Chicago Air Monitoring Study

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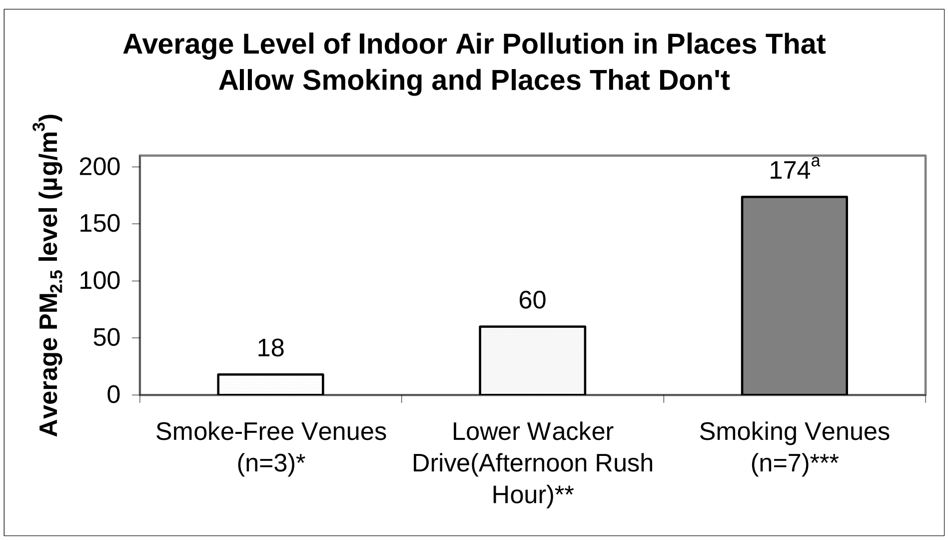
Executive Summary

Indoor air quality was assessed in 10 Chicago bars and restaurants between August 27th and October 10th, 2005 using the TSI SidePak AM510 Personal Aerosol Monitor. $PM_{2.5}$ levels were compared in the 7 locations allowing smoking to the 3 smoke-free locations. Key findings of the study include:

- The level of indoor air pollution as measured by average $PM_{2.5}$ level was 90% lower in the locations that were smoke-free compared to those where indoor smoking was permitted. $PM_{2.5}$ is the concentration of particulate matter in the air smaller than 2.5 microns in diameter. Particles of this size are released in significant amounts from burning cigarettes and are easily inhaled deep into the lungs.
- Employees in the locations allowing indoor smoking are exposed to levels of particulate matter in excess of levels recommended by the Environmental Protection Agency (EPA) to protect public health. Based on the average $PM_{2.5}$ level observed in venues where smoking was allowed in this study (174 $\mu g/m^3$), full-time bar and restaurant employees are exposed on the job to almost three times the annual EPA exposure limit of fine particulate air pollution, solely from occupational exposure.

Figure 1. $PM_{2.5}$ Levels in Chicago Bars and Restaurants, August to October 2005



a) p-value = 0.017 (Mann Whitney U-test) for difference between smoking and smoke-free venues

* These 3 venues had smoke-free policies and no smoking was observed in any of them during air monitoring

** Average $PM_{2.5}$ level on Lower Wacker Drive, Sept. 7th, 4:45PM to 5:30PM

*** These 7 venues had no smoking restrictions in place

Introduction

Secondhand smoke (SHS) contains at least 250 chemicals that are known to be toxic or carcinogenic, and is itself a known human carcinogen[i], responsible for an estimated 3,000 lung cancer deaths annually in *never smokers* in the U.S. as well as over 35,000 deaths annually from coronary heart disease in *never smokers* and respiratory infections, asthma, Sudden Infant Death Syndrome, and other illnesses in children[ii]. Although population-based data show declining SHS exposure in the U.S. overall, SHS exposure remains a major public health concern that is entirely preventable[iii,iv]. Because policies requiring smoke-free environments are the most effective method for reducing SHS exposure in public places[v], Healthy People 2010 Objective 27-13[vi] encourages all states and the District of Columbia to establish laws on smoke-free indoor air that prohibit smoking or limit it to separately ventilated areas in public places and worksites. Currently, 9 states (California, Delaware, New York, Connecticut, Maine, Massachusetts, Rhode Island, Montana and Vermont), which represent approximately 24% of the US population, have comprehensive clean indoor air regulations in force that cover virtually all indoor worksites including bars and restaurants.

The purpose of the Chicago Air Monitoring Study was to examine indoor air quality in a sample of smokefree and smoking-permitted Chicago bars and restaurants. The relation between indoor air pollution and the presence of on-premises smoking was assessed. It was hypothesized that indoor air would be less polluted in those venues where smoking is prohibited and where smoking does not occur, than in those places where smoking is present.

Methods

Overview

Between August 27th and October 10th, 2005, indoor air quality was assessed in 10 bars and restaurants in Chicago. The sites were selected to provide broad variation in type of venue (bars, restaurants, restaurants with bars), size of venue, and location. Seven of the establishments allowed smoking indoors while 3 of the places had smoke-free policies. There are currently no restrictions on smoking in indoor public places in Chicago.

Measurement Protocol

A minimum of 30 minutes was spent in each venue. The number of people inside the venue and the number of burning cigarettes were recorded every 15 minutes during sampling. These observations were averaged over the time inside the venue to determine the average number of people on the premises and the average number of burning cigarettes. The Zircon DM S50 Sonic Measure (Zircon Corporation, Campbell, CA) was used to measure room dimensions and hence the volume of each of the venues. The active smoker density was calculated by dividing the average number of burning cigarettes by the volume of the room in meters.

A TSI SidePak AM510 Personal Aerosol Monitor (TSI, Inc., St. Paul, MN) was used to sample and record the levels of RSP (respirable suspended particles) in the air (see Figure 2). The SidePak uses a built-in sampling pump to draw air through the device where the particulate matter in the air scatter the light from a laser to assess the real-time concentration of particles smaller than 2.5μm in micrograms per cubic meter, or $PM_{2.5}$. The SidePak was calibrated against a laser photometer, which had been previously calibrated and used in similar studies. In addition, the SidePak was zero-calibrated prior to each use by attaching a HEPA filter according to the manufacturer's specifications.

Figure 2. TSI SidePak AM510 Personal Aerosol Monitor

$PM_{2.5}$ is the concentration of particulate matter in the air smaller than 2.5 microns in diameter. Particles of this size are released in significant amounts from burning cigarettes, are easily inhaled deep into the lungs, and are associated with pulmonary and cardiovascular disease and mortality.

Secondhand smoke is not the only source of indoor particulate matter, but $PM_{2.5}$ monitoring is highly sensitive to it. While ambient particle concentrations and cooking are additional sources of indoor particle levels, smoking is by far the largest contributor to indoor air pollution. Furthermore, there is a direct link between levels of RSP and polycyclic aromatic hydrocarbons (PAH), known carcinogens in cigarette smoke, with RSP levels being approximately 3 orders of magnitude greater than PAH's.

The equipment was set to a one-minute log interval, which averages the previous 60 one-second measurements. Sampling was discreet in order not to disturb the occupants' normal behavior. The monitor was generally located in a central location on a table or bar and not on the floor so the air being sampled was within the occupants' normal breathing zone. For each venue, the first and last minute of logged data were removed because they are averaged with outdoors and entryway air. The remaining data points were averaged to provide an average $PM_{2.5}$ concentration within the venue.

Statistical Analyses

The primary goal was to assess the difference in the average levels of RSP in a cross-sectional sample of places that were smoke-free and places that were not, which is assessed with the Mann Whitney U-test. In addition, descriptive statistics including the venue volume, number of patrons, and average smoker density (i.e., number of burning cigarettes per 100 m^3) are also reported for each venue and averaged for all venues.

Results

The locations were visited on various days of the week (Monday, Tuesday, Thursday, Friday and Saturday) during lunchtime (between 11:45AM and 1:23PM) and in the evenings (between 5:29PM to 11:28PM). The average time spent in each location was 53 minutes (median=40 minutes). Seven places were sampled that allowed smoking in the establishment, and the average RSP level in these venues was 174 μg/m^3 (Figure 1). The level of indoor air pollution was 90% lower in the venues that were smoke-free compared to those where smoking was permitted. Additional details about each venue sampled are included in Table 1. The average volume of venues sampled was 557 m^3 and was comparable between places where smoking was allowed and where it was not (565 m^3 vs. 539 m^3, respectively); however, the average smoker density was much greater in venues where smoking was allowed (0.00 burning cigarettes per 100 m^3 vs. 1.14 burning cigarettes per 100 m^3).

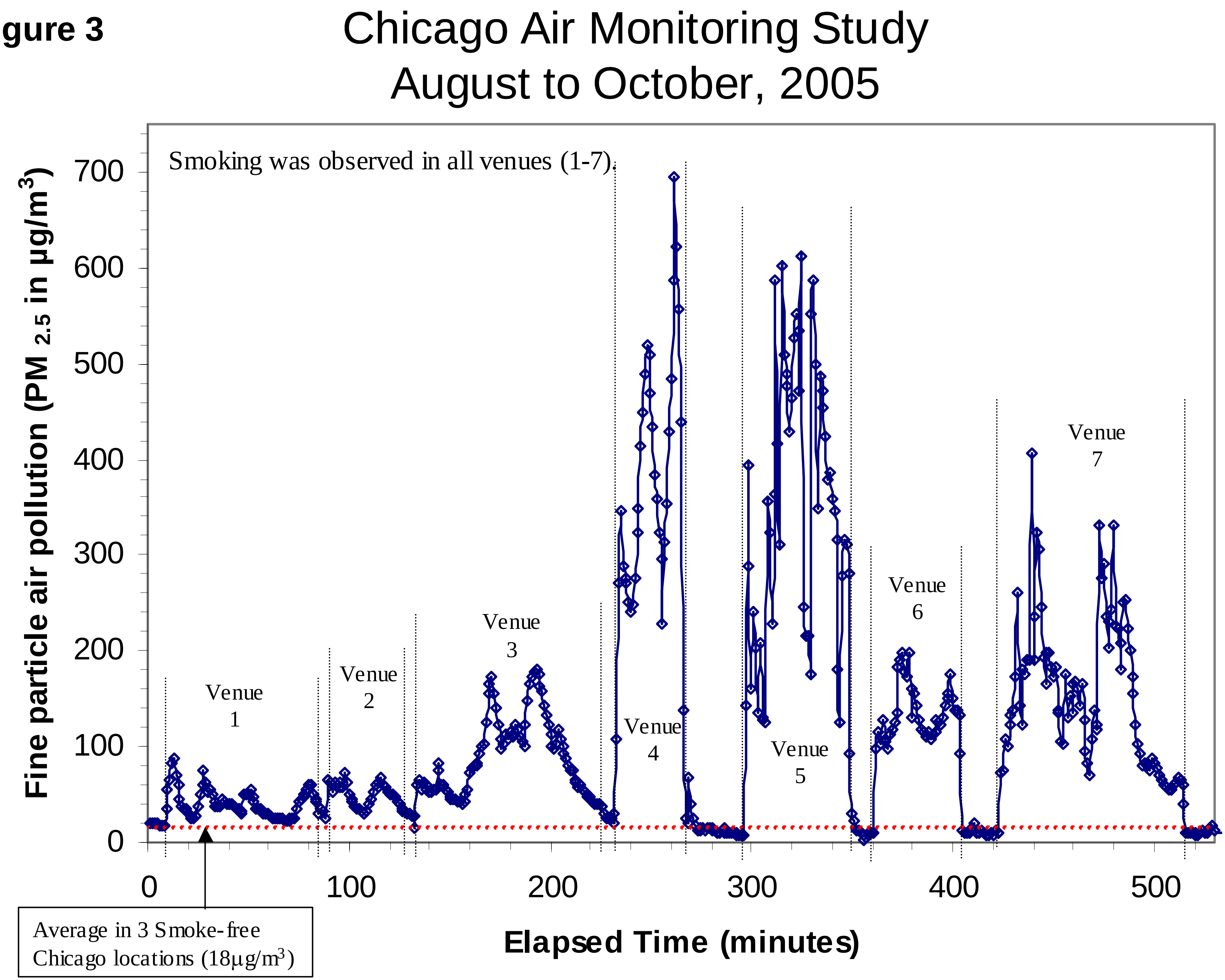
Table 1. Establishments With and Without Smoking in Chicago, IL

Venue Number	Size (m^3)	Average # people in venue	Average # burning cigs	Active smoker density*	Average $PM_{2.5}$ level (μg/m^3)
Bars/Restaurants Where Smoking Was Occuring During Sampling					
1	949	27	2.00	0.21	41
2	850	25	0.33	0.04	51
3	149	10	0.83	0.56	90
4	138	34	3.67	2.65	390
5	493	39	7.33	1.49	353
6	411	54	8.25	2.01	137
7	964	60	10.20	1.06	154
Average	**565**	**36**	**4.66**	**1.14**	**174**
Smoke-free					
8	771	8	0.00	0.00	23
9	554	24	0.00	0.00	12
10	292	22	0.00	0.00	19
Average	**539**	**18**	**0.00**	**0.00**	**18**

NOTES: * Average number of burning cigarettes per 100m^3

Details on the level of indoor air pollution in each location allowing smoking are shown in Figure 3. This combined real-time $PM_{2.5}$ plot reveals the following three general trends: 1) much higher levels of indoor air pollution are observed in the venues where smoking is permitted compared to the average level in smoke-free venues (see dotted line in graph); 2) low levels are observed indoors before and after sampling as well as outdoors when the research teams were in transit between venues; and 3) peak exposure levels in some venues can reach levels far in excess of the average recorded level.

Figure 3


Chicago Air Monitoring Study
August to October, 2005
Smoking was observed in all venues (1-7).
Fine particle air pollution (PM 2.5 in µg/m3)
0
100
200
300
400
500
600
700
Venue 1
Venue 2
Venue 3
Venue 4
Venue 5
Venue 6
Venue 7
0
100
200
300
400
500
Elapsed Time (minutes)
Average in 3 Smoke-free Chicago locations (18µg/m3)

Discussion

Chicago venues allowing smoking in this study had 10 times the levels of fine particle air pollution found in smoke-free venues (174 $\mu g/m^3$ vs. 18 $\mu g/m^3$). The difference between smoking and smoke-free venues is statistically significant according to the Mann-Whitney U-Test ($p=0.017$). The venues allowing indoor smoking were also found to be almost 3-times more polluted than Chicago's Lower Wacker Drive during rush hour where the average $PM_{2.5}$ level was 60 $\mu g/m^3$. Lower Wacker Drive is a twisting, tunnel-like roadway with very high traffic volumes during rush hours.

The EPA cited over 80 epidemiologic studies in creating a particulate air pollution standard in 1997[vii]. In order to protect the public health, the EPA has set limits of 15 $\mu g/m^3$ as the average annual level of $PM_{2.5}$ exposure and 65 $\mu g/m^3$ 24-hour exposure. For a full-time employee in one of the smoking venues sampled in this study, their average annual $PM_{2.5}$ exposure would be 40 $\mu g/m^3$ (assuming exposure to 174 $\mu g/m^3$ on the job, and a 40 hour work week). The EPA average annual $PM_{2.5}$ limit is exceeded by 2.6 times due solely to their occupational exposure, as this conservatively assumes zero particle exposure outside of work. Based on the latest scientific evidence, the EPA staff currently proposes even lower $PM_{2.5}$ standards to adequately protect the public health,[viii] making the high $PM_{2.5}$ exposures of people in smoking environments even more alarming.

The findings of this study are consistent with those of similar previous studies. Ott et al. did a study of a single tavern in California and showed an 82% average decrease in RSP levels after smoking was prohibited by a city ordinance[ix]. Repace studied 8 hospitality venues, including one casino, in Delaware before and after a statewide prohibition of smoking in these types of venues and found that about 90% of the fine particle pollution could be attributed to tobacco smoke[x]. Similarly, in a study of 22 hospitality venues in Western New York, Travers et al. found a 90% reduction in RSP levels in bars and restaurants, an 84% reduction in large recreation venues such as bingo halls and bowling alleys, and even a 58% reduction in locations where only SHS from an adjacent room was observed at baseline.[xi] A cross-sectional study of 53 hospitality venues in 7 major cities across the U.S. showed 82% less indoor air pollution in the locations subject to smoke-free air laws, even though compliance with the laws was less than 100%.[xii]

Other studies have directly assessed the effects SHS exposure has on human health. One study found that respiratory health improved rapidly in a sample of bartenders after a state smoke-free workplace law was implemented in California[xiii], and another study reported a 40% reduction in acute myocardial infarctions in patients admitted to a regional hospital during the 6 months that a local smoke-free ordinance was in effect[xiv]. The effects of even brief (minutes to hours) passive smoking on the cardiovascular system are often nearly as large (averaging 80% to 90%) as chronic active smoking. The effects of secondhand smoke are substantial and rapid, explaining the relatively large health risks associated with secondhand smoke exposure that have been reported in epidemiological studies[xii].

This study is subject to at least two limitations. First, venues sampled are not a true random sample of venues in each city. However, these venues were selected solely on the basis of sampling a wide range of venues in terms of size, location, and type of venue. Secondly, secondhand smoke is not the only source of indoor particulate matter. While $PM_{2.5}$ monitoring is not specific for secondhand smoke, it is highly sensitive to it, as evidenced by the sharp spikes in $PM_{2.5}$ levels upon entering venues where smoking is permitted. Ambient particle concentrations and cooking are additional sources of indoor particle levels; however, smoking is by far the largest contributor to indoor air pollution. Because there is a normal background level of $PM_{2.5}$, the reduction in this measure will be less than 100% even if all secondhand smoke is completely removed from the venue.

Conclusions

Smoking-permitted venues are significantly more polluted than indoor smoke-free sites in Chicago, IL. For hospitality workers, pollution levels in tested venues result in exposure to fine particle air pollution about 3 times the annual EPA exposure standard in place to protect the public health. This study demonstrates that hospitality workers and patrons are exposed to harmful levels of a known human carcinogen and toxin. Policies that prohibit smoking in public worksites dramatically reduce secondhand smoke exposure and improve worker and patron health.

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