS PM concentrations, as presented in Chapter 3, were used. Lifetime excess risks of LCD were estimated separately for servers and patrons by different smoking policies and by restaurants and bars. For restaurants or bars restricting smoking in designated smoking sections, the risks for patrons visiting designated smoking sections only or visiting designated non-smoking sections only were estimated. For servers, because they need to move between both sections to serve patrons, their time spent in each section was assumed to be proportionate to the volume of each section, and the concentrations exposed to servers were estimated by weighting the concentrations in each section as modelled in Chapter 3 by the ratio of non-smoking-section volume to smoking-venue volume (f_2). That is, the weighted SHS concentrations exposed by servers working in restaurants or bars with designated smoking sections were estimated by the following equation:

$$C_{SHS\text{-}PM} = (C_{smoking\text{-}section\ SHS\text{-}PM} + C_{nonsmoking\text{-}section\ SHS\text{-}PM} \times f_2)/(1+f_2) \qquad [6.1]$$

As assumed in Chapter 3, the ratio f_2 had a beta distribution, with the two shape parameters α=2.85, β=28, and with a mean of 1.0, a standard deviation of 0.5, and a range of 0.1 to 10.

For breathing rate (*BR*), the same assumption as in Chapter 5 was used. That is, 1.6 m^3/hr for servers at a moderate activity level and 1.0 m^3/hr for patrons at a light activity level, based on recommendations by U.S. EPA (1997). Hospitality servers were reported to work for an average of 49.1 hours/week in 2004 (male 49.8 hours/week, female 48.6hours/week) (National Bureau of Statistics and Ministry of Labour and Social Security of China 2005). Restaurant workers could be exposed to SHS during working hours for an average of 24.2±18.6 hours per week (Zheng, Fu et al. 2009). Because SHS PM concentrations were modeled for peak patronage times only, to avoid overestimating restaurant and bar servers' exposure during work, their exposure time was assumed to be four hours a day during peak patronage time for five days a week, and a working life of 45 years was also assumed, as in Chapter 5. For patrons, an average adult was reported to spend 13 minutes per day (male 16 minutes, female 9 minutes) in restaurants and bars in 2008 (National Bureau of Statistics of China 2008). Based on the assumptions, *f* equals to 5days/7days for servers and one for patrons.

The ratios of emission rate of $PM_{2.5}$ to emission rates of volatile organic compounds for Chinese cigarettes may be different than those for cigarettes of other countries, as shown by the relationship of SHS PM and airborne nicotine concentrations in Beijing restaurants and bars in Chapter 2. Therefore, the risks of other cancers than lung cancer risks due to exposure to VOCs were not estimated in this Chapter. However, they may add significantly to lung cancer risk, as reported in Chapter 5.

6.2.2 Estimate of Health Risk by Excess Risk Assessment Method (Exposed/Nonexposed)

As in Chapter 5, this method uses the population attributable fraction (PAF) to estimate the attributable deaths of lung cancer and ischaemic heart disease due to SHS exposure in restaurants and bars. Equations 3 and equations 4 from Chapter 5 were used in this Chapter.

$$AB_{SHS} = B_{ns} \times PAF_{SHS}$$

$$B_{ns} = (B - AB_{sm}) - (B - AB_{sm}) \times p_{sm} = (B - AB_{sm}) \times (1 - p_{sm})$$

$$AB_{sm} = B \times PAF_{smk}$$

$$PAF_{smk} = p_{smk}(RR_{smk} - 1)/[p_{smk}(RR_{smk} - 1) + 1]$$

$$PAF_{SHS} = p_{SHS}(RR_{SHS} - 1)/[p_{SHS}(RR_{SHS} - 1) + 1]$$

[5.3, Chapter 5]

$$AER_{SHS} = AB_{SHS}/P_{risk}$$

$$LER_{SHS} = AER_{SHS} \times Years$$

[5.4, Chapter 5]

Where

B is the total number of deaths of a disease per year among the whole population;
B_{ns} is the number of deaths of a disease per year among nonsmokers;
$AB_{sm,}$ is the attributable number of deaths of a disease per year among smokers due to smoking;
AB_{SHS} is the attributable number of deaths from a disease per year among nonsmokers due to SHS exposure;
PAF_{smk} is the PAF of the total deaths of a disease among a population due to active smoking;
PAF_{SHS} is the PAF of the deaths of a disease due to SHS exposure among nonsmokers;

p_{sm} is the prevalence of current smoking;
p_{SHS} is the prevalence of SHS exposure;
RR_{smk} is the relative risk of a disease due to active smoking;
RR_{SHS} is the relative risk of a disease due to SHS exposure among nonsmokers;
AER_{SHS} is the average annual excess risk of death due to SHS exposure among nonsmokers;
P_{risk} is the population at risk, that is, current nonsmokers aged 35 years or older;
LER_{SHS} is the life time excess risk of death due to SHS exposure among nonsmokers;
Years is the number of years of exposure during lifetime.

To be consistent with the estimates of deaths of adult lung cancer and ischaemic heart disease from SHS exposure for 2002 in China by Gan et al. (2007), the calculation in this chapter also used data on population and disease rates from the database of the regional burden of disease estimates for WPRO-B (Western Pacific Regional Office-countries with low child and adult mortality rates) published by the World Health Organization (WHO). However, because data on restaurant and bar employment were available for 2004 only, the estimates for 2004, instead of 2002 as used by Gan et al. were used for the calculation in this chapter. China made up of 82% of the population of WPRO-B region in 2004, thus this factor was applied to data from that WHO subregion to estimate the age and gender specific population and mortality (*B* in the equations above) of lung cancer and ischaemic heart disease (Table 6.1). Because of the latency of developing lung cancer or ischaemic heart disease, the calculations were restricted to adults aged above 30 years (the WHO dataset only has age groups of 30-44, thus the cutting point of 30 rather than 35, as in Chapter 5, was used in this Chapter) .

There were 11,285,000 people employed by restaurants and bars in 2004 (National Bureau of Statistics of China 2009); and gender and age distributions of restaurant and bar employees in urban areas (but not in rural areas) in 2004 could be obtained from the China Labour Statistical Yearbook (National Bureau of Statistics and Ministry of Labour and Social Security of China 2005). For this analysis, the gender and age distributions of the total restaurant and bar employees were assumed to be the same as of the urban employees. Because the mortality of lung cancer and ischaemic heart disease for this specific population was not available, the mortality rates of these two diseases among restaurant and bar workers were assumed the same as among the general population.

Age and gender specific prevalence of current smoking and SHS exposure was obtained from the 1984 and 1996 national surveys of Chinese adult smoking behaviors (Table 6.1). Detailed information on SHS exposure was not available from the 1984 survey; since the current smoking prevalence of Chinese male adults did not change so much from 1984 to 1996, SHS exposure prevalence in 1984 was assumed similar to that in 1996. To count for the latency of lung cancer and ischemic heart diseases, the 1984 current smoking prevalence and SHS exposure prevalence (assumed to be similar with the 1996 SHS exposure prevalence) of the 2004 population were used to calculate the population attributable fractions (PAF). That is, to estimate the deaths of the two diseases attributed to smoking or SHS exposure for the age group 30-44, the current smoking prevalence of the age group 15-30 in 1984 and the SHS exposure prevalence for this age group in 1996 was used. About 90% of people who went to restaurants and bars reported that they were exposed to SHS in those places in 2010 (Xiao, Yang et al. 2010), and SHS exposure in restaurants and bars in earlier times, e.g. before 1996, were expected to be higher than 90%. Therefore, for this analysis, 95% of restaurant and bar workers and patrons were assumed to be exposed to SHS.

The relative risks (*RRs*) of lung cancer and ischaemic heart disease used to calculate the PAF due to active smoking and SHS exposure were the same as used by Gan et al (Gan, Smith et al. 2007), because they were specific to the Chinese population (Table 6.2). Because the relative risks of these two diseases for different ages was unavailable, they were assumed the same across all age groups.

Table 6.1 Current smoking prevalence and SHS exposure prevalence by gender and age in 1984 and 1996 in China

	Population [a]	LCD[b]	IHD death [c]	hospitality employees	current smoking prevalence [d] 1984	1996	SHS exposure prevalence [e] 1996
total	1,299,880,000	348,469	731,647	11,283,747	34%	35%	54%
male	667,869,966	240,136	379,430	5,021,199	61%	63%	46%
15-30	328,001,739	659	4,641	1,775,729	65%	65%	60%
30-44	169,321,861	10,760	14,100	2,237,217	74%	73%	45%
45-59	105,910,826	55,405	55,662	943,042	75%	73%	45%
60+	64,635,539	173,971	309,668	65,210	65%	65%	35%
female	632,010,034	108,333	352,217	6,262,549	7%	4%	57%
15-30	300,237,820	331	1,653	2,225,430	5%	2%	65%
30-44	161,802,513	6,183	9,004	3,096,796	5%	2%	62%
45-59	101,349,079	23,360	27,456	915,247	16%	7%	56%
60+	68,620,622	78,790	315,757	25,075	17%	12%	45%

Note: [a] the Chinese population was 1,299,880,000, reported by the National Bureau of Statistics; the population by gender and age groups were estimated from the WHO WPR-B dataset with a proportion of 82% (total Chinese population/total WHO WPR-B population in 2004) because they were not available from the bureau's datasets;
[b] LCD, lung cancer deaths, estimated from the WHO WPR-B dataset;
[c] IHD, ischaemic heart disease death, estimated from the WHO WPR-B dataset;
[d,e] data from a national survey in 1984 (Weng, Hong et al. 1986) and in 1996 (Walker, Nelson et al. 1997);
The numbers in each of the first four columns may not add up to the corresponding subtotals or totals due to rounding up during calculation.

Table 6.2 Summary of relative risks of active smoking and SHS exposure used for the analysis

	Males (95% CI)	Females (95% CI)
Active smoking		
Lung cancer	2.72 (2.62 , 2.82)	2.64(2.48 , 2.80)
Ischaemic heart disease	1.72 (1.61 , 1.83)	2.69 (1.82 , 3.98)
SHS exposure		
Lung cancer	1.63 (1.12 , 2.37)	1.63 (1.12 , 2.37)
Ischaemic heart disease	1.22 (1.10 , 1.35)	1.24 (1.15 , 1.34)

Note: this table was reproduced from Gan et al. (Gan, Smith et al. 2007)

Homes, workplaces, and indoor public places, including restaurants and bars, were assumed to be the major microenvironments where people were exposed to SHS. To estimate the deaths of the two diseases due to SHS exposure in restaurants and bars, the number of total deaths attributed to overall SHS exposure was multiplied by the percentage of SHS time in this type of environment, which was estimated by weighing SHS exposure prevalence of the population of interest in different microenvironments by the average time spent in each microenvironment. Though exposure concentrations are quite different in different microenvironments, only limited studies have measured SHS concentrations in homes, workplaces, or indoor public places. In addition, representative measurements in each of the microenvironments are not available. Thus, the exposure intensity was not weighted in this analysis.

A total of 46% of male and 57% of female adult nonsmokers were reported to be exposed to SHS in 1996, and the proportion of passive smokers who reported SHS exposure in homes, workplaces, and indoor public places was 43%, 45%, and 40%, respectively, for males, and 82%, 19%, and 28%, respectively, for females (Walker, Nelson et al. 1997). The population prevalence of SHS exposure in a specific environment was estimated by multiplying the general SHS exposure prevalence by the proportion of passive smokers who reported SHS exposure in that specific environment. For example, the prevalence of male adult nonsmokers exposed to SHS in homes was 20% (46%×43%). Based on time activity surveys conducted in 10 provinces across China in 2008, each day an adult spent an average of 986 minutes (male 927, female 1042) in residences, 278 minutes (male 324, female 234) in work places, 20 minutes (male 17, female 23) in indoor public places like malls, banks, and hotels (except restaurants and bars), and 13 minutes (male 16, female 9) in restaurants and bars; for the employed, their average time spent in workplaces was 437 minutes (male 461, and female 409). In addition, people spent an average of 542 minutes (male 540, female 544) sleeping (National Bureau of Statistics of China 2008). In this analysis, restaurant and bar workers were assumed to spend similar time in homes, workplaces, and indoor public places as the general population, while their time spent in restaurants and bars as patrons was omitted. People were assumed to be exposed to SHS in residences only during waking hours. The percentage of SHS time for each type of environment was calculated as

$$\%\text{SHS\_time}_{\,i} = \frac{\text{SHS exposure prevalence}_i \times \text{time}_i}{\sum \text{SHS exposure prevalence}_i \times \text{time}_i} \qquad [6.2]$$

Where

i is the ith environment;

%SHS_time$_i$ is the percentage of time exposed to SHS in the ith environment of overall time exposed to SHS in all environments by the population;

SHS exposure prevalence$_i$ is the proportion of the nonsmoking population exposed to SHS in the ith environment;

Time$_i$ is the time spent in the ith environment.

Sensitivity analysis of percentage of SHS exposure time in restaurants and bars was conducted by varying the smoking policy in different microenvironments. With this approach, the significance of SHS exposure in restaurants and bars was examined, in terms of the percentage of overall SHS exposure time for the population of restaurant and bar servers and patrons.

6.3 Results

6.3.1 Estimate of Lung Cancer Risk Using a Continuous Approach Based on Modeled SHS Exposure Levels

Based on mass balance models and Monte Carlo simulation, the arithmetic mean (95%CI) of peak-time SHS PM concentrations was 135 (10-451) $\mu g/m^3$ in restaurants allowing smoking everywhere, 90 (6-306) $\mu g/m^3$ in designated smoking sections, and 49 (2-175) $\mu g/m^3$ in designated nonsmoking sections; these concentrations corresponded to an estimated life time excess lung cancer risk of 1 389 (103, 4 639) $\times 10^{-6}$ for servers working five days a week for 45 years in restaurants allowing smoking and 741 (51, 2 499) $\times 10^{-6}$ in restaurants restricting smoking to designated sections; and for patrons they corresponded to an estimated lifetime lung cancer risk of 88 (7, 293) $\times 10^{-6}$ due to visiting restaurants allowing smoking everywhere for an average of 13 minutes a day for 60 years, 59 (4, 199) $\times 10^{-6}$ due to visiting designated smoking sections only, and 32 (1, 114) $\times 10^{-6}$ due to visiting designated nonsmoking sections only. Both the mean concentration and estimated lifetime lung cancer risk for servers and patrons were estimated to be about twice in bars as in restaurants with the same smoking policies (Table 6.3).

Table 6.3 Estimates of lifetime attributable risk of lung cancer death due to SHS exposure in restaurant and bar for servers and patrons, using continuous approach and modeled SHS PM concentrations in Chinese restaurants and bars

	servers		patrons		
	venues allow smoking	venues restrict smoking	allow smoking everywhere	designated smoking sections	designated nonsmoking sections
Restaurants					
concentration, mean (95%CI), μg/m^3 [a]	135(10, 451)	72(5, 243)	135(10, 451)	90(6, 306)	49(2, 175)
breathing rate, m^3/hr [b]	1.6	1.6	1.0	1.0	1.0
average time exposed to SHS, hr/day [c]	4	4	0.22	0.22	0.22
number of days exposed to SHS, day/week [c]	5	5	7	7	7
number of years exposed to SHS, years	45	45	60	60	60
lifetime excess risk of lung cancer death, 10^{-6} (95% CI%) [d]	1 389 (103, 4 639)	741 (51, 2 499)	88 (7, 293)	59 (4,199)	32 (1, 114)
Bars					
concentration, mean (95%CI), μg/m^3 [a]	261(20, 872)	137(10, 463)	261(20, 872)	175(12, 606)	93(4, 333)
breathing rate, m^3/hr [b]	1.6	1.6	1.0	1.0	1.0
average time exposed to SHS, hr/day [c]	4	4	0.22	0.22	0.22
number of days exposed to SHS, day/week [c]	5	5	7	7	7
number of years exposed to SHS, years	45	45	60	60	60
lifetime excess risk of lung cancer death, 10^{-6} (95% CI%) [d]	2 685 (206, 8 969)	1 409 (103, 4 762)	170 (13, 567)	114 (8, 394)	60 (3, 216)

Note: [a] concentrations were estimated from modeling results presented in Chapter 3, servers' exposure concentrations in venues restricting smoking were estimated by weighting the concentrations in designated smoking sections and nonsmoking sections with the number seats in the two sections, respectively;

[b] breathing rates of different levels of activities specific for Chinese populations were not available and they were assumed according to recommendations by U.S. EPA (1997);

[c] servers' exposure time was based on the report that restaurants and bar workers worked for an average of about 50 hours a week (National Bureau of Statistics and Ministry of Labour and Social Security of China 2005), which corresponded to 7.2 hours a day; however, it was assumed that servers' exposure happened mostly in four hours during peak patronage time; patrons' exposure time was based on the report that people spend an average of 13 minutes (0.22 hours) a day in restaurants and bars every day (National Bureau of Statistics of China 2008);

[d] the lifetime attributable risk was calculated using the dose-response relationship estimated by Repace and Lowrey (1985) (Eq.1, Chapter 5)

6.3.3 Estimate of Health Risk by Excess Risk Assessment Method (Exposed/Nonexposed)

Servers' exposure to SHS in their work places (restaurants and bars) was estimated to account for 85% of their total SHS exposure for males and 61% for females, which corresponded to 21 lung cancer deaths (LCDs) and 16 ischaemic heart disease (IHD) deaths for males and 56 LCDs and 37 IHD deaths for females (Table 6.4 and 6.5). Patrons' exposure to SHS, due to visiting restaurants and bars allowing or restricting smoking, accounted for 9.6% for males and 3.2% for females, corresponding to 580 LCDs and 550 IHD deaths among males and 725 LCDs and 959 IHD deaths for females (Table 6.4 and 6.5). A total of 2 850 deaths from lung cancer and IHD were attributed to SHS exposure in restaurants and bars for the total population (130 among workers and 2720 among patrons). The life time excess risk for nonsmokers were estimated to be 900×10^{-6} for LCD and 470×10^{-6} for IHD deaths among servers who work in restaurants and bars for 45 years and 150×10^{-6} for LCD and 180×10^{-6} for IHD among patrons who visit restaurants and bars for 60 years.

When 95% of restaurants and bars were assumed to allow or restrict smoking, for servers who were not exposed to SHS at home, their exposure due to working in restaurants and bars accounted for almost all of their exposure time; even if servers were exposed to SHS at home, their exposure time in restaurants and bars still accounted for about half of all their exposure time. For patrons who were exposed to SHS at home, their exposure time in restaurants and bars accounted for less than 5% of their total exposure time, regardless of the smoking policy in their workplaces. However, for patrons who did not have any SHS exposure at homes or workplaces, while more than 80% of restaurants and bars allow smoking, their exposure time in restaurants and bars dominated their total exposure (Table 6.6). If only half of the restaurants and bars completely banned smoking, SHS exposure in restaurants and bars still accounts for more than 50% of the total exposure time for patrons who lived in smoke-free homes and had smoke-free workplaces and for servers who live in smoke-free homes (Table 6.6).

Table 6.4 Estimated percentage of total SHS exposure happening in different types of environments for restaurant and bar servers and patrons by gender

	Male			Female		
	SHS exposure prevalence	time spent (minutes)	%SHS-time	SHS exposure prevalence	time spent (minutes)	%SHS-time
servers						
home [a]	19.6%	380	14.4%	46.7%	493	37.0%
work place [b]	95.0%	461	85.0%	95.0%	409	62.4%
indoor public places [c]	18.2%	17	0.6%	16.0%	23	0.6%
patrons						
home [a]	19.6%	380	46.8%	46.7%	493	86.0%
work place	20.5%	324	41.7%	10.8%	234	9.5%
indoor public places [c]	18.2%	17	1.9%	16.0%	23	1.4%
restaurants and bars	95.0%	16	9.6%	95.0%	9	3.2%

Note: SHS exposure prevalence is the proportion of nonsmokers exposed to SHS;
[a] people were assumed to be exposed to SHS in residences only during waking hours;
[b] for servers, the work place was restaurants and bars, and 95% of Chinese restaurants and bars were assumed to allow smoking;
[c] indoor public places did not include restaurants and bars in this analysis.

Table 6.5 Estimated numbers of lung cancer death and ischaemic heart disease death due to SHS exposure in restaurants and bars based on excess risk assessment methods

	total deaths among the population >30	deaths attributable to smoking	deaths among nonsmokers aged >30	deaths attributable to overall SHS exposure	deaths attributable to SHS exposure in restaurants and bars		
					workers	patrons	total
male							
LCD	240 136	134 708	27 109	6 083	21	580	600
IHD	379 430	130 359	63 593	5 818	16	550	566
female							
LCD	108 333	18 616	78 366	21 011	56	669	725
IHD	352 217	34 595	270 682	32 485	37	921	959
Total							
LCD	348 469	153 324	105 475	27 094	77	1 248	1 325
IHD	731 647	164 953	334 276	38 302	53	1 472	1 525

Note: LCD: lung cancer death; IHD: ischaemic heart disease

Table 6.6 Sensitivity analysis of percentage of overall SHS time occurred in restaurants and bars for workers and patrons

SHS exposure prevalence			servers %SHS-time		patrons %SHS-time	
home	work places (patrons)	restaurants and bars	male	female	male	female
yes	yes	95%	53%	44%	3.3%	1.6%
yes	yes	80%	49%	40%	2.8%	1.4%
yes	yes	50%	38%	29%	1.7%	0.9%
yes	yes	20%	19%	14%	0.7%	0.3%
yes	no	95%	53%	44%	3.8%	1.7%
yes	no	80%	49%	40%	3.2%	1.4%
yes	no	50%	38%	29%	2.0%	0.9%
yes	no	20%	19%	14%	0.8%	0.4%
no	yes	95%	99%	99%	18%	23%
no	yes	80%	99%	99%	16%	20%
no	yes	50%	99%	98%	10%	13%
no	yes	20%	97%	96%	4.0%	6.0%
no	no	95%	99%	99%	83%	70%
no	no	80%	99%	99%	81%	66%
no	no	50%	99%	98%	72%	55%
no	no	20%	97%	96%	51%	33%

6.4 Discussion

Because limited information was available to assess the health risks of other diseases due to SHS exposure in China, including acute respiratory and sensory irritation, adult asthma initiation, breast cancer among young females, etc., only lung cancer deaths (LCDs) and ischaemic heart disease (IHD) deaths were included in this analysis. Therefore, the total health risks and mortality due to SHS exposure in Chinese restaurants and bars are expected to be greater than the estimates in this chapter.

Several studies have used the dose-response relationship estimated by Repace and Lowrey (1985) to estimate lifetime excess risk (LER) of LCD due to SHS exposure by hospitality workers. Lopez et al. (2006) estimated a LAR of LCD of $1\ 450\times10^{-6}$ for hospitality workers working for 40 years; Hedley et al. (2006) estimated a LER of LCDs and heart disease death combined of $30\ 000\times10^{-6}$ for Hong Kong catering workers working for 40 years; Siegel and Skeer (2003) estimated a LER of $4\ 100\times10^{-6}$ for U.S. bar workers for a working life of 45 years , and Chapter 5 estimated a LER of 802×10^{-6} for Minnesota restaurant and bar workers. This analysis estimated the LER of lung cancer for workers of Chinese restaurants and bars for the first time. The estimates for restaurants workers (a LER of $1\ 389\times10^{-6}$ for servers working for 45 years in restaurants allowing smoking and 741×10^{-6} in restaurants restricting smoking) were similar to the estimate by Lopez et al. (2006), and higher than that in Chapter 5 for Minnesota restaurants and bars; the estimates for bars workers ($2\ 685\times10^{-6}$ and $1\ 409\times10^{-6}$ for servers of bars allowing smoking and bars restricting smoking, respectively,) were lower than the estimate by Siegel and Skeer (2003). All these estimated LCD risks for workers are much higher than the *de manifestis risk* of 3×10^{-4}, a risk of obvious or evident concern, and one that public agencies will almost always regulate to control, or mitigate when recognized (Travis, Crouch et al. 1987). Most estimated LCD risks are also higher than the significant risk of 1×10^{-3} defined by the U.S. Occupational Safety & Health Administration (OSHA).

No studies in literature have assessed health risks for patrons. Chapter 5 and this chapter are the first to do so. Chapter 5 estimated a LER of 80×10^{-6} for Minnesota patrons visiting smoking restaurants and bars or sections only, and 18×10^{-6} for those visiting designated nonsmoking sections of restaurants and bars only for 1.4 hours/week for 60 years; this analysis estimated a LER of 32 to 88×10^{-6} and 60 to170×10^{-6}, respectively, for patrons visiting restaurants and bars allowing or restricting smoking for 0.22hours/day for 60 years. Analyses of Chapter 5 were based on measurements of SHS concentrations in a representative sample of restaurants and bars, with restaurants and bars combined and exposure from smoking venues and designated smoking sections combined, while analyses in this chapter were based on SHS exposure modeled separately for restaurants and bars and for smoking venues and nonsmoking sections. Estimated LER of lung cancer deaths of Chinese restaurant patrons were similar to Minnesota patrons of restaurants and bars combined, while they were higher for Chinese bar patrons because of higher exposure. These estimated risks are all much higher than the acceptable risk (*de minimis risk*) 1×10^{-6} for large populations (Travis, Crouch et al. 1987).

Based on the attributable risk assessment method, about 27 000 LCDs and 38 000 IHD deaths were attributable to SHS in 2004; about 20% and 10%, respectively, higher than estimates by Gan et al. (Gan, Smith et al. 2007), which were 22 200 LCDs and 33 800 IHD deaths. The reasons may be that the 2004 population of WHO WPRO-B was 1% higher than the 2002 population, and the total LCDs and IHD deaths in 2004 were 18% and 4%, respectively, higher than in 2002; furthermore, the population was divided into more subgroups in the analysis by Gan et al. than in this analysis, which may also lead to some discrepancy between the two analyses.

Jamrozik (2005) estimated a total of 54 deaths of lung cancer, IHD and stroke among restaurant and bar workers due to their work place SHS exposure in the United Kingdome; Chapter 5 estimated a total of 3 200 deaths of lung cancer and ischaemic heart disease among hospitality workers and patrons due to SHS exposure in restaurants and bars in the U.S., based on the 1992-1994 U.S. *National Human Activity Pattern Survey* (NHAPS) (Klepeis, Tsang et al. 1996) that SHS exposure accounted about 9% of total SHS exposure in the U.S.; this analysis estimated a total of 130 deaths of the two diseases among hospitality workers and a total of 2 720 deaths among patrons caused by SHS exposure in restaurants and bars, accounting for about 4% of the total LCDs and IHD deaths attributed to SHS. The total number of excess deaths of LCD and IHD caused by SHS exposure in restaurants and bars only in China (2850) is comparable to the total deaths from all sex transmitted diseases, excluding HIV, among those aged ≥30 years, or to the total deaths from skin diseases (3310 and 3586, respectively, in the whole WHO WPRO-B region, with 82% estimated to be in China). While reducing the disease burden of the later two types of diseases is very expensive and challenging, eliminating SHS exposure in restaurants and bars, and thus preventing a similar number of deaths, is much more cost effective and practical.

About 20% of nonsmoking males are exposed to SHS at home and 21% in workplaces; about 47% of nonsmoking females are exposed to SHS at homes and 11% in workplaces. This corresponds to 64% of nonsmoking males and 47% of nonsmoking females without SHS exposure in both homes and workplaces. For this population, their time exposed to SHS in restaurants and bars accounts for more than 70% of their total exposure time, if 95% of the restaurants and bars allow smoking, which is true in most Chinese cities before 2011. That is, restaurants and bars are the most significant source of SHS exposure for more than half of the nonsmoking adult population. If smoking regulations are not fully implemented, such as the 2008 Beijing governmental smoking restrictions (after which implementation, there was still smoking observed at about 50% of nonsmoking venues or sections), the time spent exposed to SHS in restaurants and bars still dominates the total exposure time for patrons who live in smoke-free homes and work in smoke-free environments, and for nonsmoking servers who live in smoke-free homes. Thus, only smoking bans completely prohibiting smoking in restaurants and bars, plus effective implementation, can protect workers of these places from health risks from SHS exposure.

The lifetime excess risks and the number of LCD and IHD deaths caused by SHS exposure in restaurants and bars are probably underestimated. Zheng et al. (2009) reported that restaurant workers in Shanghai, China were exposed to SHS during working hours for 24.2±18.6 hours on average per week, while 20 hour/week of SHS exposure for workers was assumed in this analysis when using the continuous dose-response approach. When using the attributable risk approach, exposure intensity (indicated by SHS concentrations) in different microenvironments was not weighted, while SHS concentrations are usually higher in restaurants and bars than in homes and most other work places: in the U.S. before 1999, mean airborne nicotine concentrations ranged from 2 to 6 $\mu g/m^3$ in smoking offices, from 1 to 6 $\mu g/m^3$ in smoking workplaces of blue-collar workers, from 1 to 3 $\mu g/m^3$ in homes of smokers, and from 3 to 8 $\mu g/m^3$ in restaurants (Hammond 1999). In public places in some rural and urban areas in China, the medians of one-week time-weighted average concentrations were reported to range from 0.10 to 0.68 $\mu g/m^3$ in schools, hospitals, governmental buildings, and transportations, and was 2.2 $\mu g/m^3$ in restaurants (Stillman, Navas-Acien et al. 2007); a median of week-long nicotine concentrations of 1.2 $\mu g/m^3$ in 14 office buildings in China was also reported (Gan, Hammond et al. 2008); the median of week-long nicotine concentrations in some Chinese homes was found to be about 0.2 $\mu g/m^3$ (Hammond, Tian et al. 1999). Chapter 2 found a median of week-long average nicotine concentration of 2.1 $\mu g/m^3$ in restaurants and bars in Beijing, two years after the governmental smoking restriction, similar to findings for restaurants by Stillman et al. If these median nicotine concentrations in different environments in China reported in previous studies were used to weight the exposure time, the number of LCD and IHD deaths caused by SHS exposure in restaurants and bars would be 40% higher for servers and three times higher for patrons.

6.5 Conclusions

SHS exposure only in restaurants and bars can impose high lifetime excess risks of lung cancer death and ischaemic heart disease deaths to both servers and patrons, and it can cause a significant number of deaths each year in China. These health risks and deaths can be fully prevented by banning smoking in restaurants and bars and effectively implementing these smoking bans.

Chapter 7 Conclusions

This dissertation focuses on quantifying SHS exposure in restaurants and bars among workers and patrons, and the concurrent heath risks, morbidity, and mortality due their exposure. It also includes an evaluation of the efficacy of different smoking policies adopted in Beijing restaurants and bars.

7.1 Measurements of Secondhand Smoke Exposure in Restaurants and Bars

Multiple approaches were used to assess SHS exposure by restaurant and bar servers and patrons in Beijing, which included one-hour peak-patronage-time field observation and monitoring of fine particulate matter ($PM_{2.5}$) and airborne nicotine, one-day (venue open hours only) active area and personal sampling of airborne nicotine, week-long passive area sampling of nicotine, continuous sampling of $PM_{2.5}$, and sequential area sampling of airborne nicotine for more than 24 hours. Modeling and Monte Carlo simulations were also performed to predict SHS concentrations during peak-patronage times. These approaches are described in Chapter 2 and Chapter 3. Among the objective measuring approaches, field observation is a relatively easier way to quantify the intensity of SHS sources compared to other approaches, but it cannot quantify the intensity of exposure due to the existence of many other varying factors, such as ventilation rate and other removal rates. However, environmental measurements can integrate the impact of these factors. With consideration of the cost of environmental sampling, particulate matter (PM) has been used as a SHS tracer more frequently than airborne nicotine in developing countries like China, due to its lower requirement of laboratory analysis, though airborne nicotine is more specific to SHS. In terms of the accuracy, simplicity (sampling permission, requirement of sampling devices, involvement of human subjects, and attendance of investigators), and cost of these different sampling approaches, one-day active area and personal sampling of airborne nicotine are least frequently applied, while peak-time active area nicotine sampling and week-long passive area nicotine sampling are more feasible in field studies. However, one-day personal airborne nicotine sampling is the most accurate way to assess workers' exposure, because of its integration of subjects' time activities.

Consistent with studies in literature, Chapter 2 showed that both measured $PM_{2.5}$ and airborne nicotine concentrations were significantly related to observed active smoker activities. Active smoker density (number of active smokers per 100 m^3) could explain 29% of the variance of differences between indoor and outdoor $PM_{2.5}$ concentrations and 40% of the variance of indoor nicotine concentrations. Simultaneous sampling of $PM_{2.5}$ and airborne nicotine in Beijing restaurants and bars showed a slope of 17 $\mu g/m^3$ of SHS PM per one $\mu g/m^3$ of nicotine, with a constant of 12 $\mu g/m^3$, which is attributed to other indoor $PM_{2.5}$ sources. Other studies have reported a range to 7.1 -10.9 $\mu g/m^3$ of respirable particulate matter per one $\mu g/m^3$ of airborne nicotine (Leaderer and Hammond 1991; Ellingsen, Fladseth et al. 2006; USDHHS 2006), indicating potential differences of emission rates of nicotine and respirable particulate matter between Chinese cigarettes and U.S. cigarettes. Although $PM_{2.5}$ is not specific to SHS, peak-time $PM_{2.5}$ sampling is less expensive, while easier to operate, and thus it has been used for risk assessment purpose in some previous studies (Repace and Lowrey 1990; Repace, Jiang et al. 2011). In addition, because of the health risks from $PM_{2.5}$ itself (Pope, Burnett et al. 2009) and the real-time feature of $PM_{2.5}$ sampling, it has also been frequently used for public health education program of promoting smoke-free environments (Avila-Tang, Travers et al. 2010).

Appropriate sampling time is important to characterize people's exposure to SHS. Short time sampling, such as one hour during peak patronage times, can provide information on patrons' and servers' far field exposure during these time periods; while one-day sampling and week-long sampling is crucial to understand servers' exposure in a relatively longer time period. As expected, time weighted nicotine concentrations by one-hour peak-time area sampling in Beijing restaurants and bars were higher than those by one-day area sampling and by week-long area sampling; results of peak-time sampling can explain about half of the variance of the results by the latter two sampling approaches. Though servers are exposed to lower SHS concentrations during non-peak times, they are exposed to higher concentrations than that measured by one-hour peak-time sampling, due to their frequent near field exposure when serving tables with active smokers. This may explain why peak-time area nicotine sampling results are very close to one-day personal nicotine sampling results. It indicates that peak-time area sampling is a feasible and also a reasonably accurate way to access patrons' short time exposure to SHS during their visits, and servers' exposure during their full shifts.

As for week-long passive area sampling and one-day personal sampling, because of the difference in both the sampling time and sampling approach (area and personal), and potential great variances of SHS concentrations on different days, it is not surprising that their results were not significantly related to each other. Week-long personal sampling during working hours only is needed to examine whether week-long passive sampling, including overnight sampling, can be used to estimate servers' week-long SHS exposure at work.

Continuous sampling of $PM_{2.5}$ and sequential area sampling of airborne nicotine, for more than 24 hours in multiple places in two restaurants, was used to examine servers' exposure to SHS over time during their working hours. The results showed obvious spikes of number of patrons, number of lit cigarettes, and concentrations of indoor $PM_{2.5}$ and airborne nicotine during peak times. They also showed that, although SHS concentrations at different locations may be quite different in a short time period like one hour, time weighted average concentrations over a longer time, such as over the whole peak time or all working hours, are quite close to each other. These results indicate that assuming a well mixed space for relatively longer time is reasonable. This assumption was used to model SHS exposure during peak times in Chapter 3.

When resources are limited to conduct field sampling, modeling SHS concentrations in the environments of interest is important to inform decision makers of the potential exposure, and thus helps them to plan effective preventive strategies. The mass balance models developed in Chapter 3 can predict $PM_{2.5}$ concentrations derived from SHS (SHS PM) reasonably well, but not so well as to predict airborne nicotine concentrations. Since no studies have been conducted to assess SHS exposure in a representative sample of restaurants and bars in China, these models can be used to estimate peak-time SHS PM concentrations in these places.

7.2 Secondhand Smoke Exposure in Restaurants and Bars in China

While many countries, such as Ireland, England, Argentina, Norway, and New Zealand, completely ban smoking in workplaces and public places, including restaurants and bars (ANRF 2012), SHS exposure in these places is still quite prevalent in China. Among all nonsmokers aged 15 years and older, 72% were exposed to SHS in 2010, of which 67% were exposed in homes, 63% in indoor workplaces, and 73% in public places (Xiao, Yang et al. 2010). About 89% of nonsmoking restaurant patrons were exposed to SHS, compared to 58% of nonsmoking visitors of government offices and 34% of nonsmokers who took public transportations (Xiao, Yang et al. 2010). SHS exposure rate in restaurants and bars could be even higher before 2008, when many Chinese cities like Beijing, Shanghai, Hangzhou, Guangzhou, and Yinchuan just started banning smoking in public places, including restaurants and/or bars. If 95% of restaurant and bar servers and patrons are assumed to have been exposed to SHS in 1996, more than 70% of servers' total SHS exposure and 5% of the general population' total exposure occurred in restaurants and bars, without accounting for the exposure intensity (SHS concentrations) in different environments. For servers who do not live with smokers, or patrons who are not exposed to SHS in their homes or workplaces, SHS in restaurants and bars is their major source of exposure, and this population accounts for more than half of the total nonsmoking population (Chapter 6). Even when smoking is restricted in restaurants and bars in some cities but the restrictions are poorly implemented, such as in Beijing (as shown in Chapter 4), SHS exposure in these places can still account for a significant part of people's total exposure.

SHS exposure in restaurants and bars can account for more of the populations' total exposure, if SHS concentrations in different environments are considered. Similar to findings in other countries, SHS concentrations in restaurants and bars are usually higher than in other indoor places in China. Stillman et al. measured airborne nicotine concentrations in public places in some rural and urban areas in China. They reported that the medians of one-week time-weighted average concentrations ranged from 0.10 to 0.68 $\mu g/m^3$ in schools, hospitals, governmental buildings and transportations, and it was 2.17 $\mu g/m^3$ in restaurants and 7.48 $\mu g/m^3$ in entertainment venues (Stillman, Navas-Acien et al. 2007); Gan et al (2008) reported a median of week-long nicotine concentrations of 1.15 $\mu g/m^3$ in 14 office buildings in China; Hammond (1999) found a median of week-long nicotine concentrations of 0.2 $\mu g/m^3$ in Chinese homes. Chapter 2 found a median of week-long average nicotine concentration of 2.11 $\mu g/m^3$ in restaurants and bars in Beijing, two years after the governmental smoking restriction, similar to findings by Stillman et al. for restaurants. If these median nicotine concentrations in different environments in China, reported in previous studies, were used to weight the exposure time, the number of LCD and IHD deaths caused by SHS exposure in restaurants and bars would be 40% higher for servers and three times higher for patrons.

There is no safe level of SHS exposure (USDHHS 2006; WHO 2009). After two years of implementation of Beijing governmental smoking restrictions in restaurants and bars, patrons are still exposed to a median of 27 $\mu g/m^3$ SHS PM and a median of 1.53 $\mu g/m^3$ airborne nicotine during their visits. For servers, continuous monitoring in two restaurants showed obvious spikes of indoor $PM_{2.5}$ and airborne nicotine concentrations during lunch and dinner time periods, and SHS concentrations remained high during peak time intervals or evenings due to staff smoking. Servers are exposed to a median of 2.62 $\mu g/m^3$ of airborne nicotine during their day time working hours by personal sampling and a median of 1.83 $\mu g/m^3$ of airborne nicotine during a whole week. Compared to findings in other countries, the median of week-long average nicotine concentrations are lower in smoking restaurants and bars in Beijing (two years after the smoking restriction) (Jane, Nebot et al. 2002; Navas-Acien, Peruga et al. 2004; Mulcahy, Evans et al. 2005; Gorini, Moshammer et al. 2008; Lopez, Nebot et al. 2008; Nebot, Lopez et al. 2009; Barnoya, Arvizu et al. 2011; Ochir, Shahrir et al. 2011; Jones, Wipfli et al. 2012), but they are higher in nonsmoking restaurants and bars (Gorini, Moshammer et al. 2008; Lopez, Nebot et al. 2008; Nebot, Lopez et al. 2009; Barnoya, Arvizu et al. 2011; Lopez, Burhoo et al. 2011; Jones, Wipfli et al. 2012). An obvious reason for this is the common smoking activities in normally nonsmoking restaurants and bars in Beijing.

The World Health Organization (WHO) recommends that the annual mean of $PM_{2.5}$ in ambient air should not exceed 10 μg/m^3 and the 24h-hour mean should not exceed 25 μg/m^3 (WHO 2005). Kang et al. (2007)reported an arithmetic mean of indoor $PM_{2.5}$ concentrations of 253 μg/m^3 and of outdoor concentrations of 125 μg/m^3 from visits to 92 restaurants and bars in Beijing in 2006; Liu et al. reported geometric means of indoor $PM_{2.5}$ concentrations ranging from 90 to 323 μg/m^3 and of outdoor concentrations ranging from 32 to 190 μg/m^3 from visits to 404 restaurants and bars in five Chinese cities in 2007. Lee et al. (2010) reported a geometric mean of indoor $PM_{2.5}$ concentrations of 58 μg/m^3 in five restaurants and 15 entertainment venues in Beijing, 2008. Chapter 2 found a median of 27 μg/m^3 SHS PM (adjusted for outdoor $PM_{2.5}$) in 114 restaurants and bars in Beijing, 2010, two years after the governmental smoking restriction in public places including restaurants and bars went into effect. Based on current smoking prevalence, occupancy and ventilation requirements by the national guidelines, assumptions on patrons' smoking behavior, and venue designs, restaurants in China are estimated to have a median (low-high quartile) SHS PM concentration of 76 (35-162) μg/m^3 if smoking is allowed everywhere, 49 (22-108) μg/m^3 in designated smoking sections, and 24 (10-57) μg/m^3 in designated nonsmoking sections if no one smokes in nonsmoking sections. Predicted SHS concentrations in bars are about two times as in restaurants with similar smoking policies (Chapter 3). Continuous monitoring of SHS PM found a 24-hour mean of SHS PM of 284 μg/m^3 in one smoking restaurant and of 60 in μg/m^3 in the designated smoking section of another restaurant. All these PM concentrations are much higher than the WHO recommendations, and they can impose great potential health risks to servers and patrons.

It should be noted that there are much fewer smoking patrons than nonsmoking patrons. The active smoking rate (proportions of patrons observed smoking at any time) is less than 10% during the majority of visits to restaurants and bars (Chapter 2). Even if all current smokers smoke during their visits, there will be only about 30% of all patrons smoking, while the rest 70% are nonsmokers. Thus, the smoking behaviors of the minority have caused the majority to be exposed to SHS. And these SHS concentrations, either indicated by airborne nicotine or by $PM_{2.5,}$ are all very high, and they can impose significant negative health effects in both short terms and long terms for exposed populations, e.g. nonsmoking workers and patrons.

7.3 Health Risks and Excess Morbidity and Mortality due to Secondhand Smoke Exposure in Restaurants and Bars

SHS exposure can cause acute health effects like eye and nasal irritation, asthma exacerbation, and acute coronary events, and chronic health effects like asthma induction, coronary heart disease morbidity and mortality, lung cancer, nasal sinus cancer, and breast cancer among young premenopausal women (Cal/EPA 2005; USDHHS 2006; Institute of Medicine 2009). Intensive field monitoring of SHS exposure in a representative sample of Minnesota restaurants and bars, for multiple times in each venue, showed that more than 80% of patrons were exposed to SHS concentrations above the threshold of eye and nasal irritation during more than 80% of their visits. Risk assessment analysis showed that patrons' and workers' lifetime excess risk (LER) of lung cancer death (LCDs) due to SHS exposure in restaurants and bars in both Minnesota and in China is well above the acceptable level of 1×10^{-6}. And this is true even for patrons who visit designated nonsmoking sections only for about 1.5 hours a week in their lifetime. The LER can be much higher for patrons who visit restaurants and bars more often or for patrons who also visit smoking sections or venues allowing smoking everywhere. As for servers, their LER of LCD or asthma initiation (estimated for Minnesota and U.S. restaurant and bar servers only) can be higher than the significant risk of 1×10^{-3}, an unsafe level considered by the U.S. Occupational Safety and Health Administration (OSHA). Though servers and patrons are transient populations with a high turnover, and the LER estimated in this study may overestimate the risk for servers and patrons who are not exposed as much as the assumption in this study, regulations should be made to protect those who do make a career of restaurant or bar work, as well as those who do visit restaurants and bars regularly. Thus, SHS in restaurants and bars should be considered an occupational hazard for workers of these places and an environmental hazard for patrons.

In the population level, SHS exposure in restaurants and bars caused three LCDs and 32 ischaemic heart disease (IHD) deaths per year among the general nonsmoking population and 53 new asthma cases per year among nonsmoking servers in Minnesota, 214 LCDs and 3001 IHD deaths per year among the general nonsmoking population and 1420 new asthma cases per year among nonsmoking servers in the U.S. (Chapter 5). In China, this death toll is 1325 LCDs and 1525 IHD deaths a year (Chapter 6). Jamrozik (2005) estimated a total of 54 deaths of lung cancer, IHD and stroke among restaurant and bar workers due to their work place SHS exposure in the United Kingdome. These excess morbidity and mortality due to SHS exposure in restaurants and bars were underestimated, because many other outcomes, including breast cancer among young women, acute coronary events, etc, were not included due to limited information available for analyses. Furthermore, SHS concentrations in restaurants and bars are often higher than many other indoor environments, and none of the estimates above have taken into account intensities of exposure in different environments, which could also lead to underestimates of the morbidity and mortality.

In China, excess mortality caused only by SHS in restaurants and bars in 2004 (2850 deaths) is comparable with the total deaths from all sex transmitted diseases, excluding HIV, among those aged ≥30 years, or with the total deaths from skin diseases in the same year estimated from the WHO 2004 database. The excess mortality is higher than the total mortality (2250 deaths) caused by all natural disasters, including typhoons, floods, and droughts, in the same year in China (The Central People's Government of the People's Republic of China 2007), and comparable with the death toll (2698 deaths) caused by the 7.1-magnitude earthquake that happened in Yushu of northwest China’s Qinghai Province on April 14, 2010 (People's Daily Online 2010). Though these deaths tolls have gained much attention from the public and the government, society is not well aware of the mortality and morbidity caused by SHS exposure. Only 25% of the Chinese population aged 15 years and older knows that SHS exposure can cause heart disease and lung cancer among nonsmoking adults and respiratory diseases among children (Chinese CDC 2011). Though preventing deaths from natural disasters is very challenging, preventing deaths from SHS exposure in restaurants and bars is easier and more cost effective.

The Chinese government just started to include $PM_{2.5}$ into the national air quality standards to regulate outdoor $PM_{2.5}$ pollutants in 2012 (Xinhua 2012). For restaurant and bar servers and patrons in China, their exposure to indoor $PM_{2.5}$ due to smoking is much higher than outdoor $PM_{2.5}$ levels in China, as all estimates of SHS PM levels are based on the differences of indoor and outdoor $PM_{2.5}$ concentrations, and the related health risks are expected to be much higher than the risks due to exposure to outdoor $PM_{2.5}$. Again, controlling outdoor $PM_{2.5}$ concentrations is very challenging and expensive, but comprehensive smoking bans are relatively easier as well much more cost-effective. Future efforts should be made to disseminate results of this study to the general population as well as the decision makers in China, highlighting the point supported by both international and China-specific evidence presented in this study that restaurants and bars should not be exempted from smoking restrictions.

7.4 The Efficacy of Different Smoking Policies on Reducing Secondhand Smoke Exposure in Restaurants and Bars

Different strategies have been used to prevent people from health hazards of SHS exposure. The tobacco industry has promoted accommodation of smokers and nonsmokers with separate seating (restricting smoking to designated sections), voluntary smoke free policies, and ventilation and air filtration to reduce SHS exposure (Dearlove, Bialous et al. 2002; Leavell, Muggli et al. 2006; Sebrie and Glantz 2007). However, research has repeatedly shown that these strategies are ineffective to protect against SHS exposure (ASHRAE 2008). To provide effective protection for the public from exposure to tobacco smoke, WHO states in Article 8 of the Framework Convention of Tobacco Control (FCTC) that

> *"Each Party shall adopt and implement in areas of existing national jurisdiction as determined by national law and actively promote at other jurisdictional levels the adoption and implementation of effective legislative, executive, administrative and/or other measures, providing for protection from exposure to tobacco smoke in indoor workplaces, public transport, indoor public places and, as appropriate, other public places."*

Based on the best practice worldwide in preventing SHS exposure, the Conference of the Parties to the WHO FCTC unanimously approved the guidelines of implementing Article 8 in 2007. The guidelines emphasis that there is no safe level of SHS exposure, and creating 100% smoke free environments is the only effective way to eliminate SHS exposure. Literature reviews on the effects of comprehensive smoking bans showed a median of 88% decrease of indoor $PM_{2.5}$ concentrations and 96% reduction of airborne nicotine concentrations after smoking was completely banned in restaurants and bars (Chapter 4).

Since WHO FCTC became effective in mainland China in 2006, smoking policies have been evolving rapidly in public places, including restaurants and bars. Chapter 4 presented these changes and the evaluation of different smoking policies in restaurants and bars in Beijing. In 2006, all voluntary smoking bans in restaurants and bars were completely self-motivated by owners, and in 2007, they were encouraged by the government. More than half of men smoke in China, and neither hospitality venue owners nor patrons have good knowledge on specific hazards related to SHS (Liu, Yang et al. 2008; Liu, Hammond et al. 2011). Thus, it is not surprising that only a few restaurant and bar owners were motivated to prohibit or restrict smoking either by themselves or by the government. Experience from other countries has also shown that voluntary smoke free policies do not work (Leavell, Muggli et al. 2006; ASHRAE 2008). Therefore, the guidelines of implementing WHO FCTC Article 8 explicitly point out that "*Legislation is necessary to protect people from exposure to tobacco smoke."*

When the Beijing government started to require smoking restrictions in restaurants and bars by regulations in 2008, more than 80% venues did so as required; in these venues, the active smoking rate of patrons decreased, while no significant changes were observed in venues without any policy changes. This indicates the immediate positive effects of governmental smoking restrictions. However, some venues stopped prohibiting or restricting smoking two years later, resulting in less than 60% restaurants and bars nominally prohibited or restricted smoking, showing non-continuous implementation by the government and decreasing compliance by the owners. In nominal nonsmoking venues or designated sections, after the governmental restriction became effective about half had smoking observed, compared to much better compliance by patrons before 2008. Some media reported that many restaurant and bar workers don't know the existence of the smoking restrictions, or intentionally neglected patrons who violated the smoking restrictions, to avoid potential conflicts (Beijing Evening New 2009). As a result, SHS concentrations in nonsmoking restaurants or sections are still very high even after smoking is prohibited or restricted (Chapter 4). Though SHS PM concentrations in Beijing restaurants and bars decreased after the governmental smoking restriction in both 2008 and 2010, compared to those in 2006 and 2007, this happened in all the venues followed up, regardless of how the policy changes. Two years after the smoking restrictions in 2010, both SHS PM concentrations and active smoking rates in restaurants and bars were higher than in 2008, when the restriction was first implemented, regardless of the changes in smoking policy. The similarity of SHS concentrations exposed by servers of restaurants and bars with different nominal smoking policies during their full shifts in 2010 also showed poor implementation and poor compliance of the restriction.

The Beijing governmental smoking restrictions require large restaurants to set designated nonsmoking areas at least 50% of their total dining areas. According to simultaneous monitoring in both smoking and nonsmoking areas of venues restricting smoking, the median $PM_{2.5}$ or air nicotine concentration in nonsmoking sections was still 40% of that in smoking sections. During 16 visits to Minnesota restaurants and bars where smoking was restricted to designated areas and no violation of the smoking restriction was observed, simultaneous side-by-side measurements in both sections showed that the average SHS PM level in nonsmoking sections was 52% of the average level in smoking sections. Thus, restricting smoking can reduce but cannot eliminate patrons' exposure to SHS (Chapter 4). For servers, personal sampling from nonsmoking servers of venues restricting smoking showed high level of exposure to SHS. Obviously, restricting smoking cannot protect servers from exposure to SHS at all, as they need to serve patrons in both smoking and restricts (Chapter 2), consistent with experiences from other countries.

To provide more protection of the public from SHS exposure, as required by being a party of WHO FCTC, in May 2011, the Chinese government implemented the revised implementation guidelines of the 1987 *Health Regulations in Public Places* (公共场所卫生管理条例). The revised implementation guidelines tightened the rules to prohibit smoking in all indoor public places, including restaurants and bars, nationwide. However, there are many problems with these guidelines, which are presented in Chapter 4. The definition of public places is vague and does not include all public places; there are no specifications on what reasonable steps should be taken by the civil society to discourage smoking, and no specifications on penalties for violations or on the authorities that will be responsible for enforcement. In addition, limited public education and campaigns have been performed to raise public awareness of revised guidelines and the health risks of SHS exposure. WHO states that: *"Passing a policy is only one part of the process of protecting a population from exposure to SHS; both public education and enforcement efforts are necessary when the smoke-free policy is implemented"* (WHO 2009). If the Chinese government does not learn from the failed experience of the Beijing governmental smoking restrictions and does not follow the guidelines recommended by WHO, the efficacy of the national smoking restrictions, as required by the revised guidelines, will remain limited.

7.5 Strengths and Limitations of This Study

Though studies on SHS exposure in restaurants and bars are rich in literature, very limited studies are conducted in China, which is the largest tobacco consumer in the world, and has the largest population exposed to SHS in restaurants and bars. Some studies measured indoor $PM_{2.5}$ concentrations during peak-patronage times in restaurants and bars in some Chinese cities (Kang J, Lin X et al. 2007; Lee, Lim et al. 2010; Liu, Yang et al. 2011); Stillman et al. (2007) collected 54 passive nicotine area samplers to measure week-long time weighted average airborne nicotine concentrations in some Chinese restaurants. However, this study is the first one in China to examine the profiles of both servers' and patrons' SHS exposure in restaurants and bars, using both $PM_{2.5}$ and airborne nicotine as tracers and using sampling for different time periods. This study is also the first quantitative risk assessment to estimate patrons' health risks and mortality due to SHS exposure in restaurants and bars. Many previous risk assessment analyses estimated lung cancer deaths and ischaemic heart disease deaths only for restaurant and bar workers based on SHS PM measurements from non-representative samples (El-Hougeiri and El Fadel 2002; Siegel and Skeer 2003; Hedley, McGhee et al. 2006; Lopez, Nebot et al. 2006). This study assesses the risks of asthma and cancer, other than lung cancer, for Minnesota and U.S. populations for the first time, and the quality of the underlying exposure data presented in Chapter 4 is vastly superior to that in any of the previous secondhand smoke risk studies.

The field monitoring presented in Chapter 2 was not conducted in a representative sample, and all field measurements were conducted in summer only. Thus, the results may not represent SHS concentrations in all restaurants and bars in Beijing, after the governmental smoking restriction, during different times of the year. No previous studies had used nicotine as a tracer to assess SHS exposure during peak times in restaurants and bars in China, making the comparison of results from this study and other studies in China not possible. However, one-week nicotine sampling showed similar nicotine levels in restaurants in this study with the other study (Stillman, Navas-Acien et al. 2007). This study monitored SHS concentration in restaurants and bars in Beijing for four years from 2006 to 2010, with some venues followed up every year. This provides a great opportunity to examine the changes of SHS exposure with the changes of smoking policies in restaurants and bars in Beijing, and therefore provides China-specific evidence on the efficacy of different smoking policies in protecting people from SHS exposure. The results from this study also highlight the importance of fully enforcing smoking restrictions. Future studies should be conducted to understand the reasons underlying patrons' poor compliance to the smoking restrictions so to provide experience to the implementation of the 2011 national smoking restrictions in all indoor public places. Exploring the Chinese tobacco industry's role in developing and enacting the smoking restrictions is also important to maximize the tobacco control efforts of reducing SHS exposure in China.

The policy evaluation part of this study was based on longitudinal data collected in Beijing only, while no studies were conducted in cities which did not have any legislation intervention during a similar time period to control secular changes. This makes it difficult to attribute all the changes in SHS concentrations and patrons' smoking behaviors to changes of smoking policies only. Other interventions, like public education, could also have positive effects. In addition, the evaluation used $PM_{2.5}$ as a SHS tracer for the longitudinal analysis, which is sensitive but not specific to SHS. However, the results of $PM_{2.5}$ sampling, air nicotine sampling, and observed patrons' smoking behavior during peak-patronage times are consistent with each other, indicating that using changes of $PM_{2.5}$ concentrations for the evaluation is reliable. Lastly, the study was conducted in different seasons of different years, and not all the follow-up monitoring was scheduled to be during the same peak patronage times (e.g. lunch or dinner) or on the same day of a week (e.g. weekdays or weekend), so variations due to these factors cannot be estimated.

There are limited studies measuring SHS concentrations in restaurants and bars in other cities, except some big cities like Beijing, Wuhan, Kunming, Guiyang and Xi'an. Thus, it is impossible to assess the health risks due to SHS exposure in this microenvironment based on direct field measurements, like in Minnesota restaurants and bars. As a result, modeled SHS concentrations were used, which were based on a series of assumptions, adding great uncertainties to the exposure assessment. In addition, the models are sensitive to patrons' smoking behavior and venue ventilation designs, while these two factors can vary to a great extent in different parts of China. If information on these two factors is available for different parts of China, a better approach will be modeling SHS concentrations in restaurants and bars separately for different parts of China and, correspondingly, assessing the health risks separately. Another limitation for the modeling is that though the models work well in predicting SHS PM concentrations in restaurants and bars, they are not very good at predicting nicotine concentrations, due to the more complex dynamics of airborne nicotine generation and removal in indoor environments.

In addition, there are limited studies monitoring SHS concentrations in other microenvironments like homes, workplaces, and public places (excluding restaurants and bars) in China. Analyses in Chapter 6 showed that when the exposure intensity (SHS concentrations) are not considered, home and workplace are very important SHS exposure sources, particularly for patrons, due to the amount of time spent in these two environments on average. China has started to ban smoking in indoor workplaces after its ratification of the WHO Framework Convention of Tobacco Control in 2005, while regulating smoking in homes is not feasible. Plus, women and children are particularly susceptible to SHS exposure in homes. Thus, future studies on women and children's SHS exposure at home and attributed health risks, morbidity, and mortality will be very important to contribute to reducing the disease burden from SHS exposure.

There is evidence showing that SHS exposure can cause breast cancer among younger premenopausal women (Cal/EPA 2005; Johnson, Miller et al. 2011). An estimated summary risk of 1.68 (95% CI 1.31 - 2.15) was reported (Cal/EPA 2005), though other reports concluded that the relationship is not causative (USDHHS 2006; WHO 2009). Because breast cancer is a common disease in western countries and SHS exposure is a widespread and frequent exposure, a large number of women are expected to be impacted by SHS exposure. Women working in restaurants and bars are particularly at risk because of their young ages. In China, though the breast cancer mortality rate is lower than in western countries, the absolute morbidity number is bigger, and SHS exposure among women is more common, thus the excess mortality of breast cancer among young women due to SHS exposure also cannot be ignored. However, limited information does not allow for the estimate of excess breast cancer morbidity in either U.S. or China. Similarly, many other diseases, like acute respiratory and sensory irritation, and asthma initiation among adults, were not included in the analyses of SHS exposure in restaurants and bars in China. Thus, the excess morbidity and mortality due to SHS exposure in restaurants and bars are underestimated.

7.6 Challenges of Preventing People from Being Exposed to Secondhand Smoke in China

In 2010, 28% of adults aged 15 years and older are current smokers in China, including 53% of men and 2.4% of women. That is, there are 301 million current smokers in China, making this country the largest consumer of tobacco in the world (Li, Hsia et al. 2011). Of all current smokers, 85.6% smoked daily, with smokers consuming an average of 14 cigarettes per day; about 113 million current smokers (37%) have attempted to quit but failed; among those who have attempted to quit, more than 90% do not have access to any method to assist with smoking cessation (Li, Hsia et al. 2011). High current smoking rates, inequality of smoking rates between different genders, and lack of resources for assisting smoking cessation makes protecting nonsmokers from SHS exposure in China extremely difficult.

Smoking serves an important social function and thus makes it a social norm in China. One of the important values in Chinese culture is guanxi (connection). The tobacco industry, including both domestic and international tobacco companies, has made use of this value. They have intensively promoted cigarettes offering and gifting as a social currency to build new guanxi, or to maintain and expand a person's guanxi (Ding and Hovell 2012; Rich and Xiao 2012). Under the commercial manipulation of the tobacco industry, offering cigarettes to start a conversation with either strangers or acquaintances is very popular among males, including doctors, in China. A study among male health care professionals in China found that 57% of doctors are offered cigarettes as a gift for their services; of these, 84% of smokers and 29% of nonsmokers accept the offered cigarettes (Ceraso et al., 2009). As a doctor from a focus group study said: *"If you reject the offering of a cigarette, they will think you are impolite"* (Ma, Hoang et al. 2008). The cultivated cultural practices of cigarettes offering and gifting among both smokers and nonsmokers promote the extensive use of tobacco, and thus diffuse SHS exposure almost everywhere among the most majority of nonsmokers. As noticed by some researchers, the culture value of guanxi can be used to reverse the social norm, and thus to favor tobacco control in China (Ding and Hovell 2012). If people know well of the health consequences to smokers themselves and to their nonsmoking friends and families, cigarette offering and gifting may probably not able to serve the important social function described above, while other alternative healthy behaviors can be reinforced to replace cigarette offering and gifting.

Yet the health consequences of smoking are unknown to many Chinese people. Though 130 000 lung cancer deaths and 169 600 ischaemic heart disease deaths are attributed to smoking, and 22 200 lung cancer deaths and 33 800 ischaemic heart disease deaths are attributed to SHS exposure in China in 2002 (Gan, Smith et al. 2007), about 22% of the population don't know that smoking can cause lung cancer, and 61% don't know that smoking can cause ischaemic heart disease in 2010 (Yang and Hu 2010). Smoking is just one of the many risk factors for many diseases, and usually there is a long latency for smoking to cause chronic diseases, thus, many people don't believe smoking as a causal factor of lung cancer and ischaemic heart disease. In a focus group study, a smoker from the urban area of Sichuan said, *''I find that the majority of* *smokers are healthy. Individual's health depends on his genes. Is there anyone that has died of smoking directly? I know of nobody.''* And a doctor from the urban area of Henan said, *''They say smoking can cause this disease and that disease. There is no evidence to prove it. The ex-president Deng Xiaoping is one of the heaviest smokers; still he had more than 90 years of life''* (Ma, Hoang et al. 2008). Due to lack of knowledge of smoking and health hazards, it is difficult to expect many people to know the health hazards of SHS exposure. About 50% of the Chinese population don't know SHS exposure can cause respiratory diseases among children or lung cancers, and about 72% don't know SHS exposure can cause ischaemic heart diseases (Yang and Hu 2010). A large body of studies has showed causal relationship between smoking or SHS exposure and many diseases, while making scientific evidence understandable and acceptable to the general public is challenging. It should be the government's responsibility to allocate enough resources for public health educations on tobacco use and health; and health professionals should explore methods appropriate to the Chinese society to interpret scientific evidences and educate the public.

Involving the civil society in creating a smoke free environment is extremely important; however, it is tremendously challenging if smoking remains acceptable as a popular way of socializing, and there is a lack of knowledge of the health consequences of SHS exposure. Smoking is viewed as individual freedom among both smokers and nonsmokers (Ma, Hoang et al. 2008). Thus, smokers do not hesitate to light their cigarettes when they want to smoke, while nonsmokers are not used to claiming their right to enjoy smoke free environments. This has been shown by the poor compliance to the smoking restrictions in restaurants and bars in Beijing and the phenomenon that smoking was rarely stopped by nonsmoking patrons in nominal nonsmoking venues or sections (Chapter 2 &4).

The biggest challenge of reducing tobacco consumption and eliminating SHS exposure is from the Chinese tobacco industry, which is part of the Chinese government. China ratified the WHO Framework Convention on Tobacco Control (WHO FCTC) in 2005, and it should make every effort to control the most emerging tobacco epidemic as committed. In recent years, the Chinese government, professionals from various circles, and civil society organizations have made great efforts to implement the FCTC and have achieved considerable results. In terms of preventing people from hazards of SHS exposure, some cities, including Beijing, Shanghai, and Guangzhou, have passed their own governmental smoking restrictions in public places after 2008; the central government revised the implementation guidelines of the 1987 *Health Regulations in Public Places* (公共场所卫生管理条例) to tighten the rules to prohibit smoking in all indoor public places in the country, including restaurants and bars; great efforts have been made to create smoke free Olympics, World's Expo in Shanghai, hospitals, schools, communities, and so on. The government has also regulated the cigarette packaging and labeling and raised taxes on tobacco products in 2009.

However, the Chinese tobacco industry and its related interest group have made all their efforts to counter tobacco control activities. They published comprehensive strategies, *the Counterproposal and Countermeasure Scheme against FCTC*, to interfere with and weaken the full implementation of FCTC in China; they distort the translation of FCTC into Chinese, making the articles weaker in Chinese than in English; they deny the scientific conclusions on the health hazards of smoking and secondhand smoke, and claim smoking as a smoker's right; they use "low tar and low harm" marketing strategies to mislead the public; and so on. As a result, though the FCTC has been in effect in China for five years, considerable gaps still exist between the existing status and the FCTC requirements. For example, no national level laws have been passed to ban smoking in indoor public places and workplaces; the cigarette prices are not increased as the new tobacco tax rises; and the cigarette packaging and labeling is almost completely designed as proposed by the *Counterproposal and Countermeasure Scheme against FCTC* instead of WHO FCTC, and is ineffective in warning smokers the health consequence (Yang and Hu 2010). In 2010, a panel group with both Chinese and international experts evaluated the tobacco control efforts in China using ten indicators covering five key policies articulated by the FCTC: protecting people from the hazards of SHS, offering assistance to quit smoking, warning about the harm of tobacco use, enforcing bans on tobacco advertisements, promotion and sponsorship, and raising the tobacco tax and prices. The enforcement of smoking restrictions in indoor workplaces is 36.7 of the 100 point scale, and the enforcement of smoking restrictions in indoor public places is 27.3; China's average enforcement score of the five policies is 37.2 (Yang and Hu 2010).

The constitution in China explicitly states that the government should *"protect people's heath"*; and the twelfth five-year plan of the Chinese government includes *"comprehensively enforce smoking bans in public places"* as one of its goals during the five year period of 2011 to 2015. Yet, each year the death toll reaches almost 300 000 by smoking and 56 000 by SHS exposure from lung cancer and ischaemic heart disease alone in China, without counting for other diseases or the health toll among children. To achieve these goals, the government should separate itself from the tobacco industry and continue working with professionals from various circles and the civil society to fully implement the FCTC.

References

Agbenyikey, W., E. Wellington, J. Gyapong, M. J. Travers, P. N. Breysse, K. M. McCarty and A. Navas-Acien (2011). "Secondhand tobacco smoke exposure in selected public places (PM(2.5) and air nicotine) and non-smoking employees (hair nicotine) in Ghana." Tobacco Control **20**(2): 107-111.

Akbar-Khanzadeh, F. (2003). "Exposure to environmental tobacco smoke in restaurants without separate ventilation systems for smoking and nonsmoking dining areas." Archives of Environmental Health **58**(2): 97-103.

Alfaro, M. D. (1997). "Characterisation of indoor air quality in large urban centres in Central America." Indoor and Built Environment **6**(6): 337-343.

ANRF. (2012). "American non-smokers' rights foundation. Smoke-free status of workplaces and hospitality venues around the world." Retrieved 4-17, 2010, from http://www.no-smoke.org/pdf/internationalbarsandrestaurants.pdf.

ANRF. (2012). "Smokefree Status of Workplaces and Hospitality Venues Around the World. Berkeley, CA: American Nonsmokers' Right Foundation." Retrieved January 20, 2012, from http://www.no-smoke.org/pdf/internationalbarsandrestaurants.pdf.

ANRF. (2012). "Smokfree List, Maps, and Data. Berkeley, CA: American Nonsmokers' Right Foundation " Retrieved January 21, 2012, from http://www.no-smoke.org/pdf/current_smokefree_ordinances_by_year.pdf.

ANRF. (2012). "Summary of 100% Smokefree State Laws and Population Protected by 100% U.S. Smokefree Laws. Berkeley, CA: American Nonsmokers' Right Foundation." Retrieved January 20, 2012, from http://www.no-smoke.org/pdf/SummaryUSPopList.pdf.

ASHRAE (2007). ANSI/ASHRAE Standard 62.1-2007. Ventilation for Acceptable Indoor Air Quality. Atlanta, GA, American Society of Heating, Refrigerating and AirConditioning Engineers, Inc.

ASHRAE (2008). ASHRAE Position Document on Environmental Tobacco Smoke. Atlanta, Georgia, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Avila-Tang, E., M. J. Travers and A. Navas-Acien (2010). "Promoting smoke-free environments in Latin America: a comparison of methods to assess secondhand smoke exposure." Salud Publica De Mexico **52**: S138-S148.

Ayres, J. G., S. Semple, L. MacCalman, S. Dempsey, S. Hilton, J. F. Hurley, B. G. Miller, A. Naji and M. Petticrew (2009). "Bar workers' health and environmental tobacco smoke exposure (BHETSE): symptomatic improvement in bar staff following smoke-free legislation in Scotland." Occupational and Environmental Medicine **66**(5): 339-346.

Bang, K. M. and J. H. Kim (2001). "Prevalence of cigarette smoking by occupation and industry in the United States." American Journal of Industrial Medicine **40**(3): 233-239.

Barnoya, J., M. Arvizu, M. R. Jones, J. C. Hernandez, P. N. Breysse and A. Navas-Acien (2011). "Secondhand smoke exposure in bars and restaurants in Guatemala City: before and after smoking ban evaluation." Cancer Causes & Control **22**(1): 151-156.

Beijing Evening New. (2009). "One Year after the Beijing Smoking Restriction: Restaurants Don't Want Conflicts." Retrieved June 25, 2012, from http://pic.people.com.cn/GB/1098/9130178.html.

Bi, X. H., G. Y. Sheng, Y. L. Feng, J. M. Fu and J. X. Xie (2005). "Gas- and particulate-phase specific tracer and toxic organic compounds in environmental tobacco smoke." Chemosphere **61**(10): 1512-1522.

Bohac, D. L., M. J. Hewett, K. I. Kapphahn, D. T. Grimsrud, M. G. Apte and L. A. Gundel (2010). "Change in Indoor Particle Levels After a Smoking Ban in Minnesota Bars and Restaurants." American Journal of Preventive Medicine **39**(6): S3-S9.

Bohac, D. L., M. J. Hewett, K. I. Kapphahn, D. T. Grimsrud, M. G. Apte and L. A. Gundel (2011). Comparison of secondhand smoke in bar and restaurant non/smoking sections. 12th International Conference on Indoor Air Quality and Climate--Indoor Air 2011, 5-10 June, Austin, TX, International Society of Indoor Air Quality and Climate.

Bohac, D. L., M. J. Hewett, K. I. Kapphahn, D. T. Grimsrud, L. A. Gundel and M. G. Apte (2010). Secondhand Smoke Exposure for Minnesota Bars and Restaurants. Minneapolis, MN, Center for Energy and Environment, 212 3rd Avenue North, Suite 560, Minneapolis, MN 55401.

Bohanan, H. R., J. J. Piade, M. K. Schorp and Y. Saint-Jalm (2003). "An international survey of indoor air quality, ventilation, and smoking activity in restaurants: a pilot study." Journal of Exposure Analysis and Environmental Epidemiology **13**(5): 378-392.

Bolte, G., D. Heitmann, M. Kiranoglu, R. Schierl, J. Diemer, W. Koerner and H. Fromme (2008). "Exposure to environmental tobacco smoke in German restaurants, pubs and discotheques." Journal of Exposure Science and Environmental Epidemiology **18**(3): 262-271.

Branis, M., P. Rezacova and N. Guignon (2002). "Fine particles (PM1) in four different indoor environments." Indoor and Built Environment **11**(4): 184-190.

Brauer, M. and A. Mannetje (1998). "Restaurant smoking restrictions and environmental tobacco smoke exposure." American Journal of Public Health **88**(12): 1834-1836.

Brennan, E., M. Cameron, C. Warne, S. Durkin, R. Borland, M. J. Travers, A. Hyland and M. A. Wakefield (2010). "Secondhand smoke drift: Examining the influence of indoor smoking bans on indoor and outdoor air quality at pubs and bars." Nicotine & Tobacco Research **12**(3): 271-277.

Cains, T., S. Cannata, R. Poulos, M. J. Ferson and B. W. Stewart (2004). "Designated "no smoking" areas provide from partial to no protection from environmental tobacco smoke." Tobacco Control **13**(1): 17-22.

Cal/EPA (2005). Proposed Identification of Environmental Tobacco Smoke as a Toxic Air Contaminant. Sacramento, CA, California Environmental Protection Agency Air Resources Board and Office of Environmental Health Hazard Assessment.

Cal/EPA OEHHA. (2009). "Appendix A: Hot Spots Unit Risk and Cancer Potency Values." Retrieved December 21, 2010, from http://www.oehha.ca.gov/air/hot_spots/2009/AppendixA.pdf.

Callinan, J. E., A. Clarke, K. Doherty and C. Kelleher (2010). "Legislative smoking bans for reducing secondhand smoke exposure, smoking prevalence and tobacco consumption." Cochrane Database Syst Rev(4): CD005992.

Carrington, J., A. F. R. Watson and I. L. Gee (2003). "The effects of smoking status and ventilation on environmental tobacco smoke concentrations in public areas of UK pubs and bars." Atmospheric Environment **37**(23): 3255-3266.

CDC (2005a). "Cigarette Smoking Among Adults --- United States, 2004." MMWR **54**(44): 1121-1124.

CDC (2005b). "State-Specific Prevalence of Cigarette Smoking and Quitting Among Adults --- United States, 2004." MMWR **54**(44): 1124-1127.

CDC. (2008). " Smoking-Attributable Mortality, Years of Potential Life Lost, and Productivity Losses—United States, 2000–2004." Morbidity and Mortality Weekly Report. 2008;57(45):1226–1228. Retrieved 04-17, 2010, from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5745a3.htm.

CDC (2008). "Smoking-Attributable Mortality, Years of Potential Life Lost, and Productivity Losses -- United States, 2000--2004." MMWR **57** (45): 1226-1228.

CDC. (2009). "Cigarette Smoking Among Adults and Trends in Smoking Cessation --- United States, 2008." Morbidity and Mortality Weekly Report (MMWR) Retrieved July 16, 2011, from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5844a2.htm.

CDC. (2010). "Smoking and Tobacco use: GATS: Fact Sheet: China: 2010." Retrieved 05/02/2011, from http://www.cdc.gov/tobacco/global/gats/countries/wpr/fact_sheets/china/2010/index.htm.

CDC. (2010a). "Smoking-Attributable Mortality, Morbidity, and Economic Costs (SAMMEC)." Retrieved January 23, 2011, from https://apps.nccd.cdc.gov/sammec/index.asp.

CDC (2010b). "Vital Signs: Nonsmokers' Exposure to Secondhand Smoke --- United States, 1999--2008." MMWR **59**(35): 1141-1146.

CDC/NIOSH. (2008). "Work-Related Lung Disease (WoRLD) Surveillance System." Retrieved October 25, 2010, from http://www2a.cdc.gov/drds/WorldReportData/.

Charles, S. M., S. A. Batterman and C. R. Jia (2007). "Composition and emissions of VOCs in main- and side-stream smoke of research cigarettes." Atmospheric Environment **41**(26): 5371-5384.

Chinese CDC (2011). Tobacco Control in China 2011 Report. Beijing, National Tobacco Control Office, Chinese CDC.

Collishaw NE, Boyd NF, Cantor KP, Hammond SK, Johnson KC, Millar J, Millar AB, Millar M, Palmer JR, Salmon AG and Turcotte F (2009). Canadian Expert Panel on Tobacco Smoke and Breast Cancer Risk. Special Report Series. Toronto, Canada, Ontario Tobacco Research Unit.

Daisey, J. M. (1999). "Tracers for assessing exposure to environmental tobacco smoke: What are they tracing?" Environmental Health Perspectives **107**: 319-327.

Daly, B. J., K. Schmid and M. Riediker (2010). "Contribution of fine particulate matter sources to indoor exposure in bars, restaurants, and cafes." Indoor Air **20**(3): 204-212.

Dearlove, J. V., S. A. Bialous and S. A. Glantz (2002). "Tobacco industry manipulation of the hospitality industry to maintain smoking in public places." Tobacco Control **11**(2): 94-104.

Ding, D. and M. F. Hovell (2012). "Cigarettes, Social Reinforcement, and Culture: A Commentary on "Tobacco as A Social Currency: Cigarette Gifting and Sharing in China"." Nicotine & Tobacco Research **14**(3): 255-257.

Eisner, M. D., A. K. Smith and P. D. Blanc (1998). "Bartenders' respiratory health after establishment of smoke-free bars and taverns." Jama-Journal of the American Medical Association **280**(22): 1909-1914.

El-Hougeiri, N. and M. El Fadel (2002). "Risk assessment of occupational exposure to environmental tobacco smoke emissions." Indoor and Built Environment **11**(2): 83-94.

Ellingsen, D. G., G. Fladseth, H. L. Daae, M. Gjolstad, K. Kjaerheim, M. Skogstad, R. Olsen, S. Thorud and P. Molander (2006). "Airborne exposure and biological monitoring of bar and restaurant workers before and after the introduction of a smoking ban." Journal of Environmental Monitoring **8**(3): 362-368.

Erazo, M., V. Iglesias, A. Droppelmann, M. Acuna, A. Peruga, P. N. Breysse and A. Navas-Acien (2010). "Secondhand tobacco smoke in bars and restaurants in Santiago, Chile: evaluation of partial smoking ban legislation in public places." Tobacco Control **19**(6): 469-474.

Gan, Q., S. K. Hammond, Y. Jiang, Y. Yang and T. W. Hu (2008). "Effectiveness of a smoke-free policy in lowering secondhand smoke concentrations in offices in China." Journal of Occupational and Environmental Medicine **50**(5): 570-575.

Gan, Q., K. R. Smith, S. K. Hammond and T. W. Hu (2007). "Disease burden of adult lung cancer and ischaemic heart disease from passive tobacco smoking in China." Tobacco Control **16**(6): 417-422.

Gee, I. L., A. F. R. Watson and J. Carrington (2005). "The contribution of environmental tobacco smoke to indoor pollution in pubs and bars." Indoor and Built Environment **14**(3-4): 301-306.

Gleich, F., U. Mons and M. Potschke-Langer (2011). "Air Contamination Due to Smoking in German Restaurants, Bars, and Other Venues-Before and After the Implementation of a Partial Smoking Ban." Nicotine & Tobacco Research **13**(11): 1155-1160.

Goodman, P., M. Agnew, M. McCaffrey, G. Paul and L. Clancy (2007). "Effects of the Irish smoking ban on respiratory health of bar workers and air quality in Dublin pubs." American Journal of Respiratory and Critical Care Medicine **175**(8): 840-845.

Gorini, G., H. Moshammer, L. Sbrogio, A. Gasparrini, M. Nebot, M. Neuberger, E. Tamang, M. J. Lopez, D. Galeone and E. Serrahima (2008). "Italy and Austria before and after study: second-hand smoke exposure in hospitality premises before and after 2 years from the introduction of the Italian smoking ban." Indoor Air **18**(4): 328-334.

Hammond, S. K. (1999). "Exposure of US workers to environmental tobacco smoke." Environmental Health Perspectives **107**: 329-340.

Hammond, S. K. and B. P. Leaderer (1987). "A Diffusion Monitor to Measure Exposure to Passive Smoking." Environmental Science & Technology **21**(5): 494-497.

Hammond, S. K., L. Tian and C. Li (1999). Environmental tobacco smoke exposure in China. The 8th International Conference on Indoor Air Quality and Climate, Edinburgh, Scotland, The International Academy of Indoor Air Sciences.

Hedley, A. J., S. M. McGhee, J. L. Repace, L. C. Wong, M. Y. S. Yu, T. W. Wong and T. H. Lam (2006). "Risks for heart disease and lung cancer from passive smoking by workers in the catering industry." Toxicological Sciences **90**(2): 539-548.

Hewett, M. J., D. L. Bohac, K. I. Kapphahn, D. T. Grimsrud, M. G. Apte and L. A. Gundel (2011). Secondhand smoke concentrations in repeated visits to a probability sample of bars and restaurants. 12th International Conference on Indoor Air Quality and Climate--Indoor Air 2011, 5-10 June, Austin, TX, International Society of Indoor Air Quality and Climate.

Hodgson, A. T., J. M. Daisey, K. R. R. Mahanama, J. TenBrink and L. E. Alevantis (1996). "Use of volatile tracers to determine the contribution of environmental tobacco smoke to concentrations of volatile organic compounds in smoking environments." Environment International **22**(3): 295-307.

Huss, A., C. Kooijman, M. Breuer, P. Bohler, T. Zund, S. Wenk and M. Roosli (2010). "Fine particulate matter measurements in Swiss restaurants, cafes and bars: What is the effect of spatial separation between smoking and non-smoking areas?" Indoor Air **20**(1): 52-60.

Hyland, A., M. J. Travers, C. Dresler, C. Higbee and K. M. Cummings (2008). "A 32-country comparison of tobacco smoke derived particle levels in indoor public places." Tobacco Control **17**(3): 159-165.

IARC (2004). Tobacco Smoke and Involuntary Smoking (IARC Monograph 83). Lyon, France.

IARC (2009). Handbooks of Cancer Prevention, Tobacco Control, Vol. 13: Evaluating the effectiveness of smoke-free policies. Lyon, France.

Institute of Medicine, Ed. (2009). Secondhand Smoke Exposure and Cardiovascular Effects: Making Sense of the Evidence. Washington, D.C., The National Academies Press

Institute of Medicine (2009). Secondhand Smoke Exposure and Cardiovascular Effects: Making Sense of the Evidence. Washington D.C., The National Academies Press.

Jaakkola, M. S. and J. J. K. Jaakkola (1997). "Assessment of exposure to environmental tobacco smoke." European Respiratory Journal **10**(10): 2384-2397.

Jaakkola, M. S., R. Piipari, N. Jaakkola and J. J. K. Jaakkola (2003). "Environmental tobacco smoke and adult-onset asthma: A population-based incident case-control study." American Journal of Public Health **93**(12): 2055-2060.

Jaakkola, M. S. and J. M. Samet (1999). "Occupational exposure to environmental tobacco smoke and health risk assessment." Environmental Health Perspectives **107**: 829-835.

Jamrozik, K. (2005). "Estimate of deaths attributable to passive smoking among UK adults: database analysis." British Medical Journal **330**(7495): 812-815.

Jane, M., M. Nebot, X. Rojano, L. Artazcoz, L. Sunyer, E. Fernandez, M. Ceraso, J. Samet and S. K. Hammond (2002). "Exposure to environmental tobacco smoke in public places in Barcelona, Spain." Tobacco Control **11**(1): 83-84.

Jenkins R.A., Guerin M.R. and T. B.A. (2000). The Chemistry of Environmental Tobacco Smoke: Composition and Measurement. Boca Raton, Lewis Publishers.

Jenkins, R. A. and R. W. Counts (1999). "Occupational exposure to environmental tobacco smoke: Results of two personal exposure studies." Environmental Health Perspectives **107**: 341-348.

Jenkins, R. A., R. H. Ilgner, B. A. Tomkins and D. W. Peters (2004). "Development and application of protocols for the determination of response of real-time particle monitors to common indoor aerosols." Journal of the Air & Waste Management Association **54**(2): 229-241.

Jenkins, R. A., M. P. Maskarinec, R. W. Counts, J. E. Caton, B. A. Tomkins and R. H. Ilgner (2001). "Environmental tobacco smoke in an unrestricted smoking workplace: area and personal exposure monitoring." Journal of Exposure Analysis and Environmental Epidemiology **11**(5): 369-380.

Johnson, K. C., A. B. Miller, N. E. Collishaw, J. R. Palmer, S. K. Hammond, A. G. Salmon, K. P. Cantor, M. D. Miller, N. F. Boyd, J. Millar and F. Turcotte (2011). "Active smoking and secondhand smoke increase breast cancer risk: the report of the Canadian Expert Panel on Tobacco Smoke and Breast Cancer Risk (2009)." Tobacco Control **20**(1).

Johnsson, T., T. Tuomi, H. Riuttala, M. Hyvarinen, M. Rothberg and K. Reijula (2006). "Environmental tobacco smoke in Finnish restaurants and bars before and after smoking restrictions were introduced." Annals of Occupational Hygiene **50**(4): 331-341.

Jones, M. R., H. Wipfli, S. Shahrir, E. Avila-Tang, J. M. Samet, P. N. Breysse, A. Navas-Acien and F. B. S. Investigators (2012). "Secondhand tobacco smoke: an occupational hazard for smoking and non-smoking bar and nightclub employees." Tobacco Control.

Junker, M. H., B. Danuser, C. Monn and T. Koller (2001). "Acute sensory responses of nonsmokers at very low environmental tobacco smoke concentrations in controlled laboratory settings." Environmental Health Perspectives **109**(10): 1045-1052.

Kang J, Lin X, Yang Y, Nan Y, Li Z and Liu R (2007). " A Study on the level of tobacco-generated smoke in several restaurants and bars in Beijing, China." Chinese Journal of Epidemiology **28**(8): 738-741.

Kang, J., Y. Jiang, X. Lin and Y. Yang (2007). "Study on the Level of Environmental Tobacco Smoke in Restaurants and Bars in Beijing, China." Chin J Epidemiology **28**(8): 738-741.

Kinglun Ngok and Dian Li (2010). "Tobacco control in China: process, actors and policy initiatives." Journal of Asian Public Policy **3**(1): 100-110.

Klepeis, N. E. (1999). Validity of the uniform mixing assumption: Determining human exposure to environmental tobacco smoke.

Klepeis, N. E., W. R. Ott and P. Switzer (1996). "A multiple-smoker model for predicting indoor air quality in public lounges." Environmental Science & Technology **30**(9): 2813-2820.

Klepeis, N. E., W. R. Ott and P. Switzer (2007). "Real-time measurement of outdoor tobacco smoke particles." Journal of the Air & Waste Management Association **57**(5): 522-534.

Klepeis, N. E., A. M. Tsang and J. V. Behar (1996). Analysis of the National Human Activity Pattern Survey (NHAPS) respondents from a standpoint of exposure assessment. Final EPA Report, EPA/600/R-96/074. Washington, DC.

Kuusimaki, L., K. Peltonen and S. Vainiotalo (2007). "Assessment of environmental tobacco smoke exposure of Finnish restaurant workers, using 3-ethenylpyridine as marker." Indoor Air **17**(5): 394-403.

Lai, H. K., A. J. Hedley, J. Repace, C. So, Q. Y. Lu, S. M. McGhee, R. Fielding and C. M. Wong (2011). "Lung function and exposure to workplace second-hand smoke during exemptions from smoking ban legislation: an exposure-response relationship based on indoor PM(2.5) and urinary cotinine levels." Thorax **66**(7): 615-623.

Lambert, W. E., J. M. Samet and J. D. Spengler (1993). "Environmental Tobacco-Smoke Concentrations in No-Smoking and Smoking Sections of Restaurants." American Journal of Public Health **83**(9): 1339-1341.

Leaderer, B. P. and S. K. Hammond (1991). "Evaluation of Vapor-Phase Nicotine and Respirable Suspended Particle Mass as Markers for Environmental Tobacco-Smoke." Environmental Science & Technology **25**(4): 770-777.

Leavell, N. R., M. E. Muggli, R. D. Hurt and J. Repace (2006). "Public health - Blowing smoke: British American Tobacco's air filtration scheme." British Medical Journal **332**(7535): 227-229.

Lee, J., S. Lim, K. Lee, X. B. Guo, R. Kamath, H. Yamato, A. L. Abas, S. Nandasena, A. A. Nafees and N. Sathiakumar (2010). "Secondhand smoke exposures in indoor public places in seven Asian countries." International Journal of Hygiene and Environmental Health **213**(5): 348-351.

Lee, K., E. J. Hahn, N. Pieper, C. T. C. Okoli, J. Repace and A. Troutman (2008). "Differential impacts of smoke-free laws on indoor air quality." Journal of Environmental Health **70**(8): 24-30.

Lee, K., E. J. Hahn, C. Riker, S. Head and P. Seithers (2007). "Immediate impact of smoke-free laws on indoor air quality." Southern Medical Journal **100**(9): 885-889.

Lee, K., E. J. Hahn, H. E. Robertson, S. Lee, S. L. Vogel and M. J. Travers (2009). "Strength of smoke-free air laws and indoor air quality." Nicotine & Tobacco Research **11**(4): 381-386.

Li, Q., J. Hsia and G. Yang (2011). "Prevalence of Smoking in China in 2010." New England Journal of Medicine **364**(25): 2469-2470.

Lightwood, J. M. and S. A. Glantz (2009). "Declines in Acute Myocardial Infarction After Smoke-Free Laws and Individual Risk Attributable to Secondhand Smoke." Circulation **120**: 1373-1397.

Liu, R., S. K. Hammond, A. Hyland, M. J. Travers, Y. Yang, Y. Nan, G. Feng, Q. Li and Y. Jiang (2011). "Restaurant and Bar Owners' Exposure to Secondhand Smoke and Attitudes Regarding Smoking Bans in Five Chinese Cities." International Journal of Environmental Research and Public Health **8**(5): 1520-1533.

Liu, R., Y. Lu and Y. Jiang (2012). Hospitality Workers' Exposure to Secondhand Smoke from 2006 to 2008 in Beijing, China At Work in the World: the Fourth International Conference on the History of Occupational and Environmental Health. Brian Dolan and Paul Blanc. San Francisco, UC Medical Humanities Press**:** 185-186.

Liu, R., Y. Yang, X. Liu, A. Chang, J. Gong, B. Zhao, T. Liu, Y. Jiang, A. Hyland and Q. Li (2008). "Knowledge and attitudes towards secondhand smoke among hospitality patronage in five cities in China." Chinese Journal of Epidemiology **29**(5): 421-425.

Liu, R., Y. Yang, M. Travers, G. T. Fong, R. J. O'Connor, A. Hyland, L. Li, Y. Nan, G. Feng, Q. Li and Y. Jiang (2010). "A cross-sectional study on levels of second-hand smoke in restaurants and bars in five cities in China." Tobacco Control **19**(2): 11.

Liu, R., Y. Yang, M. J. Travers, G. T. Fong, R. J. O'Connor, A. Hyland, L. Li, Y. Nan, Z. Feng, Q. Li and Y. Jiang "A cross sectional study on levels of secondhand smoke in restaurants and bars in five cities in China." Tob Control doi:10.1136/tc.2009.033233.

Liu, R., L. Zhang, C. M. McHale and S. K. Hammond (2011). "Paternal Smoking and Risk of Childhood Acute Lymphoblastic Leukemia: Systematic Review and Meta-Analysis." Journal of Oncology **2011**.

Liu, R. L., Y. Yang, M. J. Travers, G. T. Fong, R. J. O'Connor, A. Hyland, L. Li, Y. Nan, G. Z. Feng, Q. Li and Y. Jiang (2010). "A cross-sectional study on levels of second-hand smoke in restaurants and bars in five cities in China." Tobacco Control **19**.

Liu, R. L., Y. Yang, M. J. Travers, G. T. Fong, R. J. O'Connor, A. Hyland, L. Li, Y. Nan, G. Z. Feng, Q. Li and Y. Jiang (2010). "A cross-sectional study on levels of second-hand smoke in restaurants and bars in five cities in China." Tobacco Control **19 Suppl 2**: i24-29.

Liu, R. L., Y. Yang, M. J. Travers, G. T. Fong, R. J. O'Connor, A. Hyland, L. Li, Y. Nan, G. Z. Feng, Q. Li and Y. Jiang (2011). "A cross-sectional study on levels of secondhand smoke in restaurants and bars in five cities in China." Tobacco Control **20**(6): 397-402.

Lopez, M. J., P. Burhoo, L. Moussa and M. Nebot (2011). "Secondhand smoke assessment in the first African country adopting a comprehensive smoke-free law (Mauritius)." Environmental Research **111**(8): 1024-1026.

Lopez, M. J., M. Nebot, M. Albertini, P. Birkui, F. Centrich, M. Chudzikova, M. Georgouli, G. Gorini, H. Moshammer, M. Mulcahy, M. Pilali, E. Serrahima, P. Tutka and E. Fernandez (2008). "Secondhand Smoke Exposure in Hospitality Venues in Europe." Environmental Health Perspectives **116**(11): 1469-1472.

Lopez, M. J., M. Nebot, O. Juarez, C. Ariza, J. Salles and E. Serrahima (2006). "Estimation of the excess of lung cancer mortality risk associated to environmental tobacco smoke exposure of hospitality workers." Medicina Clinica **126**(1): 13-14.

Lv, J., M. Su, Z. H. Hong, T. Zhang, X. M. Huang, B. Wang and L. M. Li (2011). "Implementation of the WHO Framework Convention on Tobacco Control in mainland China." Tobacco Control **20**(4): 309-314.

Ma, G., X. Hu, D. Luan, Y. Li, F. Zhai and X. Yang (2005). "The Eating Practice of Peole in China (in Chinese)." Acta Nutrimenta Sinica **27**(4): 272-275.

Ma, S. J., M. A. Hoang, J. M. Samet, J. F. Wang, C. Z. Mei, X. F. Xu and F. A. Stillman (2008). "Myths and Attitudes that Sustain Smoking in China." Journal of Health Communication **13**(7): 654-666.

Mackay, D., S. Haw, J. G. Ayres, C. Fischbacher and J. P. Pell (2010). "Smoke-free Legislation and Hospitalizations for Childhood Asthma." New England Journal of Medicine **363**(12): 1139-1145.

Mahanama, K. R. R. and J. M. Daisey (1996). "Volatile N-nitrosamines in environmental tobacco smoke: Sampling, analysis, emission factors, and indoor air exposures." Environmental Science & Technology **30**(5): 1477-1484.

Martin, P., D. L. Heavner, P. R. Nelson, K. C. Maiolo, C. H. Risner, P. S. Simmons, W. T. Morgan and M. W. Ogden (1997). "Environmental tobacco smoke (ETS): A market cigarette study." Environment International **23**(1): 75-90.

Maskarinec, M. P., R. A. Jenkins, R. W. Counts and A. B. Dindal (2000). "Determination of exposure to environmental tobacco smoke in restaurant and tavern workers in one US city." Journal of Exposure Analysis and Environmental Epidemiology **10**(1): 36-49.

Meyers, D. G., J. S. Neuberger and J. He (2009). "Cardiovascular Effect of Bans on Smoking in Public Places." Journal of the American College of Cardiology **54**(14): 1249-1255.

Minneapolis St. Paul Business Journal. (2011, January 25). "Bill would repeal smoking ban in MN bars." Retrieved March 10, 2012, from http://www.bizjournals.com/twincities/morning_roundup/2011/01/bill-would-repeal-smoking-ban-in-mn-bars.html.

Minnesota Department of Health (2008). Creating a Healthier Minnesota: Progress in Reducing Tobacco Use. Minneapolis, MN, ClearWay Minnesota^{SM}, Blue Cross and Blue Shield of Minnesota and Minnesota Department of Health.

Moshammer, H., M. Neuberger and M. Nebot (2004). "Nicotine and surface of particulates as indicators of exposure to environmental tobacco smoke in public places in Austria." International Journal of Hygiene and Environmental Health **207**(4): 337-343.

Mulcahy, M., D. S. Evans, S. K. Hammond, J. L. Repace and M. Byrne (2005). "Secondhand smoke exposure and risk following the Irish smoking ban: an assessment of salivary cotinine concentrations in hotel workers and air nicotine levels in bars." Tobacco Control **14**(6): 384-388.

National Bureau of Statistics and Ministry of Labour and Social Security of China. (2005). "China Labour Statistical Yearbook 2005." Retrieved May 25, 2012, from http://www.molss.gov.cn/gb/zwxx/node_5435.htm.

National Bureau of Statistics of China. (2005). "Bulletin of the First National Economy Census Key Findings (No.3)." from http://www.stats.gov.cn/zgjjpc/cgfb/t20051216_402296629.htm.

National Bureau of Statistics of China. (2008). "Time Activity Patterns of Chinese People." Retrieved May 25, 2012, from http://www.stats.gov.cn/tjsj/qtsj/2008sjlydczlhb/index.htm.

National Bureau of Statistics of China. (2009, 12/16/2005). "Bulletin of the Third National Economy Census Key Findings (No.3)." Retrieved May 26, 2012, from http://www.stats.gov.cn/tjfx/fxbg/t20091225_402610157.htm.

Navas-Acien, A., A. Peruga, P. Breysse, A. Zavaleta, A. Blanco-Marquizo, R. Pitarque, M. Acuna, K. Jimenez-Reyes, V. L. Colombo, G. Gamarra, F. A. Stillman and J. Samet (2004). "Secondhand tobacco smoke in public places in Latin America, 2002-2003." Jama-Journal of the American Medical Association **291**(22): 2741-2745.

Nebot, M., M. Lopez, G. Gorini, M. Neuberger, S. Axelsson, M. Pilali, C. Fonseca, K. Abdennbi, A. Hackshaw, H. Moshammer, A. M. Laurent, J. Salles, M. Georgouli, M. C. Fondelli, E. Serrahima, F. Centrich and S. K. Hammond (2005). "Environmental tobacco smoke exposure in public places of European cities." Tobacco Control **14**(1): 60-63.

Nebot, M., M. J. Lopez, C. Ariza, M. Perez-Rios, M. Fu, A. Schiaffino, G. Munoz, E. Salto, E. Fernandez and S. S. L. E. Grp (2009). "Impact of the Spanish Smoking Law on Exposure to Secondhand Smoke in Offices and Hospitality Venues: Before-and-After Study." Environmental Health Perspectives **117**(3): 344-347.

Nelson, P. R., S. P. Kelly and F. W. Conrad (1998). "Studies of environmental tobacco smoke generated by different cigarettes." Journal of the Air & Waste Management Association **48**(4): 336-344.

NRC (1986). Environmental tobacco smoke: measuring exposure and assessing health effects. Washington, DC, National Research Council.

NRC (2006). Human biomonitoring for environmental chemicals. Washington, DC, National Research Council.

Nurminen, M. M. and M. S. Jaakkola (2001). "Mortality from occupational exposure to environmental tobacco smoke in Finland." Journal of Occupational and Environmental Medicine **43**(8): 687-693.

Oberg, M., M. S. Jaakkola, A. Woodward, A. Peruga and A. Pruess-Ustuen (2011). "Worldwide burden of disease from exposure to second-hand smoke: a retrospective analysis of data from 192 countries." Lancet **377**(9760): 139-146.

Ochir, C., S. Shahrir, L. Noijmaa, P. N. Breysse and A. Navas-Acien (2011). "Secondhand Smoke Exposure Among Bar and Nightclub Employees Mongolia." Epidemiology **22**(1): S234-S235.

Ott, W., L. Langan and P. Switzer (1992). "A Time series model for cigarette smoking activity patterns: model validation for carbon monoxide and respirable particles in a chamber and an automo-bile " J Expo Anal Environ Epidemiol **2 (Suppl 2)**: 175-200.

Ott, W., P. Switzer and J. Robinson (1996). "Particle concentrations inside a tavern before and after prohibition of smoking: Evaluating the performance of an indoor air quality model." Journal of the Air & Waste Management Association **46**(12): 1120-1134.

Ott, W. R. (1999). Mathematical models for predicting indoor air quality from smoking activity.

People's Daily Online. (2010). "China Puts Final Death Toll from Qinghai Quake at 2,698." Retrieved June 24, 2012, from http://english.peopledaily.com.cn/90001/90776/90882/7006506.html.

Pew Research Cener. (2006). "Eating More; Enjoying Less." Retrieved 09-20, 2010, from pewresearch.org/assets/social/pdf/Eating.pdf

Polanska, K., W. Hanke and K. Konieczko (2011). "Hospitality Workers' Exposure to Environmental Tobacco Smoke before and after Implementation of Smoking Ban in Public Places: A Review of Epidemiological Studies." Medycyna Pracy **62**(2): 211-224.

Pope, C. A., R. T. Burnett, D. Krewski, M. Jerrett, Y. L. Shi, E. E. Calle and M. J. Thun (2009). "Cardiovascular Mortality and Exposure to Airborne Fine Particulate Matter and Cigarette Smoke Shape of the Exposure-Response Relationship." Circulation **120**(11): 941-948.

Proescholdbell, S., J. Steiner, A. O. Goldstein and S. H. Malek (2009). "Using Indoor Air Quality Monitoring in 6 Counties to Change Policy in North Carolina." Preventing Chronic Disease **6**(3).

Repace, J. (2004). "Respirable particles and carcinogens in the air of Delaware hospitality venues before and after a smoking ban." Journal of Occupational and Environmental Medicine **46**(9): 887-905.

Repace, J., E. Hughes and N. Benowitz (2006). "Exposure to second-hand smoke air pollution assessed from bar patrons' urinary cotinine." Nicotine & Tobacco Research **8**(5): 701-711.

Repace, J. L. (1987). Indoor Concentrations of Environmental Tobacco Smoke Models Dealing with Effects of Ventilation and Room Size. O'neill, I. K., Et Al. (Ed.). Iarc (International Agency for Research on Cancer) Scientific Publications, No. 81. Environmental Carcinogens Methods of Analysis and Exposure Measurement, Vol. 9. Passive Smoking. Oxford University Press: New York, New York, USA; Oxford, England, Uk. International Agency for Research on Cancer: Lyon, France. Illus**:** 25-42.

Repace, J. L. (1987). "Indoor concentrations of environmental tobacco smoke: models dealing with effects of ventilation and room size." IARC Sci Publ(81): 25-41.

Repace, J. L. (2009). "Secondhand Smoke in Pennsylvania Casinos: A Study of Nonsmokers' Exposure, Dose, and Risk." American Journal of Public Health **99**(8): 1478-1485.

Repace, J. L., R. T. Jiang, V. Acevedo-Bolton, K. C. Cheng, N. E. Klepeis, W. R. Ott and L. M. Hildemann (2011). "Fine particle air pollution and secondhand smoke exposures and risks inside 66 US casinos." Environmental Research **111**(4): 473-484.

Repace, J. L., J. Jinot, S. Bayard, K. Emmons and S. K. Hammond (1998). "Air nicotine and saliva cotinine as indicators of workplace passive smoking exposure and risk." Risk Analysis **18**(1): 71-83.

Repace, J. L. and A. H. Lowrey (1985). "An indoor air quality standard for ambient tobacco smoke based on carcinogenic risk." N Y State J Med **85**(7): 381-383.

Repace, J. L. and A. H. Lowrey (1985). "A Quantitative Estimate of Nonsmokers Lung-Cancer Risk from Passive Smoking." Environment International **11**(1): 3-22.

Repace, J. L. and A. H. Lowrey (1990). "Risk Assessment Methodologies for Passive Smoking-Induced Lung-Cancer." Risk Analysis **10**(1): 27-37.

Rich, Z. C. and S. Y. Xiao (2012). "Tobacco as a Social Currency: Cigarette Gifting and Sharing in China." Nicotine & Tobacco Research **14**(3): 258-263.

Rosen, L. J., D. M. Zucker, B. J. Rosen and G. N. Connolly (2011). "Second-hand smoke levels in Israeli bars, pubs and cafes before and after implementation of smoke-free legislation." European Journal of Public Health **21**(1): 15-20.

Rudd, R. A. and J. E. Moorman (2007). "Asthma incidence: Data from the National Health Interview Survey, 1980-1996." Journal of Asthma **44**(1): 65-70.

Schneider, S., B. Seibold, S. Schunk, E. Jentzsch, C. Dresler, M. J. Travers, A. Hyland and M. Potschke-Langer (2008). "Exposure to secondhand smoke in Germany: Air contamination due to smoking in German restaurants, bars, and other venues." Nicotine & Tobacco Research **10**(3): 547-555.

Sebrie, E. M. and S. A. Glantz (2007). ""Accommodating" smoke-free policies: tobacco industry's courtesy of choice programme in Latin America." Tobacco Control **16**(5).

Semple, S., K. S. Creely, A. Naji, B. G. Miller and J. G. Ayres (2007). "Secondhand smoke levels in Scottish pubs: the effect of smoke-free legislation." Tobacco Control **16**(2): 127-132.

Semple, S., M. van Tongeren, K. S. Galea, L. Maccalman, I. Gee, O. Parry, A. Naji and J. G. Ayres (2010). "UK Smoke-Free Legislation: Changes in PM(2.5) Concentrations in Bars in Scotland, England, and Wales." Annals of Occupational Hygiene **54**(3): 272-280.

Siegel, M. (1993). "Involuntary Smoking in the Restaurant Workplace - a Review of Employee Exposure and Health-Effects." Jama-Journal of the American Medical Association **270**(4): 490-493.

Siegel, M. and M. Skeer (2003). "Exposure to secondhand smoke and excess lung cancer mortality risk among workers in the "5 B's": bars, bowling alleys, billiard halls, betting establishments, and bingo parlours." Tobacco Control **12**(3): 333-338.

Singer, B. C., A. T. Hodgson, K. S. Guevarra, E. L. Hawley and W. W. Nazaroff (2002). "Gas-phase organics in environmental tobacco smoke. 1. Effects of smoking rate, ventilation, and furnishing level on emission factors." Environmental Science & Technology **36**(5): 846-853.

Singer, B. C., A. T. Hodgson and W. W. Nazaroff (2003). "Gas-phase organics in environmental tobacco smoke: 2. Exposure-relevant emission factors and indirect exposures from habitual smoking." Atmospheric Environment **37**(39-40): 5551-5561.

Steenland, K. (1992). "Passive Smoking and the Risk of Heart Disease." Jama-Journal of the American Medical Association **267**(1): 94-99.

Steenland, K. (1999). "Risk assessment for heart disease and workplace ETS exposure among nonsmokers." Environmental Health Perspectives **107**: 859-863.

Stillman, F., A. Navas-Acien, J. M. Ma, S. J. Ma, E. Avila-Tang, P. Breysse, G. H. Yang and J. Samet (2007). "Second-hand tobacco smoke in public places in urban and rural China." Tobacco Control **16**(4): 229-234.

Task Force on Community Preventive Services (2005). The Guide to Community Preventive Services: What Works to Promote Health? . New York: Oxford University Press.

The Central People's Government of the People's Republic of China. (2007). "Mortality of Natural Disasters in 2006."   Retrieved June 24, 2012, from http://www.gov.cn/zhibo46/content_490836.htm.

The GTSS Collaborative Group (2006). "A cross country comparison of exposure to secondhand smoke among youth." Tobacco Control **15**: Ii4-Ii19.

Travers, M. J. (2008). Smoke-Free Air Policy: Changing What's in the Air and in the Boddy. Ph.D. Dissertation, University at Buffalo, State University of New York.

Travis, Crouch, R. Milson and E. D. Klema (1987). "Cancer risk management: A review of 132 regulatory decisions." Environmental Science and Technology **21**(5): 415-420.

Tsang, A. M. and N. E. Klepeis (1996). Descriptive Statistics Tables from a Detailed Analysis of the National Human Activity Pattern Survey (NHAPS) Data, U.S. Environmental Protection Agency, Washington, D.C.

U.S. BLS. (2011). "*Career Guide to Industries, 2010-11 Edition*, Food Services and Drinking Places."   Retrieved March 11, 2011, from http://www.bls.gov/oco/cg/cgs023.htm

U.S. BLS. (2011). "Occupational Employment Statistics. Bureau of Labor Statistics, United States Department of Labor."   Retrieved December 10, 2010, from http://www.bls.gov/oes/oes_dl.htm.

U.S. EPA (1992). Respiratory health effects of passive smoking: lung cancer and other disorders. Washington, DC, U.S. Environmental Protection Agency.

U.S. EPA (1997). Exposure Factors Handbook (Final Report). Washington, DC, U.S. Environmental Protection Agency.

U.S. EPA. (2006). "PM Standards." Retrieved March 11, 2011, from http://www.epa.gov/air/particlepollution/standards.html.

U.S. EPA. (2011). "Integrated Risk Information System (IRIS): A-Z List of Substances." Retrieved January 30, 2011, from http://cfpub.epa.gov/ncea/iris/index.cfm?fuseaction=iris.showSubstanceList.

USDHHS (1986). The health consequences of involuntary smoking: a report of the Surgeon General Rockville, MD, U.S. Department of Health and Human Services, Center for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health

USDHHS (2006). U.S.Department of Health and Human Services. The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General. Atlanta, GA, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, coordinating Center for Health Promotion, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health.

Valente, P., F. Forastiere, A. Bacosi, G. Cattani, S. Di Carlo, M. Ferri, I. Figa-Talamanca, A. Marconi, L. Paoletti, C. Perucci and P. Zuccaro (2007). "Exposure to fine and ultrafine particles from secondhand smoke in public places before and after the smoking ban, Italy 2005." Tobacco Control **16**(5): 312-317.

Van Loy, M. D., W. W. Nazaroff and J. M. Daisey (1998). "Nicotine as a marker for environmental tobacco smoke: Implications of sorption on indoor surface materials." Journal of the Air & Waste Management Association **48**(10): 959-968.

Van Loy, M. D., W. J. Riley, J. M. Daisey and W. W. Nazaroff (2001). "Dynamic behavior of semivolatile organic compounds in indoor air. 2. Nicotine and phenanthrene with carpet and wallboard." Environmental Science & Technology **35**(3): 560-567.

Vardavas, C. I., B. Kondilis, M. J. Travers, E. Petsetaki, Y. Tountas and A. G. Kafatos (2007). "Environmental tobacco smoke in hospitality venues in Greece." Bmc Public Health **7**.

Walker, J. C., P. R. Nelson, W. S. Cain, M. J. Utell, M. B. Joyce, W. T. Morgan, T. J. Steichen, W. S. Pritchard and M. W. Stancill (1997). "Perceptual and psychophysiological responses of non-smokers to a range of environmental tobacco smoke concentrations." Indoor Air **7**(3): 173-188.

Wallace, L. (1996). "Indoor particles: A review." Journal of the Air & Waste Management Association **46**(2): 98-126.

Waring, M. S. and J. A. Siegel (2007). "An evaluation of the indoor air quality in bars before and after a smoking ban in Austin, Texas." Journal of Exposure Science and Environmental Epidemiology **17**(3): 260-268.

Weng, X., Z. Hong, D. Chen, B. Chen and B. Tian (1986). "A National Survey of Smoking Behaviors of 500 000 Adullts in China, 1984." Journal of Cardiovascular and Pulmonary Diseases (in Chinese) **02**: 44-48.

White, E., B. Armstrong and R. Saracci (2008). Principles of exposure measurement in epidemiology: Collecting, evaluating, and improving measures of disease risk factors. Oxford, Oxford University Press.

WHO (1999). International consultation on environmental tobacco smoke (ETS) and child Health. Geneva. Switzerland, World Health Organization

WHO. (2005). "WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide." WHO/SDE/PHE/OEH/06.02 Retrieved March 10, 2011, from http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf.

WHO (2007). Guidelines for Article 8 of the Framework Convention on Tobacco Control Geneva, Switzerland, World Health Organization.

WHO. (2007). "Guidelines for implementation of Article 8 of the WHO FCTC." 2011, from http://www.who.int/fctc/protocol/guidelines/adopted/article_8/en/index.html.

WHO. (2009). "World Health Organization report on the global tobacco epidemic, 2009: implementing smoke-free environments." Retrieved October 20, 2010, from http://www.who.int/tobacco/mpower/2009/en/.

WHO. (2011, August 2011). "China and the WHO Framework Convention on Tobacco Control (WHO FCTC)." Retrieved August 29, 2011, from http://www.wpro.who.int/china/media_centre/news/BN20110107.htm.

WHO. (2011). "Framework Conventioin on Tobacco Control." Retrieved 05/01, 2011, from http://www.who.int/fctc/en/.

WHO IARC (2004). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Lyon, France, World Health Organization International Agency for Research on Cancer.

Wilson, N., R. Edwards, A. Maher, J. Nathe and R. Jalali (2007). "National smokefree law in New Zealand improves air quality inside bars, pubs and restaurants." Bmc Public Health **7**.

Woodward, A. and W. Al-Delaimy (1999). Measures of exposure to environmental tobacco smoke - Validity, precision, and relevance, New York Acad Sciences.

Xiao, L., Y. Yang, Q. A. Li, C. X. Wang and G. H. Yang (2010). "Population-Based Survey of Secondhand Smoke Exposure in China." Biomedical and Environmental Sciences **23**(6): 430-436.

Xinhua. (2012, March 1st). "PM2.5 in China's air quality standards." Retrieved March 12, 2012, from http://www.china.org.cn/environment/2012-03/01/content_24767087.htm.

Yang, G. and A. Hu, Eds. (2010). Tobacco Control and the Future in China. Beijing, Economic Daily Press.

Yang, G. H., L. X. Fan, J. Tan, G. M. Qi, Y. F. Zhang, J. M. Samet, C. E. Taylor, K. Becker and J. Xu (1999). "Smoking in China - Findings of the 1996 National Prevalence Survey." Jama-Journal of the American Medical Association **282**(13): 1247-1253.

Yang GH., Ma JM., Liu N. and Zhou L. (2005). "Smoking and Passive Smoking in China, 2002." Chinese Journal of Epidemilology **2**(26): 77-83.

Yang, Y., Y. Jiang, X. Wu and G. Feng (2008). "Analysis of Policies on Banning Smoking in Public Places and Their Implementation in China." Chinese Journal of Health Education **24**(9): 657: 660.

Zaidi, S. M. A., O. Moin and J. A. Khan (2011). "Second-hand smoke in indoor hospitality venues in Pakistan." International Journal of Tuberculosis and Lung Disease **15**(7): 972-977.

Zheng, P. P., H. Fu and G. Y. Li (2009). "Smoke-free restaurants in Shanghai: Should it be mandatory and is it acceptable?" Health Policy **89**(2): 216-224.

Appendices

Table A 1 100% smoke-free laws in workplaces and hospitality venues around the world, January, 2012

country	non-hospitality workplaces	restaurants	bars	gambling	notes
			North America		
United States	Yes in 29 of the 51 states, Puerto Rico, U.S.Virgin Islands and another 422 cities and counties	Yes in 33 states, American Samoa, Puerto Rico, u.s. Virgin Island and another 336 cities and counties	yes, in 29 of the, Puerto Rico, U.S. Virgin Island and another 245 cities or counties	Yes in 19 states, American Samoa, Puerto Rico and the U.S. Virgin Islands	
Canada	Yes in12 of the 13 provinces	Yes in 11 provinces	Yes in 11 provinces	Yes in 6 states	
			Latin America and Caribbean		
Argentina	No national law; Yes in 7 of the 23 provinces	Yes	Yes	No national law, in 5 provinces	
Barbados	No	Yes	Yes		
Bermuda	Yes	Yes	Yes		
Bolivia	Yes	No	No	No	
Brazil	No national law, yes in 8 of the 26 states and another 8 cities	No national law, yes in 8 states and another 7 cities	No national law, yes in 8 states and another 7 cities		Weak national law with exemptions
Bolivia	Yes	No	No	No	
British Virgin Islands	Yes	Yes	Yes		
Cayman Islands	No	Yes	Yes		
Chile*	No	No	No	No	larger restaurants must provide smoking sections, and smaller restaurants must decide to permit smoking throughout or not.
Columbia*	No	Yes	Yes	Yes	
Cuba	No	No	No		Restaurants and cafeterias may have designated smoking areas.
Ecuador*	Yes	Yes	Yes	No	
El Salvador	Yes	No	No	No	
Guatemala*	Yes	Yes	Yes	Yes	
Honduras*	Yes	Yes	Yes	Yes	
Mexico*	No national law, yes in Mexico City	No national law, yes in Mexico City	No national law, yes in Mexico City	No national law, yes in Mexico City	
Panama*	Yes	Yes	Yes	Yes	
Paraguay*	Yes	Yes	Yes	Yes	
Peru*	Yes	Yes	Yes	Yes	
Trinidad and Tobago*	No	Yes	Yes	Yes	

country	non-hospitality workplaces	restaurants	bars	gambling	notes
Uruguay*	Yes	Yes	Yes	Yes	
Venezuela*	Yes	Yes	Yes	Yes	
			Europe		
Austria*	No	No	No	No	
Alderney	Yes	Yes	Yes	No	
Bailiwick of Jersey	Yes	No	No	No	
Belgium*	Yes	Yes	Yes	Yes	
Bulgaria*	No	No	No	No	The owners of restaurants, clubs and coffee shops with an area less than 50 square meters can decide if smoking is allowed.
Czech Republic	No	No	No	No	Restaurants, cafes, and bars are 100% smoke-free or have completely enclosed smoking rooms. Smoking is not permitted in restaurants during meals. As of July 2010, Czech restaurant owners must decide whether they allow or ban smoking in their facilities. They also can have separate smoking and non-smoking rooms that are not connected.
Croatia*	No	No	No	No	Restaurants and bars that are up to 50 square meters may allow smoking if appropriate ventilation system is provided. Larger establishments must have designated and separately ventilated smoking areas not exceeding 20% of total area.
Cyprus*	Yes	Yes	Yes	No	Smoking is also prohibited in nightclubs.
Denmark*	Yes	No	No	No	Smoking is prohibited in restaurants and bars larger than 100 square meters, except in separate smoking areas. Bars smaller than 40 square meters which do not serve food are exempt.
England	Yes	Yes	Yes	Yes	
Finland*	No	No	No	No	Smoking is restricted to separately enclosed smoking rooms. No food or beverage may be brought into these areas. Large restaurants have until June 2009 to construct separately enclosed smoking rooms.
France*	Yes	Yes	Yes	Yes	
Germany*	No	No	No	No	Restaurants, bars, and pubs have smoking sections. Under German High Court ruling in 2008, German states must prohibit smoking in all pubs or restaurants or offer exceptions for single-room establishments.
Greece*	No	Yes	No	No	Nightclubs and casinos larger than 3230 square feet may purchase license to allow smoking in half of

country	non-hospitality workplaces	restaurants	bars	gambling	notes
					establishment.
Guernsey	Yes	Yes	Yes	Yes	
Hungary*	Yes	Yes	Yes	No	
Iceland*	Yes	Yes	Yes		
Italy*	No	No	No	No	Restaurants and bars are smoke-free or have separately ventilated smoking rooms.
Ireland*	Yes	Yes	Yes	Yes	
Lithuania*	Yes	Yes	Yes	No	
Macedonia	No	Yes	Yes	No	
Malta*	No	No	No	No	
Netherlands*	No	No	No	No	Smoking is prohibited in restaurants and bars other than family-run bars and cafes smaller than 70 m^2, except in closed designated smoking rooms in which no service is provided
Northern Ireland*	Yes	Yes	Yes	Yes	Smokers may pay ??1 to access a designated smoking area at the airport (coin-op opens doors).
Norway*	Yes	Yes	Yes	Yes	
Poland*	No	No	No	No	Workplaces, restaurants, and bars may have separately ventilated smoking rooms.
Portugal*	Yes	No	No	No	Restaurants, bars, and clubs smaller than 100 m^2 may permit smoking, provided that a ventilation system is installed and signs are posted at the entrance.
Romania*	No	No	No	No	Smoking permitted in cafes, bars and restaurants smaller than 100 m^2
Russia*	No	Yes	Yes	No	
Scotland*	Yes	Yes	Yes	Yes	
Serbia*	No	No	No	No	Restaurants and bars that are larger than 80 square meters must have nonsmoking area of more than half of establishment size. Smaller places must indicate if they allow smoking.
Spain*	Yes	Yes	Yes	No	
Sweden*	No	No	No	No	Restaurants, bars, and cafes are 100% smoke-free or have completely enclosed smoking rooms. Food and beverages may not be served in smoking rooms.
Switzerland	No	No	No	No	Smoking is prohibited in public places, including restaurants and bars, but individual cantons may allow smoking in restaurants and bars under specified circumstances.
Wales*	Yes	Yes	Yes	Yes	

country	non-hospitality workplaces	restaurants	bars	gambling	notes
			Africa		
Algeria*	No	No	No		
Eritrea	Yes	No	No		Restaurants without liquor licenses are smoke-free.
Gambia*	Yes	No	No	No	
Kenya*	Yes	Yes	No	No	Bars may have designated smoking areas.
Liberia*	Yes	Yes	Yes	Yes	
Mauritius*	No	Yes	Yes		
Niger*	No	Yes	Yes		
Nigeria*	No	Yes	Yes	Yes	
South Africa*	No	No	No	No	Smoking is prohibited in all indoor public places and workplaces, but separately ventilated designated smoking rooms are allowed, provided they take up no more than 25% of floor area.
Uganda*	Yes	No	No	No	Restaurants, bars, and discos are allowed to have ventilation smoking rooms or must be smoke-free.
			Middle East		
Bahrain	No	No	No	No	Restaurants are required to create separate smoking areas.
Egypt*	Yes	No	No	No	
Iran*	Yes	Yes			Any roofed area is 100% smoke-free
Israel*	No	No	No	No	Smoking is permitted in areas of restaurants (15 m^2 limit) and bars.
Jordan*	No	Yes		No	
Lebanon*	Yes	Yes	Yes	No	
Libya*	Yes	No	No		
Qatar*	No	Yes	No	No	Smoking is prohibited in restaurants, public places and educational institutions.
Syria*	No	Yes	Yes		Employees may not smoke during meetings.
Turkey*	Yes	Yes	Yes		
Central Asia					
Kazakhstan*	No	Yes	Yes		
Kyrgyzstan*	No	Yes	Yes		
Turkmenistan	No	Yes	Yes		
			South Asia, East Asia & the Western Pacific		
Bhutan*	Yes	Yes	Yes		
Brunei*	No	Yes			Smoking is prohibited in certain public places, including shopping and eating areas, bus stops and stations and government buildings.
China* #	No	yes	yes	No	Smoking is prohibited in all indoor public places since May, 2011

country	non-hospitality workplaces	restaurants	bars	gambling	notes
Fiji*	No	Yes	No	No	Smoking is prohibited in some public places such as restaurants, theatres, hospitals, and public transport.
Hong Kong	Yes	Yes	Yes	Yes	
India*	Yes	No	No	No	The law allows restaurants and bars with 30 seats or more, to build separate smoking rooms, with no food or drink allowed to be served in these rooms.
Laos*	No	Yes	No		
Macau	Yes	Yes	Yes	No	Smoking is permitted on up to half the floor area of casinos. Bars have until 2014 to comply.
Malaysia*	No	No	No	No	Smoking is prohibited in 21 areas, including air-conditioned restaurants
Maldives*	Yes	Yes	Yes		
Nepal*	Yes	Yes	Yes	Yes	
New Zealand*	Yes	Yes	Yes	Yes	Smoking also prohibited in prisons.
Pakistan*	No	Yes			
Philippines*	No	No	No	No	Smoking is prohibited in public buildings and enclosed public places, except in private places of work and duly designated smoking areas. Smoking is completely prohibited in specified public places, such as schools, health facilities, and public transport.
Singapore*	Yes	Yes	Yes	Yes	
South Korea	No	Yes	Yes	No	Smoking is prohibited in public places, both indoor and outdoor, as of January 1, 2011.
Taiwan	No	No	No		All workplaces and indoor public places with three or more employees must be 100% smoke-free.
Thailand*	No	Yes	Yes		
Vietnam*	Yes	No	No	No	Smoking is prohibited in offices and factories and in some public places. In other public places, including restaurants and bars, designated smoking areas are permitted.
			Australia		
Australia	no national law, yes in 7 of the 8 states	no national law, yes in 6 states	no national law, yes in 6 states	no national law, yes in 2	

Data from American Nonsmokers' Right Foundation website http://www.no-smoke.org/
* Countries that have ratified the World Health Organization Frame Work Convention on Tobacco Control
# different from the information listed on the American Nonsmokers' Right Foundation website

Table A 2 Secondhand smoke concentrations as indicated by particulate matters in restaurants and bars

Region/Countries	References	N	mean	SD	GM	median	min	max	25%	75%	notes
Restaurants: summary results reported in references											
Asia: China	Liu, 2011	404			176						
Asia: Japan	Bohanan, et al. 2003	16	242	175	172	194	0	611			
Asia: Korea	Bohanan, et al. 2003	50	109	30	105	107	54	172			
Asia: Pakistan	Zaidi, 2011	39	846	1109	374	342	38	4491	124	1113	13 nonsmoking restaurants and cafes, 13 venues with cigarette smoking, 13 venues with Shisha smoking
Asian: 7 countries	Lee, 2010	55	92		65		17	565			
Asian: Lebanese	Saade, 2010	25	315	192	245	304	39	723	181	477	14 venues mostly with water pipe smoking
Australia	Dingle, et al. 2002	4	36	28							
Europe: Czech	Branis, et al. 2002	2	186				169	203			
Europe: France	Bohanan, et al. 2003	15	188	76	170	194	56	312			restaurants allowing smoking or restricting smoking; results from smoking and nonsmoking sections combined
Europe: Germany	Schneider, 2008	38	223	185		173	22	831			
Europe: Germany	Bolte, 2008	11	206		172	178	69	437			including cafes; 3 venue had nonsmoking sections; monitoring in smoking sections;
Europe: Switzerland	Bohanan, et al. 2003	31	92	68	68	75	0	277			
Europe: Switzerland	Daly 2010	dnk	61	63		38	0.4	364	24	79	
Europe: UK	Bohanan, et al. 2003	15	195	84	177	201	62	391			
Europe: Italy	Valente, 2007	12	111	30	78						
Europe: Norway	Ellingsen, 2006	14	115				52	218			14 samples from 3 restaurants
Centeral America	Alfaro 1997	14	203	151	147	163	34	421	71	369	13 smoking venues, 1 nonsmoking venue
Canada	Brauer and Mannetje 1998	20	79	77			7	253			
U.S	Siegel 1993	211	117				27	690			summary of 211 venues from 12 studies
U.S.	Maskarinec, Jenkins et al. 2000	32	73	67		66	0	233			

Region/Countries	References	N	mean	SD	GM	median	min	max	25%	75%	notes
U.S.	Lee 2009	62	161								seven communities, included the two published by Lee in 2007 and in 2008
U.S.	Lee 2009	10	304								
Restaurants with smoking permitted everywhere (smoking restaurants)											
Africa: Ghana	Agbenyikey, 2010	75				553	3	2103	259	1038	venues with smoking observed during sampling
Asia: China	Liu, 2011	372			187						
Asia: HongKong	Lai, 2011	36				212					
Asia: Pakistan	Zaidi, 2-11	26	1218	1199	763	663	153	4491	345	1929	13 venues with cigarette smoking, 13 venues with Shisha smoking
Europe: Czech	Branis, et al. 2002	2	186				169	203			
Europe: Switzerland	Huss 2010	45	185	26	110						
Europe: UK	Carrington, 2003	93				95	15	356	60	310	n=samplers
Europe: Germany	Gleich, 2011	29	198	164		161	20	688			all allowed smoking
Centeral America	Alfaro 1997	13	216	149	165	203	54	421	72	401	
Canada	Brauer and Mannetje 1998	4	190	95			47	253			
U.S.	Travers, 2008	67	97	85	63	68	1	400			
U.S.	Proescholdbell, 2009	40	253								
32 countries	Hyland, 2008	607			157						smoking observed during sampling
Designated smoking sections of restaurants											
Europe: Greece	Vardavas, 2007	12	298	142	259	310	64	541	175	412	
Europe: Switzerland	Huss 2010	25	151	25	110						
Europe: UK	Carrington, 2003	40				90	8	320	35	120	n=samplers
U.S	Lambert, et al. 1993	7				53	22	131			
U.S.	Proescholdbell, 2009	67	67								PM concentration in the whole venue with smoking and nonsmoking sections
U.S.	Akbar-Khanzadeh 2003	8	58	56		50	4	226			FPM, RSP not reported
Designated nonsmoking sections of restaurants											
Asia: China	Liu, 2011	9			89						

Region/Countries	References	N	mean	SD	GM	median	min	max	25%	75%	notes
Europe: Switzerland	Huss 2010	18	96	18	72						
Europe: UK	Carrington, 2003	21				70	75	160	55	110	n=number of samples
Canada	Brauer and Mannetje 1998	11	57	45			11	163			
U.S	Lambert, et al. 1993	7				28	21	69			
U.S.	Akbar-Khanzadeh 2003	8	28	35		14	2	111			FPM, RSP not reported
					Restaurants with smoking banned everywhere						
Africa: Ghana	Agbenyikey, 2010	13				16	12	30	14	17	smoking not observed during sampling
Africa: Mauritius	Lopez, 2011	12				18			11	36	
Asia: China	Liu, 2011	23			85						
Asia: HongKong	Lai, 2011	63			60						
Asia: Pakistan	Zaidi, 2-11	13	103	57	90	92	38	217	57	123	
Europe: Switzerland	Huss 2010	19	25	4	20						
New Zealand	Wilson, 2007	8	14	7	12	13	5	26	11	18	
Centeral America	Alfaro 1997	1	34								
Canada	Brauer and Mannetje 1998	5	38	21			7	65			
U.S.	Travers, 2008	40	29	49	15	12	3	278			smoking not observed during sampling
U.S.	Proescholdbell, 2009	45	15								
32 countries	Hyland, 2008	290			26						smoking not observed during sampling
					Bars						
Africa: Mauritius	Lopez, 2011	12				16			7	26	nonsmoking bars
Asia: 7 countries	Lee, 2010	34	169		106		4	881			
Australia	Brennan, 2010	19	103	99	61		6.4	338			
Europe: England	Gee, 2005	81	109	10		83					
Europe: England	Semple, 2010	24				184	16	872	78	327	
Europe: German	Schneider, 2008	11	539	510		378	144	2022			
Europe: German	Gleich, 2011	5	406	198		377	146	604			all allowed smoking

Region/Countries	References	N	mean	SD	GM	median	min	max	25%	75%	notes
Europe: Germany	Bolte, 2008	7	383		251	192	105	1380			including pubs; 2 venues with designated smoking sections
Europe: Greece	Vardavas, 2007	31	271	149	226	265	49	612	150	376	Designated smoking section of bars
Europe: Irish	Goodman, 2007	42	35.5	18							
Europe: Israel	Rosen, 2011	15	436	267		465	66	862			Bars and pubs; used the same data with Rosen 2008
Europe: Italy	Valente, 2007	14	47	8	40						
Europe: Norway	Ellingsen, 2006	10	298				89	662			57 samples from 10 pubs, discos, bars
Europe: Stotland	Semple, 2010	42				197	8	902	87	350	
Europe: Switzerland	Daly 2010	dnk	81	88		51	3	452	24	118	
Europe: Wales	Semple, 2010	52				92	5	1005	37	183	
New Zealand	Wilson, 2007	18	17	10	14	16	4	38	8	23	only nonsmoking venues
U.S.	Siegel 1993	16	348				75	1320			summary of 16 venues from 10 studies
U.S.	Maskarinec, Jenkins et al. 2000	53	135	146		82	0	768			
U.S.	Waring, 2007	16	151	67	137	155	63	311	102	188	
U.S.	Repace, 2006	6	179	129							
U.S.	Lee, 2008	3	495			347	29	1110			
U.S.	Lee, 2008	3	293			313	144	422			
U.S.	Travers, 2008	33	29	45	15	13	1	240			smoking not observed
U.S.	Travers, 2008	137	413	380	290	336	18	2335			smoking observed
32 countries	Hyland, 2008	116			20						smoking not observed
32 countries	Hyland, 2008	429			303						smoking observed

Table A 3 Secondhand smoke concentrations indicated by airborne nicotine in restaurants and bars

region/country	reference	n	mean	SD	GM	median	min	max	25%	75%	notes
					Restaurants: Summary results reported in references						
Asia: China	Stillman, 2007	54				2.17	1.02	4.63			n= number of samples
Asia: Japan	Bohanan, 2003	16	5.40	3.40	10.50	11.10	3.40	22.40			n= number of samples
Asia: Korea	Bohanan, 2003	47	5.70	4.10	4.60	4.00	1.60	18.80			n= number of samples
Australia	Dingle, 2002	4	1.90	2.80							
Europe: eight cities	Lopez, 2008	82				2.09	0.49	6.73			248 samples
Europe: Finland	Hyvarinen, 2000	3	7.00	2.30							28 samples from 3 venues
Europe: Finland	Johnsson,2003	16	3.90	4.70		5.10	0.03	39.00			25 volunteers from 16 venues
Europe: Finland	Johnsson, 2006	4			0.70				0.20	2.80	measurement in 1999
Europe: Finland	Kuusimaki, 2007	23	16.00	11.00			0.11	81.00			including pubs, bars and nightclubs
Europe: France	Bohanan, 2003	15	30.30	21.10	19.70	24.10	0.00	71.60			n= number of samples
Europe: Norway	Ellingsen, 2006	14	7.70								14 samples from 3 restaurants
Europe: Spain	Jane, 2002	2	12.40								
Europe: Spain	Nebot, 2009	79				2.71			1.39	3.77	
Europe: Switzerland	Bohanan, 2003	32	7.80	10.70	3.80	4.00	0.10	39.60			n= number of samples
Europe: UK	Bohanan, 2003	20	9.78	6.92	6.90	10.10	0.80	27.60			n= number of samples
Europe, Italy	Gorini, 2008	10				2.03			0.93	4.17	
Latin l America: 6 countries	Alfaro 1997	14	1.64	3.21	0.10	0.57	0.00	12.00	0.00	0.95	
Latin America: Argentina	Navas-Acien, 2004	7				2.04			0.90	2.60	
Latin America: Brazil	Navas-Acien, 2004	19				2.52			1.25	3.95	
Latin America: Chile	Navas-Acien, 2004	13				2.08			1.08	3.56	
Latin America: Costa Rica	Navas-Acien, 2004	15				0.73			0.46	1.80	
Latin America: Paraguay	Navas-Acien, 2004	14				0.24			0.06	0.36	
Latin America: Peru	Navas-Acien, 2004	15				0.80			0.15	2.42	
Latin America: Uruguay	Navas-Acien, 2004	14				1.41			0.41	2.48	

region/country	reference	n	mean	SD	GM	median	min	max	25%	75%	notes
U.S.	Siegel 1993	402	6.50				3.40	34.00			Summary of 402 venues from 17 studies
U.S.	Maskarinec, 2000	32	6.00	11.90		0.80	0.00	49.30			
U.S.	Bohanan, 2003	18	3.00	3.40	1.30	1.50	0.04	9.40			n= number of samples
			Restaurants with smoking permitted everywhere								
Africa: Ghana	Agbenyikey, 2010	8				1.83	0.33	6.01	0.91	4.25	smoking policy reported by owners
Asia: Kyrgyzstan	Vinnikov, 2010	10	7.11			6.82	0.34	23.19	2.89	8.86	including 1 karaoke bar, 2 pizza place, 2 clubs, 2 restaurants and 3 cafes
Europe: Austria	Gorini, 2008	9				2.57			0.37	8.21	
Europe: Austria	Nebot, 2005	11				17.00					including both smoking venues and smoking sections; n= n of samples
Europe: Austria	Moshammer, 2004	??	38.00	60.60							
Europe: Finland	Hyvarinen, 2000	7	2.30								28 samples from 3 venues
Europe: France	Nebot, 2005	14				9.30					including both smoking venues and smoking sections; n= n of samples
Europe: Germany	Bolte, 2008	11	21.30		9.10	15.00	0.70	83.30			including cafes; 3 venue had nonsmoking sections; monitoring in smoking sections;
Europe: Greece	Nebot, 2005	7				4.70					including both smoking venues and smoking sections; n= n of samples
Europe: Italy	Nebot, 2005	17				1.60					including both smoking venues and smoking sections; n= n of samples, n of venues not specified
Europe: Portugal	Nebot, 2005	6				0.01					including both smoking venues and smoking sections; n= n of samples,
Europe: Spain	Nebot, 2005	8				7.80					including both smoking venues and smoking sections; n= n of samples,
Europe: Spain	Jane, 2002	1	10.60								

region/country	reference	n	mean	SD	GM	median	min	max	25%	75%	notes
Europe: Sweden	Nebot, 2005	14				7.10					including both smoking venues and smoking sections; n= n of samples
Europe: UK	Carrington, 2003	93				60.00	0.50	516.70	20.00	135.00	n=number of samplers
Latin America: Guatemala	Barnoya, 2011	5			0.56	0.58			0.44	0.71	Used the same data with Barnoya, 2007
Designated smoking sections of restaurants											
Europe: Austria	Moshammer, 2004	??	21.30	6.10							
Europe: Finland	Kuusimaki, 2007	15	20.00	16.00			0.19	81.00			
Europe: German	Schneider, 2008	10	38.30	34.00	18.10	37.00	0.70	103.00	11.20	52.30	
Europe: Spain	Jane, 2002	1	15.00								
Europe: UK	Carrington, 2003	40				60.00	0.50	380.00	30.00	120.00	n=number of samplers
Latin America: 6 countries	Alfaro 1997	13	1.77	3.30	0.14	0.60	0.00	12.00	0.00	1.00	4 venues with nicotine below the detection limit, they were assumed to be 0.001 $\mu g/m^3$
Latin America: 7 countries	Navas-Acien, 2004	dnk				1.24			0.34	2.45	
U.S.	Lambert, 1993	7				3.20	1.50	3.80			
U.S.	Akbar-Khanzadeh 2003	8	24.90	31.90		16.80	0.50	121.70			
Designated nonsmoking sections of restaurants											
Europe: Austria	Moshammer, 2004	??	23.30	15.90							
Europe: Austria	Nebot, 2005	6				18.00					included nonsmoking venues and sections; n=n of samples
Europe: Finland	Kuusimaki, 2007	9	4.10	1.20			0.11	18.00			
Europe: France	Nebot, 2005	6				1.60					included nonsmoking venues and sections; n of samples
Europe: German	Schneider, 2008	10	5.40	6.60	1.60	1.12	0.12	14.90	0.42	10.50	
Europe: Italy	Nebot, 2005	3				2.20					included nonsmoking venues and sections; n=n of samples
Europe: Spain	Jane, 2002	1	11.50								
Europe: Sweden	Nebot, 2005	8				0.10					included nonsmoking venues and sections; n=n of samples
Europe: UK	Carrington, 2003	21				30.00	0.50	80.00	10.00	50.00	n=number of samplers

region/country	reference	n	mean	SD	GM	median	min	max	25%	75%	notes
Latin America	Navas-Acien, 2004	dnk				0.60			0.11	0.95	
U.S.	Lambert, 1993	7				1.00	0.20	2.80			
U.S.	Akbar-Khanzadeh 2003	8	7.20	14.90		0.70	0.10	54.40			
Restaurants with smoking banned everywhere											
Africa: Ghana	Agbenyikey, 2010	2	0.03			0.03	0.02	0.04			
Africa: Mauritius	Lopez, 2011	6				0.03			<LD	0.05	LD: limit of detection
Latin l America	Alfaro 1997	1	<LD								LD= 0.05 μg/m^3
Latin America: Guatemala	Barnoya, 2011	11			0.03	0.04			0.01	0.11	Used the same data with Barnoya, 2007
Europe: Italy	Gorini, 2008	15				0.01			0.01	0.14	
Bars: summary results reported in references											
Africa	Jones, 2012	19				1.50			0.30	2.90	
Americas	Jones, 2012	88				1.50			0.30	3.90	
Asia	Jones, 2012	75				2.10			0.80	5.40	
Asia: Mongolia	Ochir, 2011	10				14.80					
Eastern Europe	Jones, 2012	56				7.10			2.90	12.90	
Europe: England	Gee, 2005	81	62.00	8.67		62.00					
Europe: Finland	Johnsson, 2006	20			6.10				1.40	34.00	1999 results; included bar counter only, not pubs or nightclubs
Europe: Ireland	Mulcahy, 2005	20	35.81	25.74		35.52					
Europe: Italy	Gorini, 2008	3				19.02			1.72	45.07	
Latin America: Argentina	Navas-Acien, 2004	12				3.65			3.58	3.65	
Latin America: Brazil	Navas-Acien, 2004										
Latin America: Chile	Navas-Acien, 2004	6				3.33			2.06	4.82	
Latin America: Costa Rica	Navas-Acien, 2004	6				1.32			0.75	7.43	
Latin America: Paraguay	Navas-Acien, 2004	6				1.59			0.78	6.68	
Latin America: Peru	Navas-Acien, 2004	8				6.21			4.00	9.12	

region/country	reference	n	mean	SD	GM	median	min	max	25%	75%	notes
Latin America: Uruguay	Navas-Acien, 2004	6				3.14			0.77	4.82	
Latin America：Guatemala	Barnoya, 2011	5			3.02	4.59			1.71	6.45	Used the same data with Bamoya, 2007
U.S.	Siegel 1993	25	19.70				7.40	65.50			summary of 25 venues from 10 studies
U.S.	Maskarinec, 2000	53	14.40	16.90		5.80	0.00	61.30			
Bars with smoking permitted everywhere											
Americas	Jones, 2012	61				3.00			1.20	5.70	
Asia: Kyrgyzstan	Vinnikov, 2010	10	7.11			6.82	0.34	23.19	2.89	8.86	including 1 karaoke bar, 2 pizza place, 2 clubs, 2 restaurants and 3 cafes
Asia	Jones, 2012	63				3.40			0.90	6.80	
Africa	Jones, 2012	17				1.60			1.00	2.90	
Eastern Europe	Jones, 2012	53				8.50			3.60	13.40	
Europe: Germany	Bolte, 2008	7	53.70		33.50	31.00	9.10	180.00			including pubs; 2 venues had smoking sections
Europe: Austria	Gorini, 2008	4				31.43			17.81	37.44	
Bars with smoking banned everywhere											
Americas	Jones, 2012	27				0.20			0.10	0.40	
Asia	Jones, 2012	12				0.90			0.40	1.10	
Africa	Jones, 2012	2				0.03			0.03	0.04	
Africa: Mauritius	Lopez, 2011	5				0.16			0.06	0.27	
Eastern Europe	Jones, 2012	3				0.10			0.03	0.20	

Table A 4 Summary of nine studies using airborne nicotine concentration to evaluate the efficacy of smoking restrictions in restaurants and bars

Reference/ location	**study time**	**restriction on smoking**	**study participant**	**sampling method**	**pre-ban SHS levels**	**post-ban SHS levels**	**comments**
Mulcahy, 2005 Ireland	2004.3, 2004.5	2004 March Ireland comprehensive smoking ban	20 bars	Area passive nicotine sampling for 7-10 hours	mean (sd): 5.81(25.74) median: 35.52	mean (sd): 10.23(9.66) median 5.95	
Johnsson, 2006 Finland	1999.9-1999.12, 2000.10-2001.3, 2001.10-2002.4, 2003.10-2004.3	Finland Tobacco Control Act: 2000 March, smoking area ≤ 70 % for venues ≥100 m^3; 2001 July, smoking area should ≤ 50% if a client area >50 m^2; 2003 July more intensive	20 venues with a serving area >100m^2 from three Finnish cities, with 16 the same through all 4 rounds	Area active nicotine sampling using Tenax tubes for 4 hours during peak time; ≥ 2 measurements at each venue and in both smoking and nonsmoking sections	Restaurants in 1999: GM (GSD): 0.7(7.7) IQR: 0.2-2.8 ; All types of venues: in 1999: GM (GSD): 7.1(7.9) IQR: 2.1-31.0	Restaurants: 2000: GM (GSD) 1.1(10.5) IQR 0.2-11.1 2002: GM (GSD) 0.7 (5.0) IQR 0.2-2.1 2004: GM (GSD) 0.6 (5.2) IQR 0.2-2.2; All types of venues: 2000: GM (GSD) 6.2(5.8) IQR 2.8-21.6 2002: GM (GSD) 7.1(7.9) IQR: 2.1-31.0 2004: GM (GSD) 7.3(5.8) IQR 2.6-26.1	none establishments completely banned smoking after the bans
Gorini, 2008 Florence and Belluno, Italy; Vienna, Austria	2002-2004, 2007	2005 Italy smoking ban: restaurants and bars are smoke-free or have separately ventilated smoking rooms	28 venues (10 restaurants 3 bars and 15 pubs and discos) in Italy and 19 in Austria	Area passive nicotine sampling for 7 days	median (IQR) 10 restaurants: 2.03 (0.93-4.17) 3 bars: 19.02 (1.72-45.07) All 28 venues: 8.86 (2.41-45.07)	median (IQR) 10 restaurants: 0.10 (0.01-0.18); 3 bars: 0.25 (0.01-0.41); all 28 venues: 0.01 (0.01-0.41)	compared to Austria (no smoking ban); no significant changes of SHS in Austria
Larsson, 2008 Sweden	2005. 4-5, 2006. 4-5	June 1st, 2005, Sweden smoke-free policy to include bars and restaurants	54 bars and restaurant employees	personal passive nicotine sampling for nonsmokers and area passive sampling for smokers	median 7.5	median 0.16	results from 37 volunteer gaming workers not included
Nebot, 2009 Spain	2005, 2006	2006.1 Spain partial smoking ban	79 restaurants and bars	Area passive nicotine sampling for 7 days	median (IQR) 2.71 (1.39–3.77)	median (IQR) 0.09 (0.01–0.26)	Results are for venues completely banned smoking after the ban
Blanco-Marquizo, 2010 Uruguay	2002.11, 2007.7	2006 Uruguay comprehensive smoking ban	10 restaurants with 8 matched pre and post the ban	Area passive nicotine sampling for 7 days	GM 1.06 median (IQR): 1.5 (0.54-2.71)	GM 0.32 median (IQR): 0.27 (0.19-0.67)	

Erazo, 2010 Santiago, Chile	2002.10, 2008.4	2007 Chilean smoking ban, venues could be smoke free, have segregated smoking and non-smoking areas, or allow smoking in all areas	6 restaurants and bars	Area passive nicotine sampling for 7 days	mean (sd): 4.08 (2.96) Median: 3.46	mean (sd): 3.43 (2.95) median: 3.85	In the two venues banned smoking, nicotine decreased 85% and 97%, respectively
Barnoya, 2011 Guatemala	2006, 2009.8	2009 February Guatemala comprehensive smoking ban	5 restaurants and 5 bars pre ban and 10 restaurants and 11 bars post ban	Area passive nicotine sampling for 7 days	Restaurants: GM 0.56 median (IQR) 0.58 (0.44-0.71); Bars: GM 3.02 median (IQR): 4.59 (1.71-6.45)	Restaurants: GM 0.03 median (IQR) 0.04 (0.01-0.11); Bars: GM 0.32 median (IQR) 0.28 (0.17-0.66)	
Ellingsen, 2006 Norway	2004.5, 2004.9-2005.2	2004.7, total ban in bars, night clubs and restaurants	3 restaurants and 10 bars	area air nicotine sampling with XAD-4 tubes	mean (range) nicotine 28.3 (0.4-88.0)	mean (range) nicotine 0.6 (nd-3.7);	

Note: all studies used repeated measurements, except Barnoya, 2011, which used two cross-sectional monitoring. Ellingsen, 2006 used both airborne nicotine and particulate matters for the evaluation;
IQR: inter-quartile range

Table A 5 Summary of 16 studies using concentration of particulate matters to evaluate the efficacy of smoking restrictions in restaurants and bars

reference/ location	study time	restriction on smoking	study participant	sampling method/ sampling time	pre-ban SHS levels	post-ban SHS levels	comments
Repace, 2004 Delaware	2002, 2003	2002 Delaware smoking ban including bars	8 venues, including 1 casino, 1 taproom, 1 pool hall and 5 bar/restaurants	MIE PDR; 6 hours	mean (sd) 141 (113) median (IQR) 103 (44-337)	mean (sd) 9.5 (8.5) median (IQR) 7.4 (2.5-24)	only results from 5 bars included; results calculated from data presented
Travers, 2004 Western New York	2003. 7, 2003.9-11	2003July 24 New York comprehensive state law: all indoor workplaces and public places to be smoke free	seven bars, six bar/restaurants, five restaurants, two bowling alleys, a pool hall, and a bingo hall.	$PM_{2.5}$, SidePak510 22-140 minutes, median 38 minutes	mean 324	mean 25	
Repace, 2006 Boston, Massachusetts	2003.4.17, 2003.10.17	2003 May Boston smoking ban including restaurants and bars	the sample included 7 pubs with restaurant and bar sections	$PM_{3.5}$, ThermoMIE; mean sampling time: about 40 minutes	mean (sd) 179 (129)	mean (sd) 7.7 (6.1)	result from one pub was excluded because the authors decided that there was other indoor sources of RSP
Ellingsen, 2006 Norway	2004.5, 2004.9-2005.2	2004.7, total ban in bars, night clubs and restaurants	3 restaurants and 10 bars	total dust by gravimetric sampling	mean (range) total dust: 262 (52-662)	mean (range) total dust 77 (nd-261)	
Valente, 2007 Rome, Italy	2004.11, 2005.3, 2005.11	January 10th 2005 smoking ban in all indoor public places	14 bars, six fast food restaurants, eight restaurants	DustTrak; >8 hours	bars: mean (95%CI) 46.8 (30.2 - 63.5), GM 39.6 fast food restaurants: mean (95%CI) 29.8 (21.2-38.3) GM 28.5 restaurants: mean (95%CI) 111.0 (52.4- 169.6), GM 78.0	3 months post ban: bars: mean (95%CI) 25.6 (21.7 - 29.5), GM 24.7 fast food restaurants: mean (95%CI) 31.7 (21.5-42.0) GM 30.6 restaurants: mean (95%CI) 60.9 (8.8- 112.9), GM 46.5 12 months post ban: bars: mean (95%CI) 33.7 (23.9 - 43.5), GM 29.9 fast food restaurants: mean (95%CI) 25.1 (9.8-40.4)	To increase the statistical efficiency and avoid a ‘‘learning effect,’’ the number of locations studied was constant (40), but 50% of them were rotated out of the study for each successive measurement, and replaced with other establishments.

reference/ location	study time	restriction on smoking	study participant	sampling method/ sampling time	pre-ban SHS levels	post-ban SHS levels	comments
						GM 23.2 restaurants: mean (95%CI) 36.5 (13.6- 59.4), GM 29.7	
Alpert,2007 Massachusetts	2004	2004 Massachusetts Smoke-Free Workplace Law including bars and restaurants	10 free standing bars and 17 restaurants with bars	$PM_{2.5}$, SidePak510 35 minutes	mean 206	mean 14	
Goodman, 2007 Dublin, Irish	2003.10, 2004.10	March 2004 Irish comprehensive smoking ban	42 pubs	Aerocet Met One 531; ≥3 hours	mean (sd) 35.5 (17.8)	mean (sd) 5.8 (2.2)	
Waring, 2007 Austin, TX, U.S.	2005.8, 2005.9	2005.9 Austin comprehensive smoking ban	17 bars	DusTrak in 8 venues, SidePak510 in the rest venues; 30-90 minutes	mean (sd) 151 (67) median (IQR) 155 (102-188)	mean (sd) 11 (13) median (IQR) 8 (2-13)	one bar not adopt smoking ban was excluded
Gotz, 2008 England	2007.6, 2007.8	July 2007 England comprehensive smoking ban	41 hospitality venues in baseline 43 in follow up, with 35 matched venues	$PM_{2.5}$, SidePak510 ≥30 mins	mean 217, GM (GSD) 127 (2.9)	mean 11.3, GM (GSD) 7.9 (2.4)	Hospitality venues as identified by the authors, including bar, pub
Lee 2009 Kentucky	dnk	comprehensive smoking ban in seven communities	62 hospitality venues	$PM_{2.5}$, SidePak510 40 minutes	mean 161	mean 20	
Kentucky	dnk	a partial ban in a community	10 hospitality venues	$PM_{2.5}$, SidePak510 40 minutes	mean 304	mean 338	
Bohac, 2010 Minnesota	2007.2-10, 2007 10	2007.10 Minnesota comprehensive smoking ban	19 bars and 43 restaurants	$PM_{2.5}$, SidePak510 10 minutes, 8% with 2 hours	mean 77 median 52	mean 3 median 2	
Brennan, 2010 Victoria, Australia	2007.4, 2007. 12	July 2007 Victoria smoking ban including pubs and bars	19 bars and pubs	$PM_{2.5}$, SidePak510; 30 minutes	mean (sd) 103 (99) GM (GSD) 61 (3.1) range 6.4-338	mean (sd) 26 (31) GM (GSD) 17 (2.4) range 3-136	

reference/ location	study time	restriction on smoking	study participant	sampling method/ sampling time	pre-ban SHS levels	post-ban SHS levels	comments
Schoj, 2010 3 cities in Argentina	2007-2009	local city smoking bans including hospitality venues	hospitality venues, including bars, restaurants, discos and gambling establishments	$PM_{2.5}$, SidePak510 ≥30 minutes	mean 76	mean 7	results derived from table 1; mean PM2.5 levels in each community weighted by number of samples
Semple, 2010 Scotland UK	2005, 2006	March 2006 Scotland comprehensive smoking ban	42 bars	$PM_{2.5}$, SidePak510 ≥30 minutes	four months pre-ban: median (IQR) 197 (87–350) range 8–902	two months postban: median (IQR) 15 (8–23) range 6–104	
Wales, UK	2007, 2008	April 2007 Wales comprehensive smoking ban	52 bars	$PM_{2.5}$, SidePak510 ≥30 minutes	four months pre-ban median (IQR) 92 (37–183) range 5–1005	two months postban: median (IQR) 11 (5–11) range1–154; 12 months postban: median (IQR) 18 (12–20) range 4–90	
England, UK	2007, 2008	July 2007 England comprehensive smoking band	12 bars	$PM_{2.5}$, SidePak510 ≥30 minutes	four months pre-ban: median (IQR) 184 (78–327) range 16–872	12 months postban: median (IQR) 24 (15–47) range 5–68	
Zhang, 2010 Ontario, Canada	2006.5, 2006.7-8	May 31 2006 smoke-free Ontario Act, comprehensive	15 coffee shops and 17 bars in Toronto; 10 coffee shops and 10 bars in Windsor	EcoChem DC 2000CE and PAS 2000CE; ≥15 minutes	mean (range) 492 (0-3140)	mean (range) 72 (2-517)	
Gleich, 2011 German	2005, 2009	2009 German partial smoking ban	29 restaurants and 5 bars	$PM_{2.5}$, SidePak510 median 61 min	restaurants: mean (sd) 198 (164) median (range) 161 (20-688); bar: mean (sd) 406 (198) median (range) 377 (146-604)	restaurants: mean (sd) 37 (53) median (range) 20 (4-259); bar: mean (sd) 91 (94) median (range) 49 (5-241)	

reference/ location	study time	restriction on smoking	study participant	sampling method/ sampling time	pre-ban SHS levels	post-ban SHS levels	comments
Rosen, 2011 Jerusalem and Tel Aviv Israeli	2007.1-7, 2008. 5-9	2007.11 Israel smoking ban, including restaurants and pubs	33 randomly selected venues, including bars, pubs and cafes	$PM_{2.5}$, SidePak510	mean (sd) 245 (266) median (range) 85 (18-862)	mean (sd) 161 (210) median (range) 70 (11-1052)	

Note: all studies used repeated measurements.

IQR: inter-quartile range; RSP: respirable suspended particles