Indiana Air Monitoring Study, December 2004 – January 2005.

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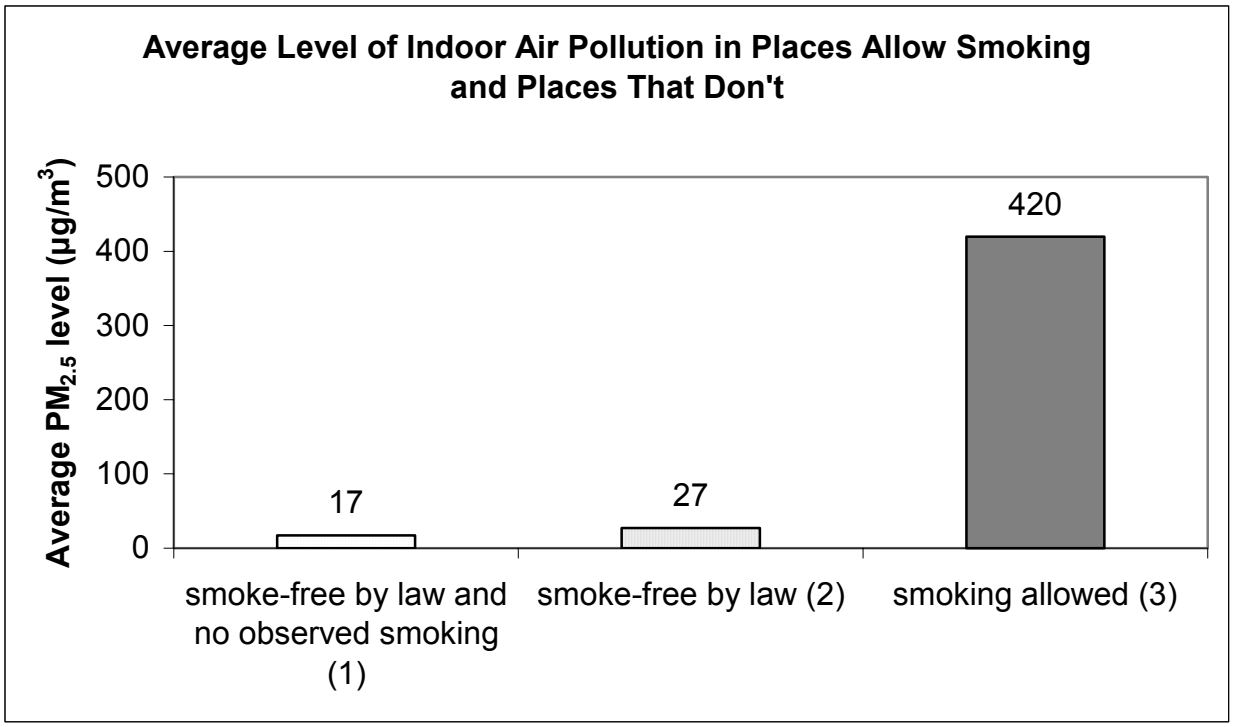
Executive Summary

Indoor air quality was assessed in 30 bars and restaurants between December 10th, 2004 and January 22nd, 2005 using the TSI SidePak AM510 Personal Aerosol Monitor. Venues were sampled in three Indiana cities, Bloomington, Indianapolis and Fort Wayne. The 9 locations in Bloomington were visited twice, once before and once after the implementation of a clean indoor air law requiring bars to be smokefree, to determine the change in air quality in these venues. Key findings of the study include:

- Overall, across all 3 cities the level of indoor air pollution as measured by average $PM_{2.5}$ level was 94% lower in the venues that were required to be smoke-free compared to those where 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.
- The level of $PM_{2.5}$ decreased by 89% in seven venues sampled in Bloomington after indoor smoking was prohibited by local ordinance. In the two Bloomington venues that were smoke-free at baseline the level of $PM_{2.5}$ was unchanged.
- Employees were exposed to levels of particulate matter far in excess of levels recommended by the Environmental Protection Agency (EPA). Based on the average level $PM_{2.5}$ observed in venues where smoking was not restricted by law in this study (420 $\mu g/m^3$), full-time bar and restaurant employees are exposed on the job to more than seven times the annual limit of fine particulate air pollution recommended by the U.S. Environmental Protection Agency.
- The highest average level of indoor air pollution was seen in Indianapolis (432 $\mu g/m^3$ of $PM_{2.5}$) where there were no restrictions on indoor smoking. This level is 14-times higher than that seen in smoke-free Bloomington.

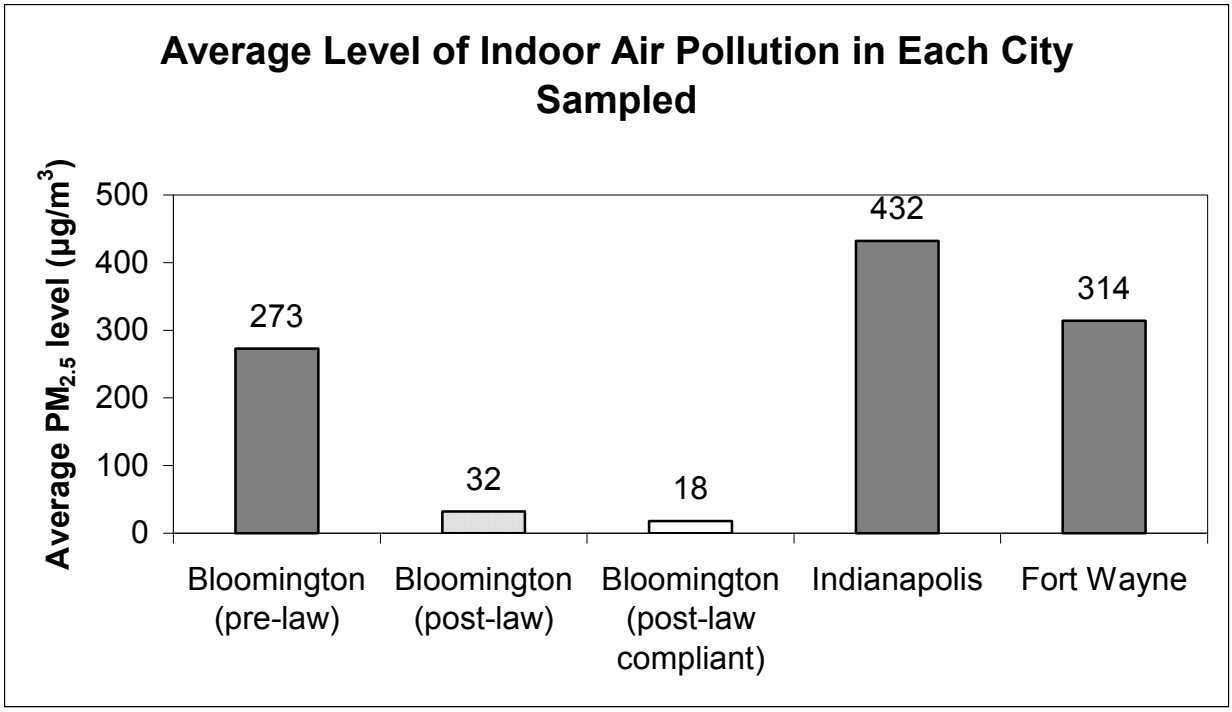
- The average level in Fort Wayne (314 μg/m^3 of $PM_{2.5}$) was 10-times higher than in smoke-free Bloomington.
- In post-law Bloomington, observed compliance was high – no smoking was observed in 89% of the venues that were required to be smoke-free by law.

Figure 1. Fine Particle Air Pollution in All Indiana Venues, December 10, 2004 to January 22, 2005



(1) These 13 venues were smoke-free by law and no smoking was observed during air monitoring; i.e. all venues that were compliant with the law
(2) These 14 venues were smoke-free by law but they include 1 venue where smoking was observed; i.e. 1 venue was non-compliant with the law
(3) These 25 venues had no smoking restrictions in place

Figure 2. $PM_{2.5}$ Levels in 3 Indiana Cities, December 10, 2004 to January 22, 2005



City	Total # of locations	# of locations smoke-free by law	Avg. size (m^3)	Avg. # people in venue	Avg. active smoker density*	Average $PM_{2.5}$ level ($\mu g/m^3$)
Bloomington (pre-law)	9	2	738	78	0.58	273
Bloomington (post-law)	9	9	738	99	0.08	32
Bloomington (post-law compliant)	8	8	806	93	0.00	18
Indianapolis	13	0	491	64	0.87	432
Fort Wayne	8	3	736	64	0.59	314

NOTES:

* Average number of burning cigarettes per $100m^3$

Introduction

Secondhand smoke (SHS) contains at least 250 chemicals that are known to be toxic or carcinogenic, and is itself a known human carcinogen[1], 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[2]. 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[3,4]. Because policies requiring smoke-free environments are the most effective method for reducing SHS exposure in public places[5], Healthy People 2010 Objective 27-13 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, 7 states (California, Delaware, New York, Maine, Connecticut, Massachusetts and Rhode Island), which represents 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 Rhode Island legislation takes full effect in 2006).

The EPA cited over 80 epidemiologic studies in creating a particulate air pollution standard in 1997[6]. 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[6]. $PM_{2.5}$ 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.

Previous studies have evaluated air quality by measuring the change in levels of respirable suspended particles (RSP) between smoke-free venues and those that permit smoking. 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[7]. Repace studied 8 hospitality venues 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[8]. 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.[9]

Other studies have directly assessed the role SHS exposure has on human health. One study found that respiratory health improved rapidly in a sample of bartenders after a state clean smoke-free workplace law was implemented in California[10], 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[11].

The purpose of this study was to examine indoor air quality in a sample of bars and restaurants in 3 Indiana cities, Bloomington, Indianapolis and Fort Wayne. We assessed the relation between indoor air pollution, the presence of smoke-free regulations, and the presence of on-premises smoking. These associations were assessed across the 3 cities and also longitudinally in Bloomington where locations were visited before and after the implementation of a clean indoor air law prohibiting smoking in these locations. We hypothesize that indoor air quality will be greater in those venues where smoking is prohibited by law and where no smoking is occurring than in those places where smoking is unregulated. We also hypothesize that the improvement in indoor air quality will be consistent across study locations.

Methods

Overview

Between December 10th, 2004 and January 22st, 2005, indoor air quality was assessed in 30 bars and restaurants in three cities located in Indiana; Bloomington, Indianapolis and Fort Wayne. The 9 locations in Bloomington were visited twice, once before and once after the implementation of a clean indoor air law. Descriptive information about each venue is presented in Table 1.

Bloomington, Indiana is in Monroe County and is the home of Indiana University, a large state university. All public places except bars but including most restaurants went smoke free on August 1, 2003. Bars and all remaining restaurants went smoke free on January 1, 2005 making Bloomington Indiana's first comprehensive smoke free city.

Fort Wayne had a smoke free law go into effect January 1, 1999 to make restaurants, workplaces and enclosed public places smoke free. However, restaurants and bars may allow smoking if the section is completely enclosed by floor to ceiling walls and there is a separate entrance. Freestanding bars may allow smoking. Fort Wayne makes up most of Allen County, one of the five largest counties in Indiana.

There is no law restricting smoking in restaurants or bars in Indianapolis. Indianapolis includes all of Marion County with a population of approximately 1 million. Indianapolis is the state's capital and largest city.

There are no smoke free policies at the state level regarding restaurants, bars, workplaces, or public places. Indiana communities are not preempted in passing local ordinances.

Procedure for Selection of Cities and Venues to be Sampled

The three cities were selected to represent highly populated but geographically different areas of Indiana with various types of clean indoor air legislation in effect. Within each city, efforts were made to visit a minimum of 3 bars and 3 restaurants in each city, and at least two popular entertainment districts were visited in each city. With the help of local contacts, a list of candidate venues believed to be representative of hospitality venues in each entertainment district was created. This list served as the basis for selecting venues for air sampling. Additional locations, which were in close proximity to other locations sampled, were selected throughout the course of the evening in some cities. Most sampling was performed on Friday and Saturday evenings (90% of visits) while four restaurants (10%) were visited on Saturday mornings. All evening sampling occurred between 6PM and 1AM while the four morning visits occurred between 9AM and 11:30AM. Table 1 presents some general descriptive information on each venue.

Table 1.

Venue Number	City	Smoke-free By Law?*	Was Smoking Observed?	Date Sampled	Size (m^3)	Active smoker density**	Average $PM_{2.5}$ level ($\mu g/m^3$)
1a	Bloomington	Yes	No	12/10/2004	475	0.00	19
1b	Bloomington	Yes	No	1/21/2005	475	0.00	12
2a	Bloomington	No	Yes	12/10/2004	330	0.91	309
2b	Bloomington	Yes	Yes	1/21/2005	330	0.71	153
3a	Bloomington	No	Yes	12/10/2004	676	0.25	172
3b	Bloomington	Yes	No	1/21/2005	676	0.00	10
4a	Bloomington	No	Yes	12/10/2004	644	0.72	920
4b	Bloomington	Yes	No	1/21/2005	644	0.00	13
5a	Bloomington	No	Yes	12/10/2004	1879	0.20	92
5b	Bloomington	Yes	No	1/21/2005	1879	0.00	18
6a	Bloomington	No	Yes	12/10/2004	350	0.38	61
6b	Bloomington	Yes	No	1/21/2005	350	0.00	10
7a	Bloomington	No	Yes	12/10/2004	772	1.34	543
7b	Bloomington	Yes	No	1/21/2005	772	0.00	45
8a	Bloomington	No	Yes	12/10/2004	515	1.04	335
8b	Bloomington	Yes	No	1/21/2005	515	0.00	11
9a	Bloomington	Yes	No	12/11/2004	1001	0.00	9
9b	Bloomington	Yes	No	1/22/2005	1001	0.00	15
10	Indianapolis	No	Yes	1/7/2005	686	0.58	102
11	Indianapolis	No	Yes	1/7/2005	270	0.46	133
12	Indianapolis	No	Yes	1/7/2005	319	1.36	605
13	Indianapolis	No	Yes	1/7/2005	565	1.77	465
14	Indianapolis	No	Yes	1/7/2005	327	1.43	681
15	Indianapolis	No	Yes	1/7/2005	949	1.05	823
16	Indianapolis	No	Yes	1/7/2005	468	0.28	33
17	Indianapolis	No	Yes	1/8/2005	797	0.38	238
18	Indianapolis	No	Yes	1/8/2005	129	0.58	79
19	Indianapolis	No	Yes	1/8/2005	174	0.58	95
20	Indianapolis	No	Yes	1/8/2005	590	0.62	654
21	Indianapolis	No	Yes	1/8/2005	549	0.79	529
22	Indianapolis	No	Yes	1/8/2005	557	1.38	1178
23	Fort Wayne	No	Yes	1/14/2005	943	0.42	358
24	Fort Wayne	Yes	No	1/14/2005	340	0.00	29
25	Fort Wayne	No	Yes	1/14/2005	834	0.08	40
26	Fort Wayne	No	Yes	1/14/2005	502	1.40	632
27	Fort Wayne	Yes	No	1/14/2005	815	0.00	13
28	Fort Wayne	No	Yes	1/14/2005	1370	0.32	629
29	Fort Wayne	No	Yes	1/14/2005	471	2.27	787
30	Fort Wayne	Yes	No	1/15/2005	617	0.00	22
Avg.					655	0.55	279

* Used to compare indoor air pollution levels between places that are required to be smoke-free and places that are not.

** Average number of burning cigarettes per $100m^3$

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 in the air (see Figure 3). 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 milligrams per cubic meter. 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 3. TSI SidePak AM510 Personal Aerosol Monitor

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[8].

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.

Definition of 'Smoke-free' Venue

'Smoke-free' venues are defined as those venues that are required to be smoke-free by law. These venues include two of the restaurants in Bloomington that were required to be smoke-free before and after the law that went into effect on January 1st, 2005 and the other seven Bloomington venues when they were visited after January 1st, 2005. There were also three smoke-free restaurants visited in Fort Wayne, IN. In one instance, smoking was observed in a venue that was required to be smoke-free. Treating this venue as 'smoke-free' even though there was smoking provides a conservative test of the difference in indoor air quality across different hospitality venue regulations.

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. The second goal was to assess the change in average levels of RSP longitudinally in a sample of places in Bloomington before and after the implementation of a clean indoor air law, which is assessed with the Wilcoxon signed-rank 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 average time spent in each venue was 42 minutes (range, 30 minutes to 85 minutes). There were 39 total visits to 30 individual bars and restaurants in this study with 2 visits to each of the 9 locations in Bloomington, one before and one after the implementation of their recent clean indoor air law. Across all 39 bars and restaurants sampled in this study (including 2 visits to each of the 9 Bloomington locations), 14 were required to be smoke-free by local ordinance and the average RSP level in these venues was 27 $\mu g/m^3$. Twenty-five venues were sampled that were not required to be smoke-free, and the average RSP level in these venues was 420 $\mu g/m^3$ (Figure 1). The level of indoor air pollution was 94% lower in the venues that were required to be 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 655 m^3 and was comparable between places where smoking was prohibited and where it was not (706 m^3 vs. 627 m^3, respectively); however, the average smoker density was much greater in venues where smoking was not restricted by law (0.05 burning cigarettes per 100 m^3 vs. 0.82 burning cigarettes per 100 m^3).

The average RSP level in the 13 venues where no smoking was observed during sampling was 17 $\mu g/m^3$ compared to 420 $\mu g/m^3$ in the 31 venues where smoking was observed (96% reduction).

Averaged across each city, the lowest levels of indoor air pollution were found in Bloomington post-law (32 $\mu g/m^3$) and the highest levels were found in Indianapolis (432 $\mu g/m^3$) where there is no clean indoor air legislation. Fort Wayne, which has some restrictions on smoking in restaurants, had a lower average RSP than Indianapolis (314 $\mu g/m^3$). See Figure 2.

Details on the level of indoor air pollution in each city sampled are presented in Figures 4 through 14. Results from the real-time $PM_{2.5}$ plots throughout the duration of sampling for each city reveal the following three general trends: 1) much higher levels of indoor air pollution are observed in venues where smoking is permitted; 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.

Bloomington, IN – December 10-11, 2004 (Figures 4 and 5)

Nine venues were sampled in Bloomington, Indiana on December 10 and December 11, 2004. Since August 1, 2003, most restaurants in Bloomington are required to be smoke-free by law. Freestanding bars and some restaurants with exemptions were not required to be smoke-free as of this sampling period. Of the nine venues sampled, smoking was observed in seven venues and no smoking was observed in two venues. The two venues where no smoking was observed were restaurants that were required to be smoke-free by law. The seven locations where smoking was observed included six bars and one restaurant that were all permitted under the current provisions to allow smoking. Eight locations were sampled on the evening of Friday, December 10 between 6PM and 1AM. One location was sampled on the morning of Saturday, December 11 from 10:40AM to 11:25AM. The average number of people in the nine venues was 78. In the seven venues where smoking was observed, the average room volume was 788 m^3 and the average smoker density was 0.69 burning cigarettes per 100 m^3. In the two venues where no smoking was observed the average room volume was 738 m^3 and the average smoker density was 0.00 burning cigarettes per 100 m^3. Average $PM_{2.5}$ level was 273 $\mu g/m^3$ for all nine venues, but was 25-fold higher in the seven venues where smoking was observed (average 347 $\mu g/m^3$) compared to the average in the two smoke-free venues (average 14 $\mu g/m^3$).

Bloomington, IN – January 21-22, 2005 (Figures 6 and 7)

The same nine locations that were sampled in December, 2004 were sampled again on January 21 and January 22, 2005. All of the locations were sampled on the same day of the week and at approximately the same time of day as the visits in December. As of January 1, 2005, according to Bloomington law, all indoor public places including all bars and restaurants were required to go smoke-free. Therefore, during these sampling visits no smoking was permitted by law in any of the nine locations. Of the nine locations, smoking was observed in one of them and there was no observed smoking in the other eight (compliance rate = 89%). The average number of people in the nine venues was 99. The overall average smoker density was 0.08 burning cigarettes per 100 m^3 with an average smoker density of 0.71 burning cigarettes per 100 m^3 in the one bar where smoking was observed and 0.00 in the other eight. Average $PM_{2.5}$ level was 32 $\mu g/m^3$ for all nine venues, but was 9-fold higher in the one venue where smoking was observed (153 $\mu g/m^3$) compared to the average in the eight smoke-free venues (average 17 $\mu g/m^3$).

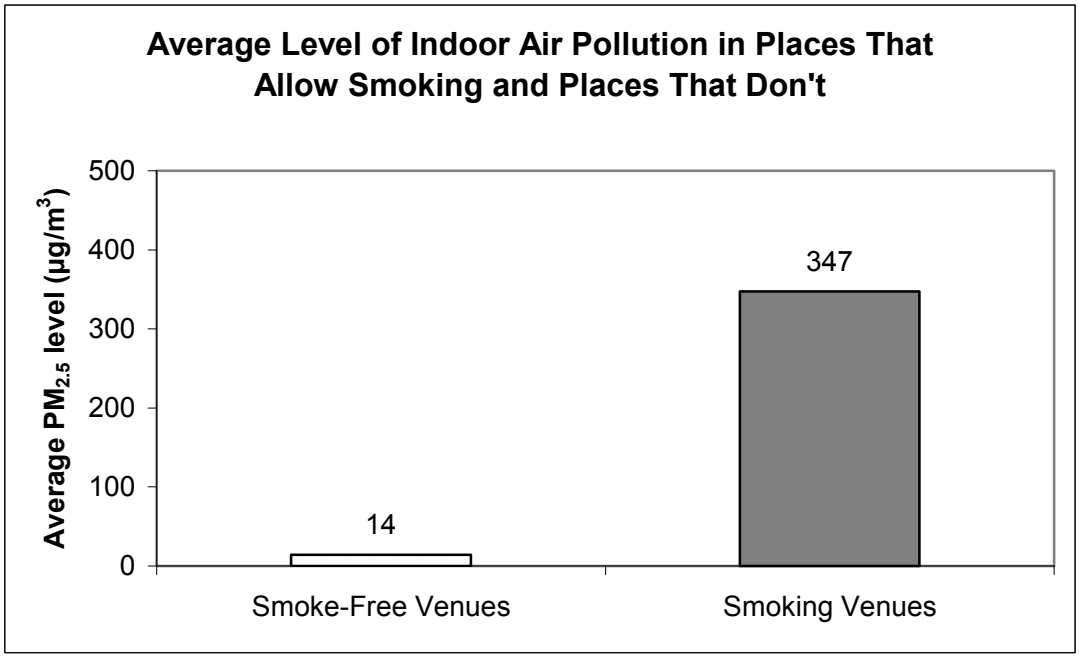
Indianapolis, IN – January 7-8, 2005 (Figures 10,11,12)

Thirteen locations were sampled on January 7 and 8, 2005 in Indianapolis, IN. There was no law restricting smoking in indoor public places in effect for Indianapolis. Smoking was observed in all thirteen locations sampled. Six bars and restaurants were sampled on the evening of Friday, January 7 from 6:30PM to 12:30AM. One restaurant was sampled on the morning of Saturday, January 8 from 9AM to 9:35AM and six more bars and restaurants were sampled on that evening from 7:30PM to 12:45AM. The average volume of the thirteen locations was 491 m^3 and the average smoker density was 0.87 burning cigarettes per 100 m^3. The average number of people in the venues was 77. Average $PM_{2.5}$ level was 432 $\mu g/m^3$ for all thirteen venues.

Fort Wayne, IN – January 14-15, 2005 (Figures 13 and 14)

Eight bars and restaurants were sampled in Fort Wayne, IN on January 14 and 15, 2005. Seven bars and restaurants were sampled on the evening of Friday, January 14 from 6:20PM to 12:30AM and one restaurant was visited on the morning of Saturday, January 15 from 9:15AM to 10:15AM. Overall, in the eight locations the average room volume was 736 m^3, the average smoker density was 0.56 burning cigarettes per 100 m^3, and the average number of people was 64. In the five locations where smoking was observed the average room volume was 824 m^3, the average smoker density was 0.90 burning cigarettes per 100 m^3, and the average number of people was 66. In the 3 locations where there was no observed smoking the average room volume was 591 m^3, the average smoker density was 0.00 burning cigarettes per 100 m^3, and the average number of people was 61. Average $PM_{2.5}$ level was 314 $\mu g/m^3$ for all eight venues, but was 23-fold higher in the five venues where smoking was observed (average 489 $\mu g/m^3$) compared to the average in the three smoke-free venues (average 21 $\mu g/m^3$).

Figure 4. Pre-Law RSP Levels in bars and restaurants sampled in Bloomington, IN on December 10-11, 2004



Venue Number	Size (m3)	# people in venue	Active smoker density*	Average PM2.5 level (µg/m3)
Bars/Restaurants Where Smoking Was Occuring During Sampling				
2a	330	22	0.91	309
3a	676	87	0.25	172
4a	644	35	0.72	920
5a	1879	71	0.20	92
6a	700	51	0.38	61
7a	772	104	1.34	543
8a	515	53	1.04	335
Average	788	60	0.69	347
Smoke-free Bars/Restaurants				
1a	475	171	0.00	19
9a	1001	106	0.00	9
Average	738	139	0.00	14
Overall average	777	78	0.54	273

NOTES:

* Average number of burning cigarettes per $100m^3$

Figure 5.

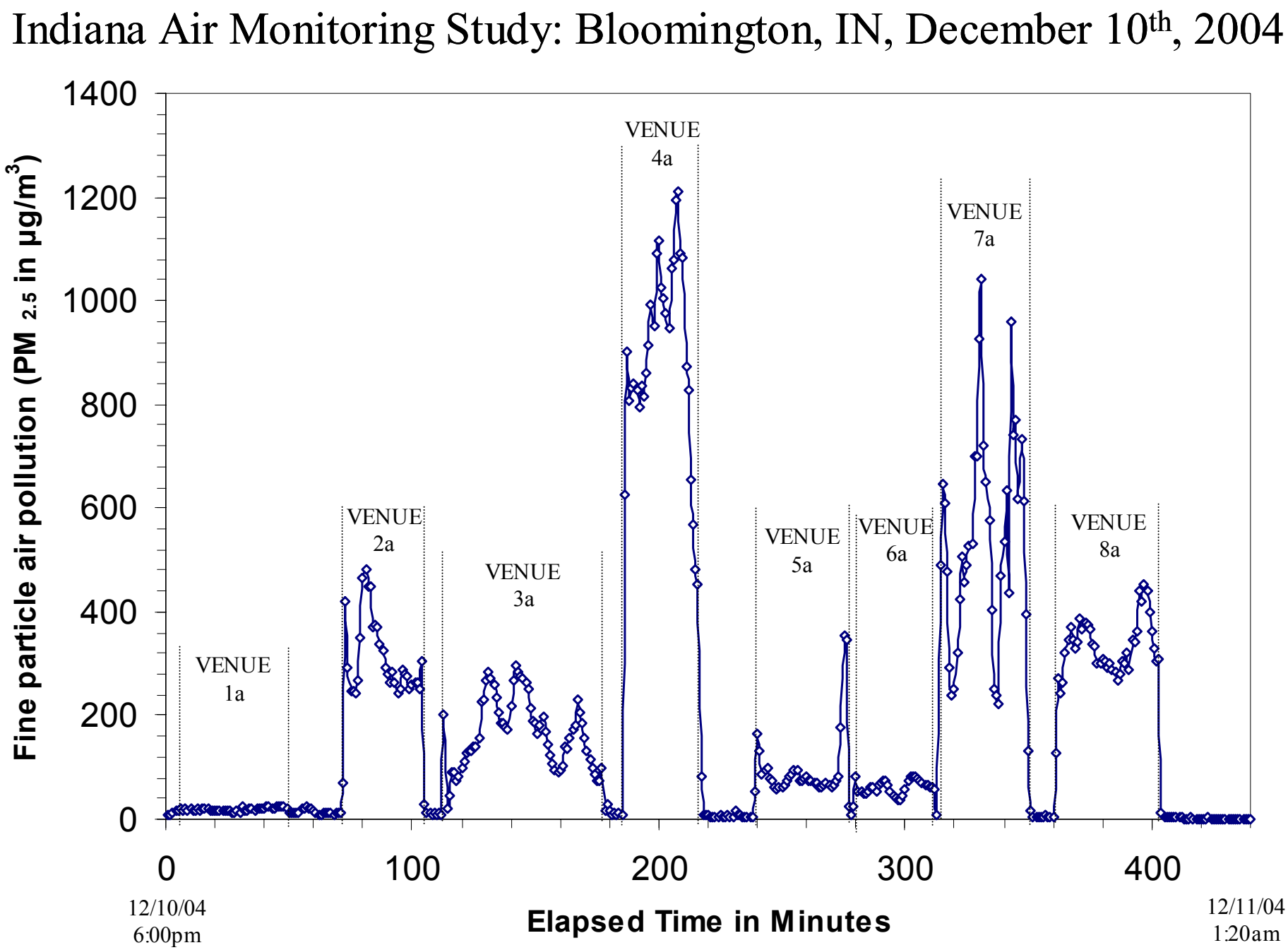
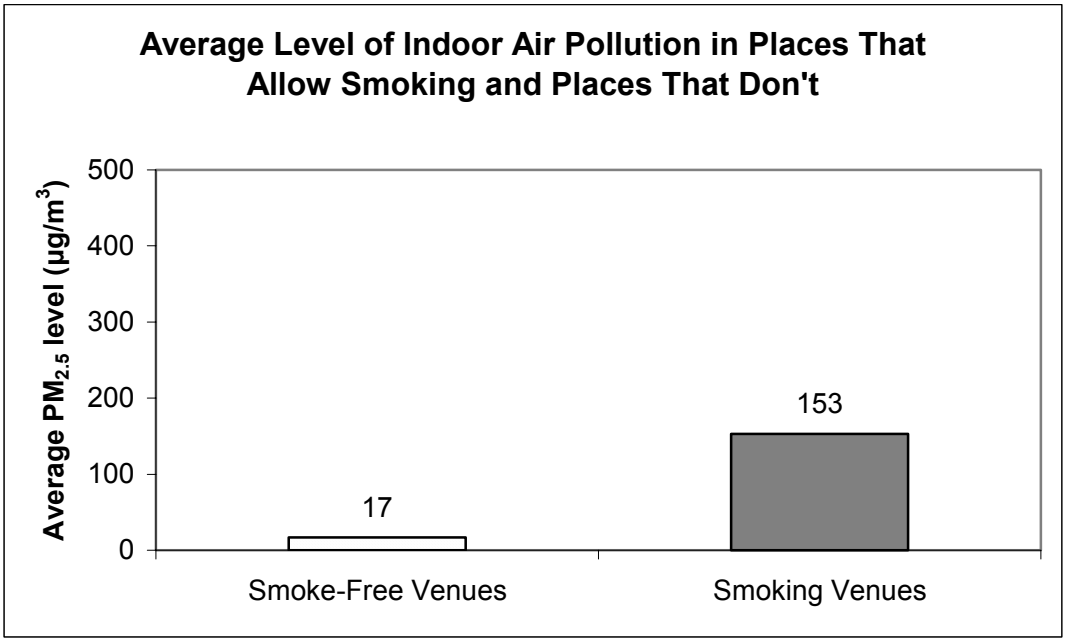

Indiana Air Monitoring Study: Bloomington, IN, December 10th, 2004
Fine particle air pollution (PM 2.5 in µg/m3)
1400
1200
1000
800
600
400
200
0
VENUE 1a
VENUE 2a
VENUE 3a
VENUE 4a
VENUE 5a
VENUE 6a
VENUE 7a
VENUE 8a
0
100
200
300
400
12/10/04 6:00pm
Elapsed Time in Minutes
12/11/04 1:20am

Figure 6. Post-Law RSP Levels in bars and restaurants sampled in Bloomington, IN on January 21-22, 2005



Venue Number	Size (m3)	# people in venue	Active smoker density*	Average PM2.5 level (µg/m3)
Bars/Restaurants Where Smoking Was Occuring During Sampling				
2b	330	31	0.71	153
Average	330	31	0.71	153
Smoke-free Bars/Restaurants				
1b	475	195	0.00	12
3b	676	80	0.00	10
4b	644	31	0.00	13
5b	1879	158	0.00	18
6b	350	101	0.00	10
7b	772	142	0.00	45
8b	515	50	0.00	11
9b	1001	104	0.00	15
Average	789	107	0.00	17
Overall average	738	99	0.08	32

NOTES:

* Average number of burning cigarettes per $100m^3$

Figure 7.

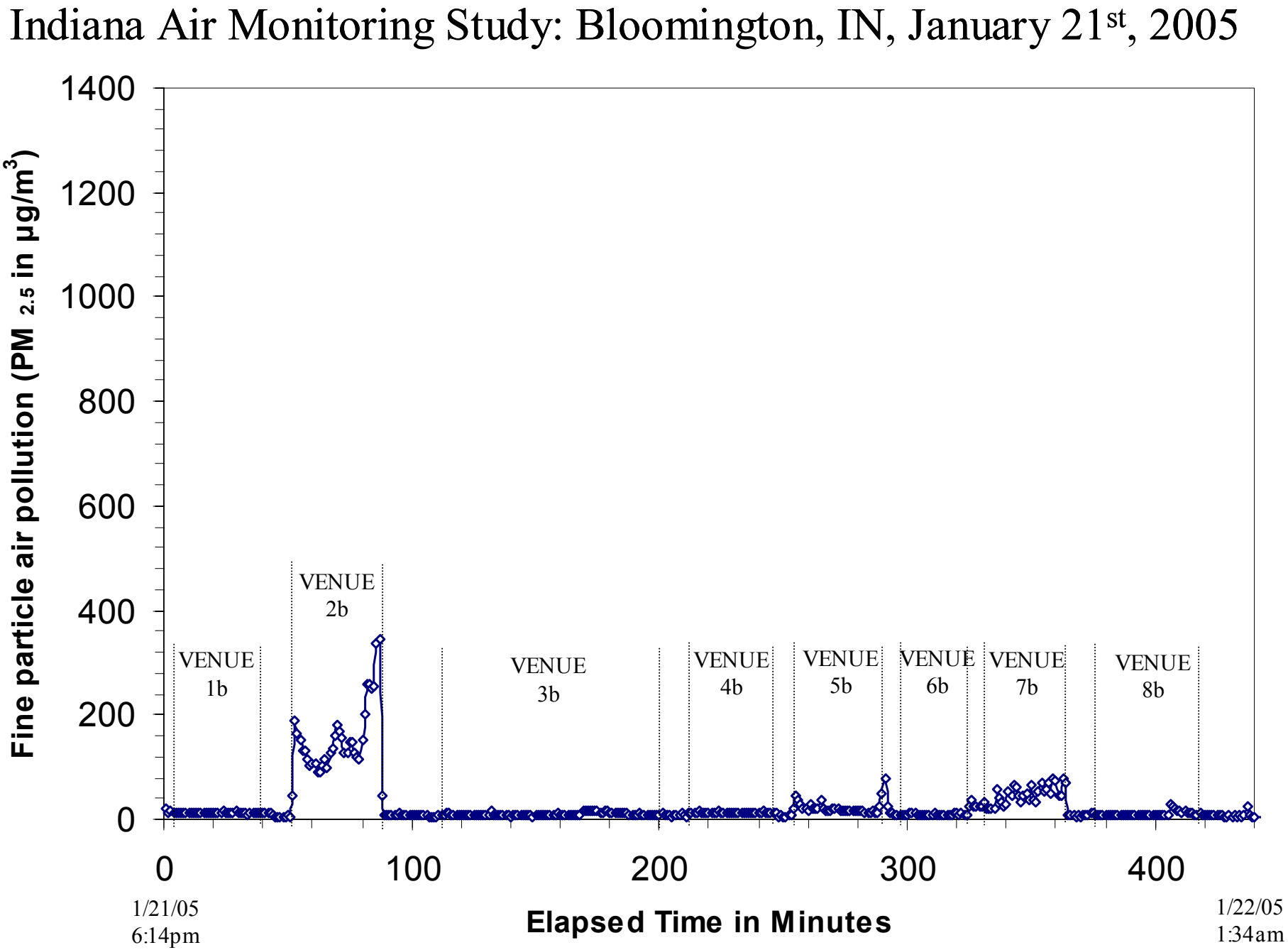
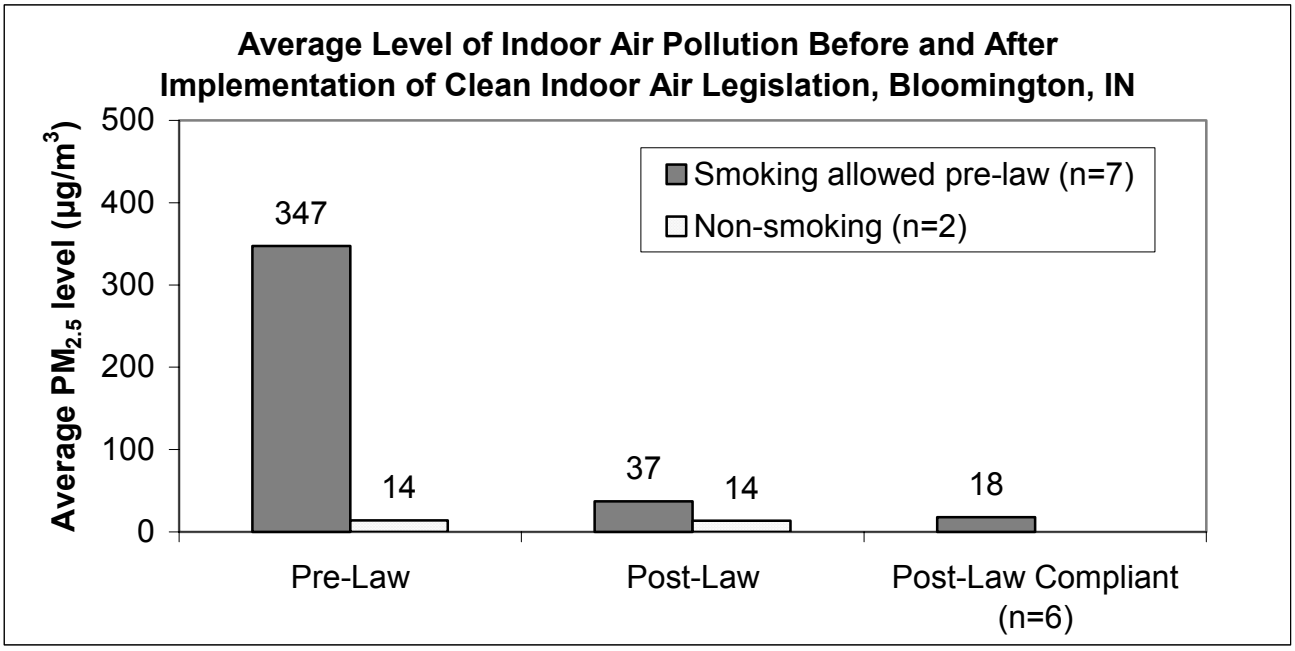

Indiana Air Monitoring Study: Bloomington, IN, January 21st, 2005
Fine particle air pollution (PM 2.5 in µg/m3)
1400
1200
1000
800
600
400
200
0
VENUE 1b
VENUE 2b
VENUE 3b
VENUE 4b
VENUE 5b
VENUE 6b
VENUE 7b
VENUE 8b
0
100
200
300
400
1/21/05 6:14pm
Elapsed Time in Minutes
1/22/05 1:34am

Figure 8. Change in RSP Levels in bars and restaurants sampled in Bloomington, IN before and after implementation of a clean indoor air law



Venue Number	Size (m3)	# people in venue pre-law	# people in venue post-law	Active smoker density* pre-law	Active smoker density* post-law	Average $PM_{2.5}$ level ($\mu g/m^3$) pre-law	Average $PM_{2.5}$ level ($\mu g/m^3$) post-law	% Reduction in $PM_{2.5}$
Non-smoking locations at baseline								
1	475	171	195	0.00	0.00	19	12	37%
9	1001	106	104	0.00	0.00	9	15	-67%
Average	738	139	150	0	0	14	14	4%
Smoking allowed at baseline								
2	330	22	31	0.91	0.71	309	153	50%
3	676	87	80	0.25	0.00	172	10	94%
4	644	35	31	0.72	0.00	920	13	99%
5	1879	71	158	0.20	0.00	92	18	80%
6	350	51	101	0.38	0.00	61	10	84%
7	772	104	142	1.34	0.00	543	45	92%
8	515	53	50	1.04	0.00	335	11	97%
Average	738	60	85	1	0	347	37	89%

NOTES:

* Average number of burning cigarettes per $100m^3$

Figure 9.

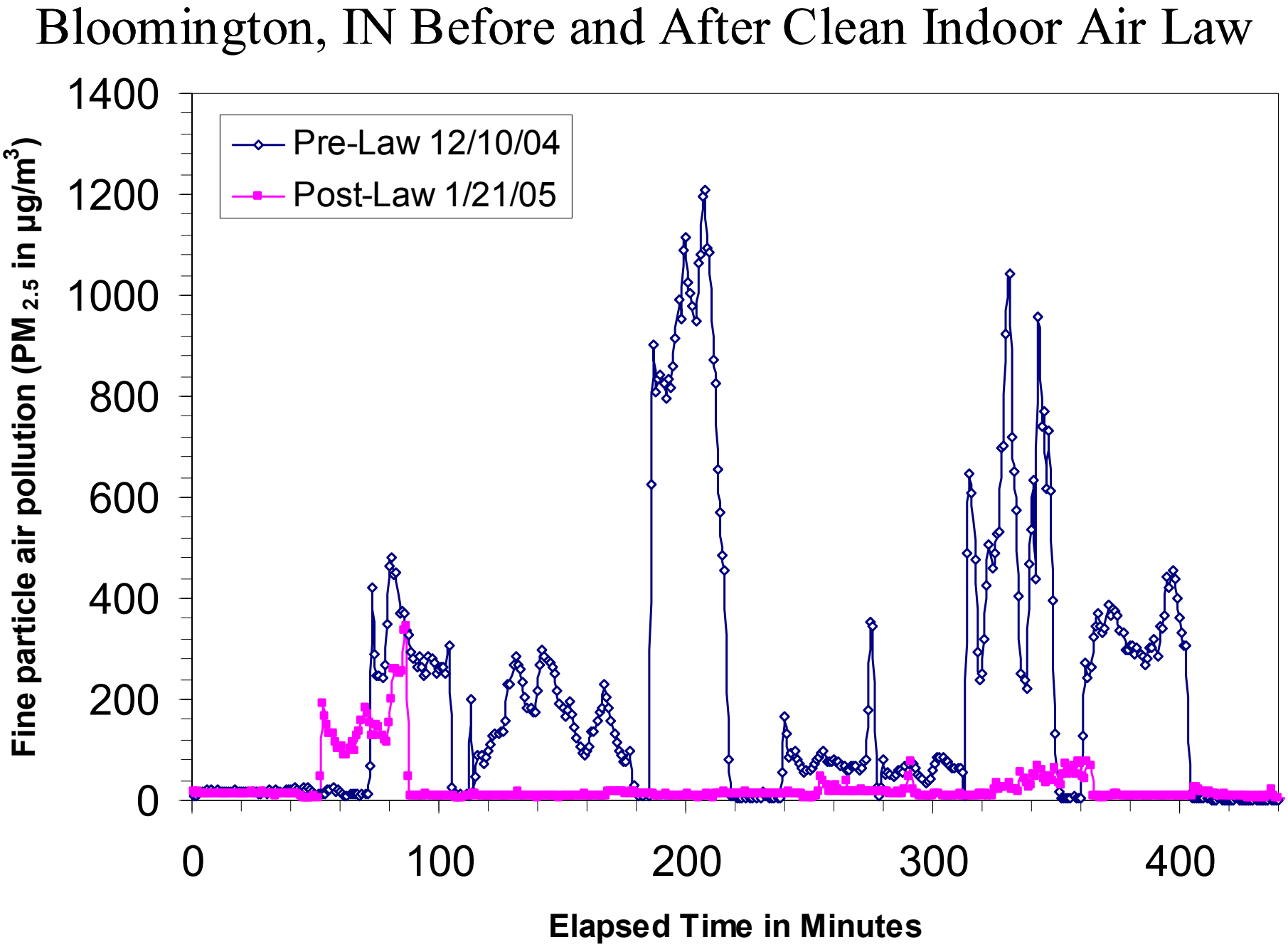
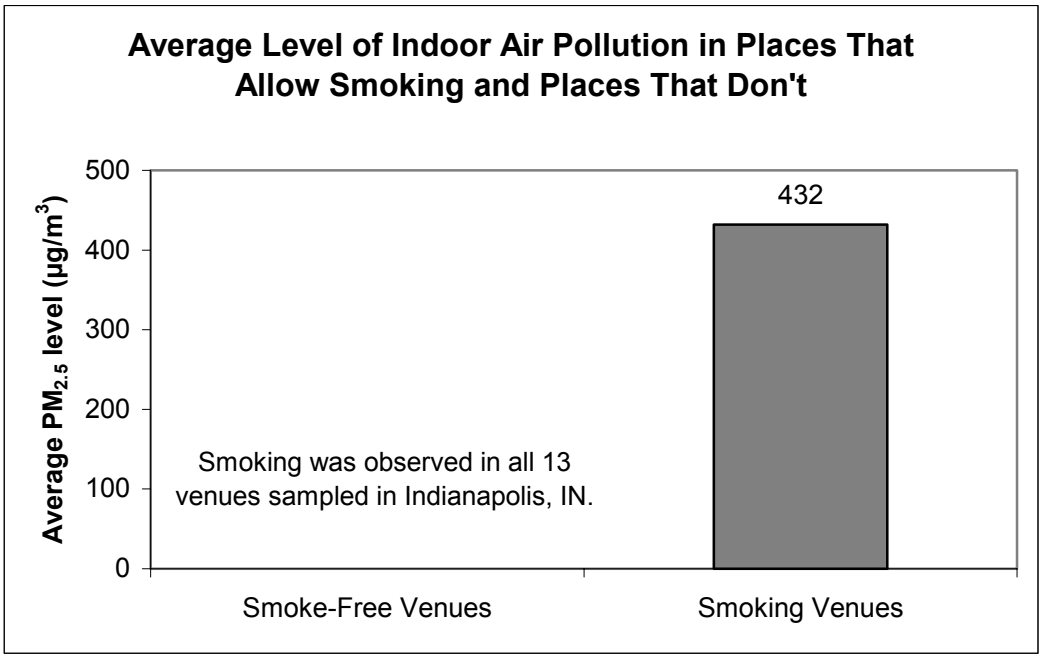

Bloomington, IN Before and After Clean Indoor Air Law
Pre-Law 12/10/04
Post-Law 1/21/05
Fine particle air pollution (PM 2.5 in µg/m3)
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
Elapsed Time in Minutes

Figure 10. RSP Levels in bars and restaurants sampled in Indianapolis, IN on January 7-8, 2005



Venue Number	Size (m3)	# people in venue	Active smoker density*	Average $PM_{2.5}$ level ($\mu g/m^3$)
Bars/Restaurants Where Smoking Was Occuring During Sampling				
10	686	225	0.58	102
11	270	43	0.46	133
12	319	38	1.36	605
13	565	52	1.77	465
14	327	27	1.43	681
15	949	203	1.05	823
16	468	86	0.28	33
17	797	80	0.38	238
18	129	20	0.58	79
19	174	25	0.58	95
20	590	97	0.62	654
21	549	70	0.79	529
22	557	33	1.38	1178
Average	491	77	0.87	432

NOTES:

* Average number of burning cigarettes per $100m^3$

Figure 11.

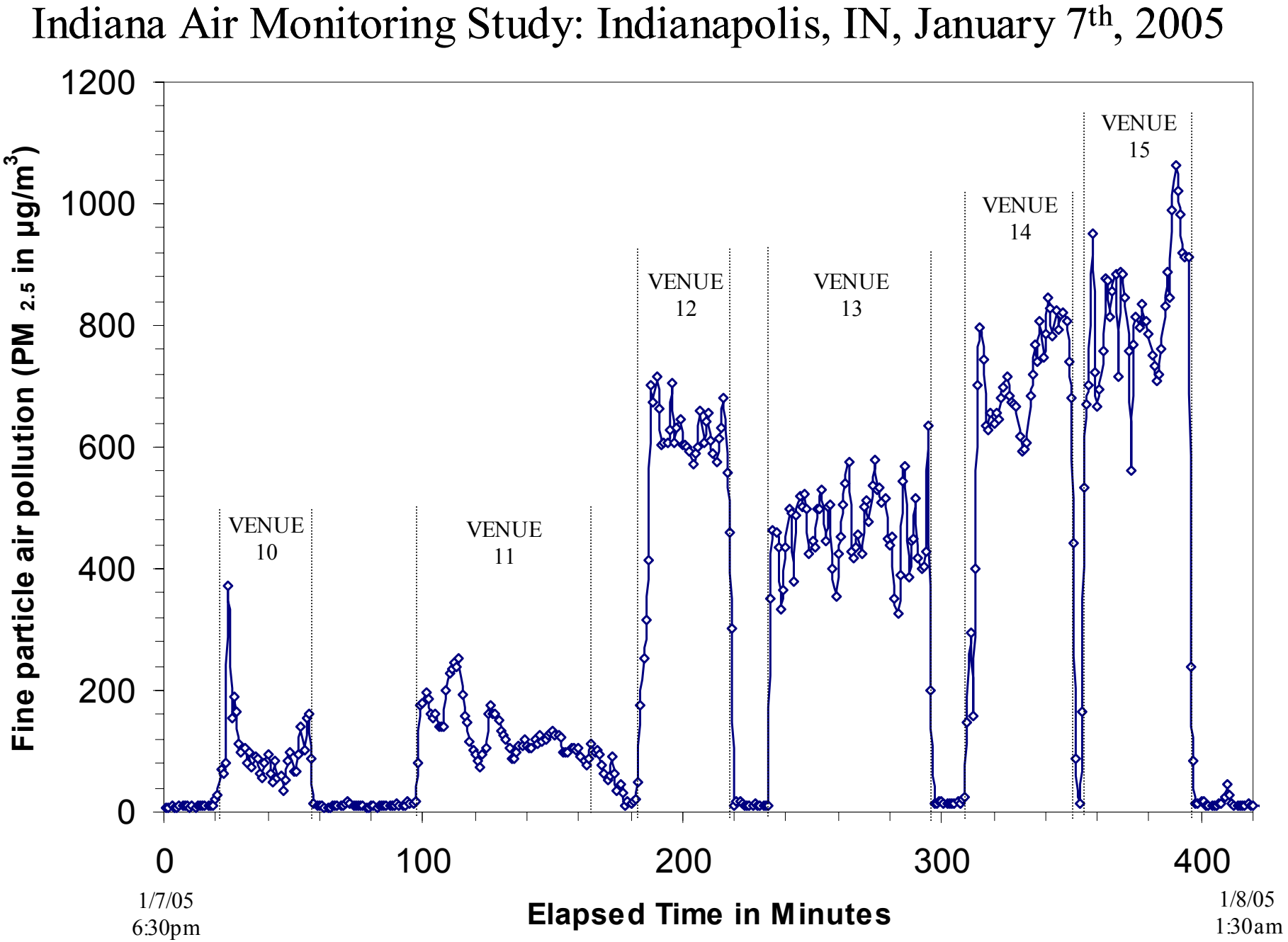

Indiana Air Monitoring Study: Indianapolis, IN, January 7th, 2005
Fine particle air pollution (PM 2.5 in µg/m3)
1200
1000
800
600
400
200
0
VENUE 10
VENUE 11
VENUE 12
VENUE 13
VENUE 14
VENUE 15
0
100
200
300
400
1/7/05 6:30pm
Elapsed Time in Minutes
1/8/05 1:30am

Figure 12.

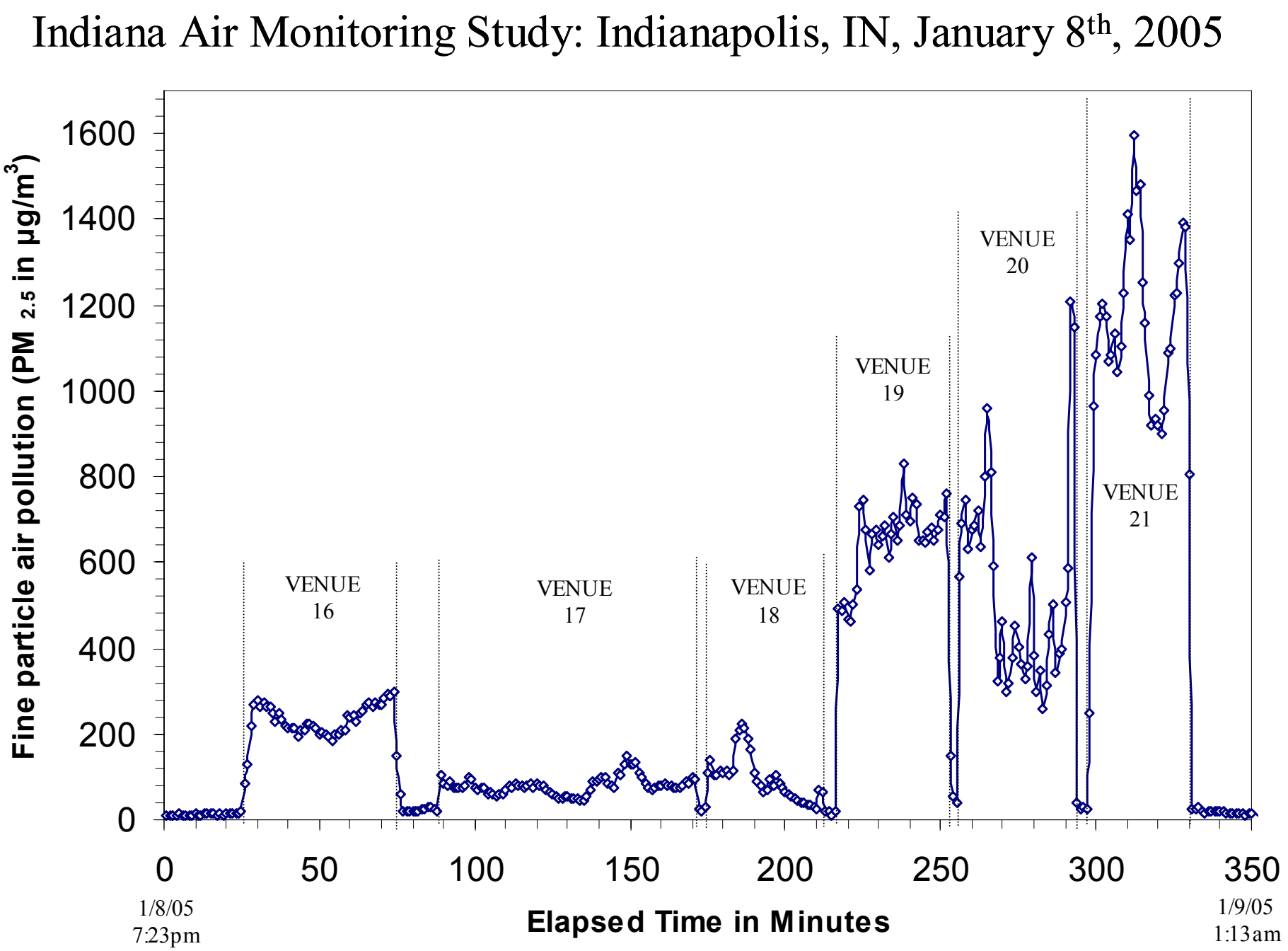
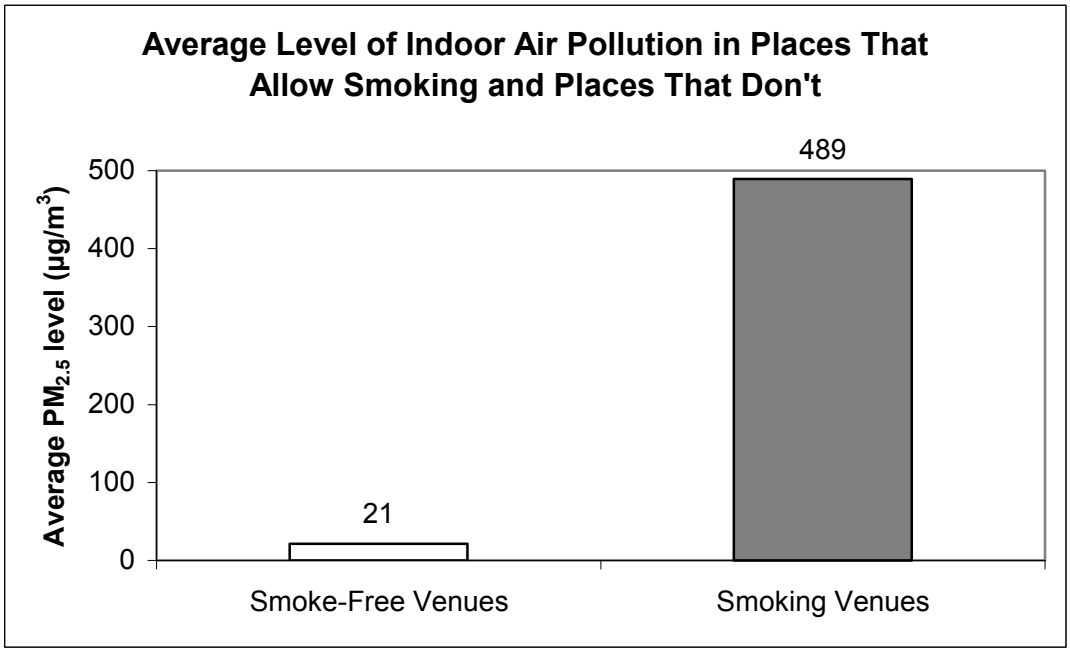

Indiana Air Monitoring Study: Indianapolis, IN, January 8th, 2005
Fine particle air pollution (PM 2.5 in µg/m3)
1600
1400
1200
1000
800
600
400
200
0
VENUE 16
VENUE 17
VENUE 18
VENUE 19
VENUE 20
VENUE 21
0
50
100
150
200
250
300
350
1/8/05 7:23pm
Elapsed Time in Minutes
1/9/05 1:13am

Figure 13. RSP Levels in bars and restaurants sampled in Fort Wayne, IN on January 14-15, 2005

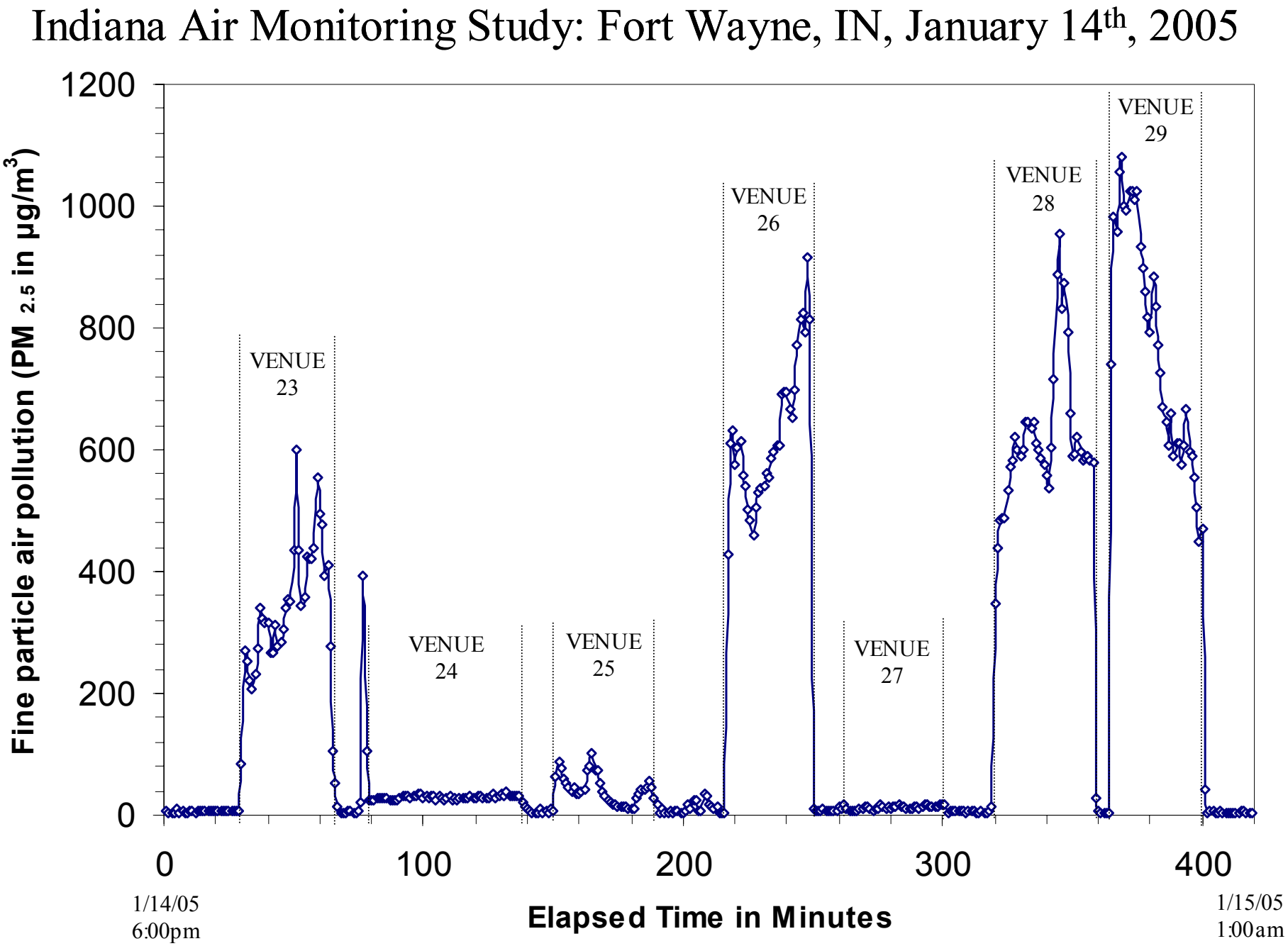


Venue Number	Size (m3)	# people in venue	Active smoker density*	Average $PM_{2.5}$ level (µg/m^3)
Bars/Restaurants Where Smoking Was Occuring During Sampling				
23	943	78	0.42	358
25	834	32	0.08	40
26	502	45	1.40	632
28	1370	89	0.32	629
29	471	85	2.27	787
Average	824	66	0.90	489
Smoke-free Restaurants				
24	340	28	0.00	29
27	815	48	0.00	13
30	617	108	0.00	22
Average	591	61	0.00	21
Overall average	736	64	0.56	314

NOTES:

* Average number of burning cigarettes per $100m^3$

Figure 14.


Indiana Air Monitoring Study: Fort Wayne, IN, January 14th, 2005
Fine particle air pollution (PM 2.5 in µg/m3)
1200
1000
800
600
400
200
0
VENUE 23
VENUE 24
VENUE 25
VENUE 26
VENUE 27
VENUE 28
VENUE 29
0
100
200
300
400
1/14/05 6:00pm
Elapsed Time in Minutes
1/15/05 1:00am

Discussion

This study demonstrates that laws to eliminate smoking in enclosed workplaces and public places dramatically reduces the levels of $PM_{2.5}$ in a wide range of hospitality venues. The implementation of a citywide law in Bloomington providing a completely smoke-free indoor work environment led to an average 89% reduction in $PM_{2.5}$ levels. This result is statistically significant ($p<0.001$) according to the Mann Whitney U-Test. This estimate represents the level of indoor air pollution reductions observed in a real-life setting because it includes data categorized according to the citywide law regulating smoking in bars and restaurants. During the observational period, smoking was observed in one venue that was required to be smoke-free after the law went into effect. When the analysis is restricted to those venues that were actually compliant with the law, the level of indoor air pollution was 95% lower after the law went into effect.

In contrast to the low levels of indoor air pollution found post-law in Bloomington bars and restaurants, the levels were dramatically higher in two other Indiana cities, Indianapolis and Fort Wayne. Indianapolis, which has no clean indoor air legislation, had average $PM_{2.5}$ levels that were 14-fold higher than in smoke-free Bloomington. Fort Wayne, which had limited clean indoor air provisions providing only for separate enclosed smoking areas in restaurants, had average $PM_{2.5}$ levels that were 10-fold higher than in smoke-free Bloomington. These differences are statistically significant ($p<0.001$) according to the Wilcoxon signed-rank test.

The findings of this study are consistent with those of similar previous studies. For example, one study found a similar 90% decline in RSP levels in 8 hospitality venues in Delaware after smoking was prohibited there by a state law[8]. Another study found a similar 90% decline in RSP levels in 14 bars and restaurants in Western New York after a clean indoor air law went into effect.[9]

This study adds to the evidence that smoke-free policies provide employees and patrons protection from the health effects associated with secondhand smoke exposure. Several previous studies have assessed this more directly. For example, one study found that respiratory health improved rapidly in a sample of bartenders after a state clean smoke-free workplace law was implemented in California[10], and another study reported a 40% reduction in acute myocardial infarctions admitted to a regional hospital during the 6 months that a local smoke-free ordinance was in effect[11]. While this study does not assess health effects, it does provide a strong measure of secondhand smoke exposure reduction likely to be experienced by hospitality workers when their worksites become smoke-free.

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 in order to protect the public health[6]. The average $PM_{2.5}$ level observed in venues where smoking was permitted without restriction was 420 $\mu g/m^3$. For a full-time employee in such a venue, the average annual limit is exceeded by 7-fold (assuming zero exposure to $PM_{2.5}$ off the job and a 40 hour work week) and the 24-hour exposure limit is exceeded on a daily basis, on average, when the employee is on the job. Based on the latest scientific evidence the EPA staff currently proposes even lower $PM_{2.5}$ standards to adequately protect the public health,[12] making the high $PM_{2.5}$ exposures of people in smoking environments even more alarming.

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. Furthermore, venues were selected in at least two popular entertainment districts in each city to further enhance the sample representation. The finding that levels of $PM_{2.5}$ were consistently lower in locations that were required to be smoke-free by law compared to venues without such regulations across several cities and a variety

of types of hospitality venues provides evidence that these results may be generalizable to other venues, cities, states, and nations. 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.

In summary, results indicate that the level of indoor air pollution was more than 90% reduced in venues in a city that require bars and restaurants to provide a smoke-free environment compared to those venues in cities without such restrictions. Policies that remove secondhand smoke are an effective strategy to reduce workers exposure to this toxin, which may translate into improved health outcomes for these employees.

Acknowledgement

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