

Wyoming Air Monitoring Study

August 2005

A Report to the Wyoming Department of Health,
Substance Abuse Division

by

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Under contract with WYSAC, Roswell Park Cancer Institute (RPCI) staff partnered with WYSAC staff to conduct this study and write this report. RPCI's effort was subsidized with additional funding from the Flight Attendant Medical Research Institute.

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Organization of this report

The Introduction to this report summarizes the purpose of the study and the health consequences of secondhand smoke (SHS) as they relate to the findings of this study. Second, the Methods section provides an overview of the study design, the measurement protocol that was used, and a summary of the statistical methods used to analyze the results. Third, the Key Findings section provides a concise presentation of the most relevant findings of this study. Next, the complete findings of the study are presented in the Results Section. This report is concluded with a Discussion section.

Introduction

The purpose of this study was to examine indoor air quality in a sample of bars and restaurants in two Wyoming cities, Laramie and Cheyenne. The relation between indoor air pollution, the presence of smoke-free regulations, and the presence of on-premises smoking was assessed. These associations were assessed across both cities and also longitudinally in Laramie where locations were visited before and after the implementation of a clean indoor air law prohibiting smoking in these locations. It was hypothesized that indoor air quality would be greater in those venues where smoking is prohibited by law and where smoking does not occur, than in those places where smoking is unregulated. It was also hypothesized that the improvement in indoor air quality would be consistent across study locations.

The Wyoming Survey & Analysis Center (WYSAC) is under contract with the Substance Abuse Division (SAD) of the Wyoming Department of Health to evaluate the impact of state tobacco prevention and control efforts as well as measures enacted by state and local governments that influence the sale and use of tobacco products. On behalf of SAD, WYSAC's tobacco evaluation team is undertaking a comprehensive study of the Laramie ordinance that includes air quality monitoring, an analysis of cotinine in bar patrons, an analysis of economic impact, a documentary film, and a series of telephone surveys designed to assess possible changes in attitudes, knowledge, and behaviors of Laramie residents

Secondhand smoke (SHS) contains at least 250 chemicals that are known to be toxic or carcinogenic, and is itself a known human carcinogenⁱ, 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 childrenⁱⁱ. 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 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, Maine, Connecticut, Massachusetts, Rhode Island, Vermont and Montana), 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 EPA cited over 80 epidemiologic studies in creating a particulate air pollution standard in 1997^{vi}. In order to protect the public health, the EPA has set limits of 15 $\mu\text{g}/\text{m}^3$ as the average annual level of $\text{PM}_{2.5}$ exposure and 65 $\mu\text{g}/\text{m}^3$ 24-hour exposure^{vi}. $\text{PM}_{2.5}$ 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.

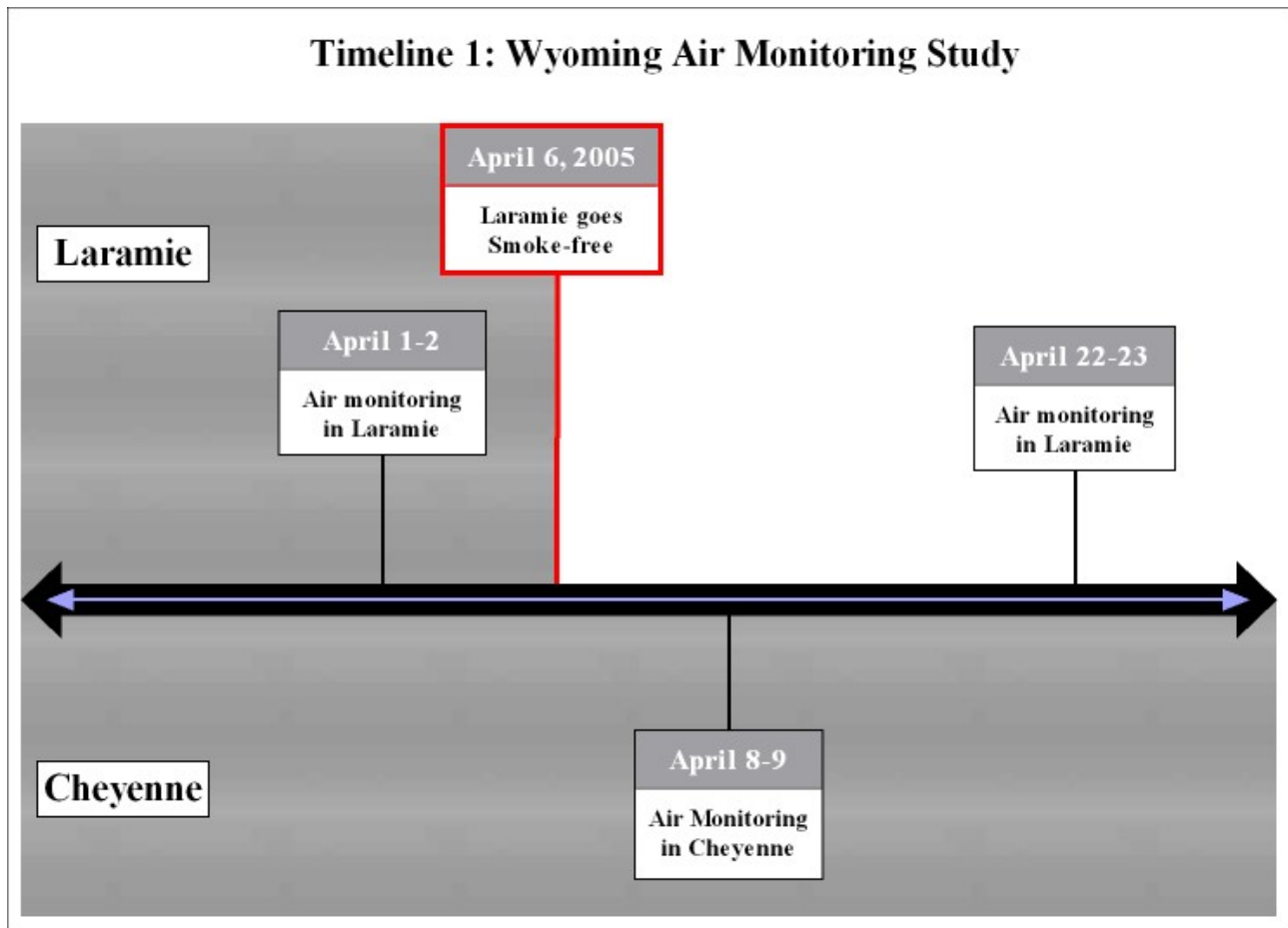
Previous studies have evaluated air quality by measuring the change in levels of respirable suspended particles (RSP) between smoke-free venues and those that permit smoking. Ott et al. did a study of a single tavern in California and showed an 82% average decrease in RSP levels after smoking was prohibited by a city ordinance^{vii}. 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^{viii}. 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.^{ix}

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 smoke-free workplace law was implemented in California^x, 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^{xi}.

Methods

Overview

Between April 1st, 2005 and April 23rd, 2005, indoor air quality was assessed in 37 hospitality venues including bars, restaurants, bowling alleys, dance clubs and pool halls, in two Wyoming cities, Laramie and Cheyenne. Eighteen of the nineteen locations in Laramie were visited once before and once after the implementation of a local clean indoor air law that went into effect on April 6th, 2005 (Timeline 1, next page). Original Ordinance No. 1650 amended Chapter 8.56 and Chapter 8.32 of the Laramie Municipal Code to prohibit smoking in enclosed areas to which the public has access and places of employment, including but not limited to, restaurants, bars and private clubs, thus making essentially all public places in the city smoke free. Laramie is the first Wyoming city to implement a comprehensive smoke-free ordinance.



Laramie, the third largest city in the state and home to the University of Wyoming has approximately 27,000 residents and is located 45 miles west of Cheyenne at an elevation of 7,200 feet. Cheyenne is an active economic, cultural and political center for the northern plains and is the capital of the state of Wyoming. Located in southeast Wyoming at an elevation of 6,062 feet, Cheyenne has a population of approximately 53,000 and is little more than an hour's drive from Denver, Colorado. There is no law restricting smoking in restaurants, bars or other hospitality venues in Cheyenne. There are no smoke-free policies at the state level regarding restaurants, bars, workplaces, or public places. Wyoming communities are not preempted in passing local ordinances.

Procedure for Selection of Cities and Venues to be Sampled

The cities were selected to represent well populated but geographically different areas of Wyoming 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 venues 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 city 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. All but one of the 55 total sampling visits occurred on Friday and Saturday evenings from 4:30PM to 1:30AM. One visit occurred on Saturday afternoon from 12:20PM to 1:20pm. 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 (µg/m ³)
1a	Laramie	No	No	4/1/2005	771	0.00	8
1b	Laramie	Yes	No	4/22/2005	771	0.00	32
2a	Laramie	No	Yes	4/1/2005	1397	0.55	363
2b	Laramie	Yes	No	4/22/2005	1397	0.00	12
3a	Laramie	No	Yes	4/1/2005	3471	0.10	56
3b	Laramie	Yes	No	4/22/2005	3471	0.00	7
4a	Laramie	No	Yes	4/1/2005	452	0.88	193
4b	Laramie	Yes	No	4/22/2005	452	0.00	5
5a	Laramie	No	Yes	4/1/2005	917	1.89	603
5b	Laramie	Yes	No	4/22/2005	917	0.00	24
6a	Laramie	No	Yes	4/1/2005	228	1.46	453
6b	Laramie	Yes	No	4/22/2005	228	0.00	18
7a	Laramie	No	No	4/1/2005	554	0.00	7
7b	Laramie	Yes	No	4/22/2005	554	0.00	9
8a	Laramie	No	Yes	4/1/2005	487	0.75	185
8b	Laramie	Yes	No	4/22/2005	487	0.00	9
9a	Laramie	No	Yes	4/1/2005	1284	0.34	23
9b	Laramie	NA	NA	NA	NA	NA	NA
10a	Laramie	No	Yes	4/2/2005	322	1.24	28
10b	Laramie	Yes	No	4/23/2005	322	0.00	10
11a	Laramie	No	Yes	4/2/2005	706	0.19	156
11b	Laramie	Yes	No	4/23/2005	706	0.00	6
12a	Laramie	No	No	4/2/2005	292	0.00	10
12b	Laramie	Yes	No	4/23/2005	292	0.00	15
13a	Laramie	No	Yes	4/2/2005	331	1.11	180
13b	Laramie	Yes	No	4/23/2005	331	0.00	7
14a	Laramie	No	Yes	4/2/2005	147	0.91	87
14b	Laramie	Yes	No	4/23/2005	147	0.00	11
15a	Laramie	No	Yes	4/2/2005	218	1.07	146
15b	Laramie	Yes	No	4/23/2005	218	0.00	9
16a	Laramie	No	No	4/2/2005	373	0.00	6
16b	Laramie	Yes	No	4/23/2005	373	0.00	12
17a	Laramie	No	Yes	4/2/2005	875	0.42	416
17b	Laramie	Yes	No	4/23/2005	875	0.00	13
18a	Laramie	No	Yes	4/2/2005	2358	0.25	422
18b	Laramie	Yes	No	4/23/2005	2358	0.00	8
19a	Laramie	No	Yes	4/2/2005	729	0.00	38
19b	Laramie	Yes	No	4/23/2005	729	0.00	4
20	Cheyenne	No	Yes	4/8/2005	112	0.89	36
21	Cheyenne	No	Yes	4/8/2005	1312	0.33	147
22	Cheyenne	No	Yes	4/8/2005	561	1.19	279
23	Cheyenne	No	No	4/8/2005	702	0.00	7
24	Cheyenne	No	Yes	4/8/2005	602	1.33	288
25	Cheyenne	No	Yes	4/8/2005	700	1.05	395
26	Cheyenne	No	Yes	4/8/2005	84	3.95	77
27	Cheyenne	No	Yes	4/8/2005	231	4.34	781
28	Cheyenne	No	Yes	4/8/2005	812	0.04	43
29	Cheyenne	No	Yes	4/9/2005	1133	0.15	25
30	Cheyenne	No	Yes	4/9/2005	2309	0.14	144
31	Cheyenne	No	Yes	4/9/2005	202	0.50	15
32	Cheyenne	No	Yes	4/9/2005	195	1.71	378
33	Cheyenne	No	Yes	4/9/2005	668	1.00	295
34	Cheyenne	No	Yes	4/9/2005	1203	0.33	81
35	Cheyenne	No	Yes	4/9/2005	1464	0.48	155
36	Cheyenne	No	Yes	4/9/2005	1620	1.85	457
37	Cheyenne	No	Yes	4/9/2005	1231	0.38	198
Avg.					831	0.56	134

* 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 100m³

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 $2.5\mu\text{m}$ 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 $\text{PM}_{2.5}$ 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^{viii}.

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 $\text{PM}_{2.5}$ 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. The second goal was to assess the change in average levels of RSP longitudinally in a sample of places in Laramie 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.

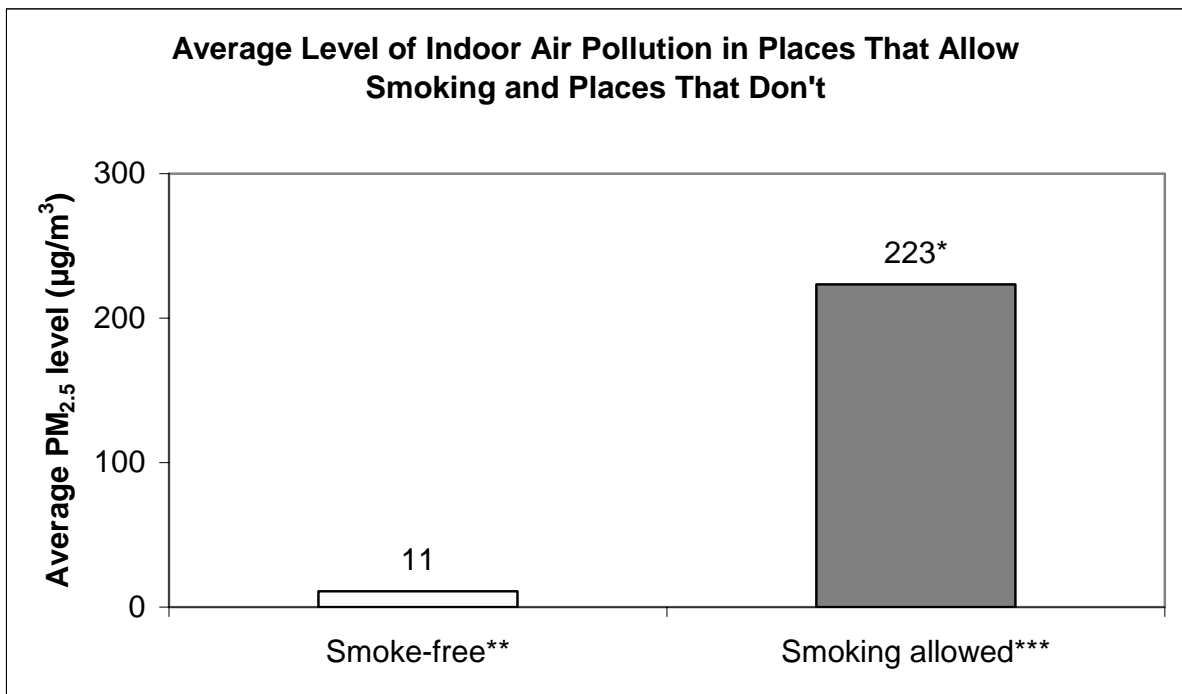
Key Findings

Indoor air quality was assessed in 37 bars, restaurants and other hospitality establishments between April 1st and April 23rd, 2005 using the TSI SidePak AM510 Personal Aerosol Monitor. Venues were sampled in two Wyoming cities, Laramie and Cheyenne. Eighteen of the nineteen locations in Laramie were visited twice, once before and once after the implementation of a clean indoor air law requiring all indoor public places to be smoke-free, to determine the change in air quality in these venues. Key findings of the study include:

- Overall, across both cities the level of indoor air pollution as measured by average PM_{2.5} Level (Box 1) was 95% lower in the venues that were smoke-free compared to those where smoking was permitted (Figure 1).

Box 1: 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.

Figure 1. Fine Particle Air Pollution in All Wyoming Venues, April 1, 2005 to April 23, 2005



* p-value < 0.001 (Mann Whitney U-test)

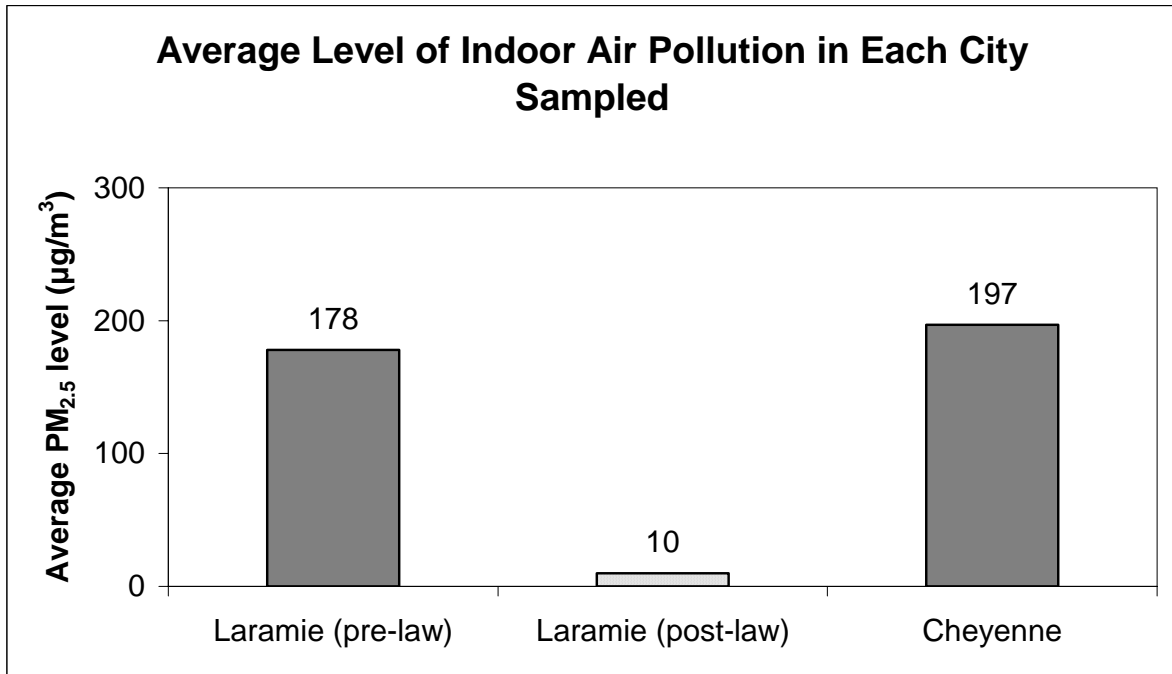
** These 23 venues were either voluntarily smoke-free or smoke-free by law and no smoking was observed in any of them during air monitoring

*** These 32 venues had no smoking restrictions in place

- The level of PM_{2.5} decreased by 96% in eighteen venues sampled in Laramie after indoor smoking was prohibited by local ordinance. In the four Laramie venues that were smoke-free at baseline the levels of PM_{2.5} were low and unchanged.

- The average level of indoor air pollution in Cheyenne hospitality venues (197 $\mu\text{g}/\text{m}^3$ of $\text{PM}_{2.5}$) was 20-times higher than in smoke-free Laramie.

Figure 2. $\text{PM}_{2.5}$ Levels in 2 Wyoming Cities, April 1 to 23, 2005



City	Total # of locations	# of smoke-free venues	Avg. size (m^3)	Avg. # people in venue	Avg. active smoker density*	Average $\text{PM}_{2.5}$ level ($\mu\text{g}/\text{m}^3$)
Laramie (pre-law)	19	4	837	50	0.59	178
Laramie (post-law)	18	18	813	59	0.00	10
Cheyenne	18	1	768	45	1.09	197

NOTES:

* Average number of burning cigarettes per 100m^3

- 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 $\text{PM}_{2.5}$ observed in venues where smoking was allowed in this study ($223 \mu\text{g}/\text{m}^3$), full-time bar and restaurant employees are exposed on the job to four times the annual limit of fine particulate air pollution recommended by the U.S. Environmental Protection Agency.
- In post-law Laramie, observed compliance was high – no smoking was observed in any of the venues that were required to be smoke-free by law (100% compliance).

Results

The average time spent for each visit was 38 minutes (range, 30 minutes to 64 minutes). There were 55 total visits to 37 individual establishments in this study with 2 visits to 18 of the 19 locations in Laramie, one before and one after the implementation of their recent clean indoor air law. Across all 55 total visits in this study (including 2 visits to the 18 Laramie locations), 23 of the venues were smoke-free at the time of the visit and the average RSP level in these venues was $11 \mu\text{g}/\text{m}^3$. Thirty-two places were sampled that allowed smoking in the establishment, and the average RSP level in these venues was $223 \mu\text{g}/\text{m}^3$ (Figure 1). The level of indoor air pollution was 95% 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 831 m^3 and was comparable between places where smoking was allowed and where it was not (886 m^3 vs. 753 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. 0.96 burning cigarettes per 100 m^3).

There was 100% compliance in this study with smoke-free policies and the smoke-free law in Laramie. In other words, no smoking was observed during any of the visits when the venue either had a smoke-free policy of their own (n=5) or was required to be smoke-free by law (n=18).

Averaged across each city, the lowest levels of indoor air pollution were found in Laramie post-law ($10 \mu\text{g}/\text{m}^3$) and the highest levels were found in Cheyenne ($197 \mu\text{g}/\text{m}^3$) where there is no clean indoor air legislation. Pre-law Laramie had a somewhat lower average RSP than Cheyenne ($178 \mu\text{g}/\text{m}^3$). See Figure 2.

Details on the level of indoor air pollution in each city sampled are presented in Figures 4 through 15. Results from the real-time $\text{PM}_{2.5}$ 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.

Laramie, WY – April 1-2, 2005 (Figures 4,5,6)

Nineteen venues were sampled in Laramie, Wyoming on April 1 and April 2, 2005. There were no laws restricting smoking in indoor places in effect during this sampling period. Of the nineteen venues sampled, smoking was observed in fifteen venues and no smoking was observed in four venues. The four venues where no smoking was observed included one restaurant with bar that just happened to have no one smoking during the sampling visit as well as one bar and two restaurants with bars that had no smoking policies. The fifteen locations where smoking was observed included five restaurants with bars, eight bars, two restaurants, one pool hall, two dance halls and one bowling alley. Eight locations were sampled on the evening of Friday, April 1 between 6:20PM and 12:40AM. One location was sampled on the afternoon of Saturday, April 2 from 12:20PM to 1:25PM. Ten locations were sampled on the evening of Saturday, April 2 from 5:40PM to 12:55AM. The average number of people in the nineteen venues was 50. In the fifteen venues where smoking was observed, the average room volume was 928 m^3 and the average smoker density was 0.74 burning cigarettes per 100 m^3 . In the four venues where no smoking was observed the average room volume was 498 m^3 and the average smoker density was 0.00 burning cigarettes per 100 m^3 . Average $\text{PM}_{2.5}$ level was $178 \mu\text{g}/\text{m}^3$ for all nineteen venues, but was 28-fold higher in

the fifteen venues where smoking was observed (average $223 \mu\text{g}/\text{m}^3$) compared to the average in the four smoke-free venues (average $8 \mu\text{g}/\text{m}^3$).

Laramie, WY – April 22-23, 2005 (Figures 7,8,9)

Eighteen of the same nineteen locations that were sampled in on April 1-2, 2005 were sampled again on April 22-23, 2005. All of the locations were sampled on the same day of the week and at approximately the same time of day as the earlier visits. As of April 6, 2005, according to Laramie 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 eighteen locations. No smoking was observed in any of the eighteen places (compliance rate = 100%). The average number of people in the eighteen venues was 54. The overall average smoker density was 0.00 burning cigarettes per 100 m^3 . The average $\text{PM}_{2.5}$ level for the eighteen venues was $11 \mu\text{g}/\text{m}^3$. Please note the y-axis scale in Figures 8 and 9 is 1/10 the size of Figures 5 and 6.

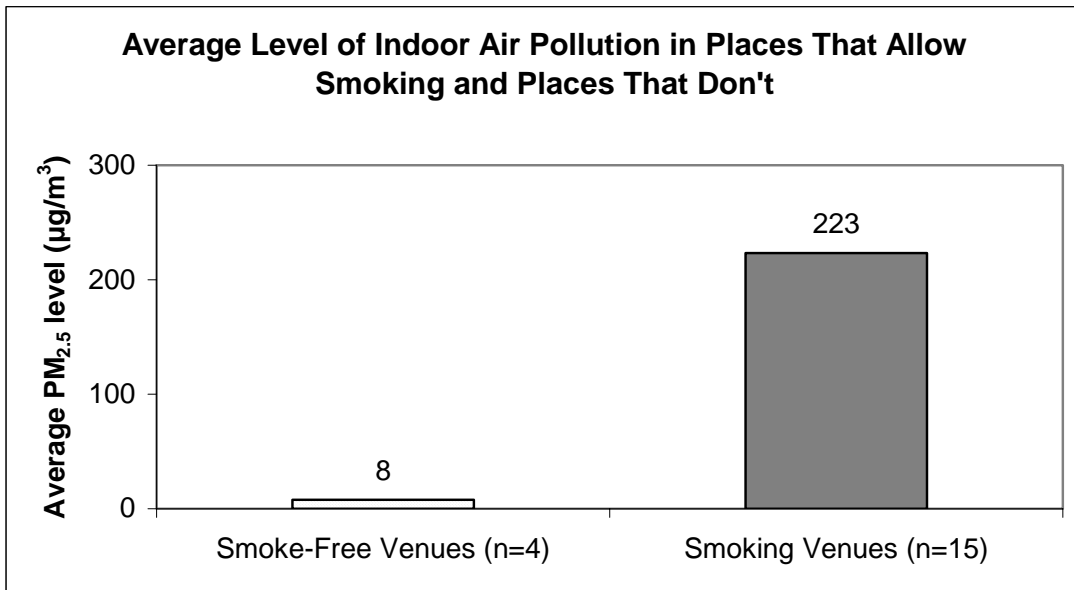
Laramie, WY – Before and After Law comparison (Figures 10,11,12)

As previously stated the indoor air quality was assessed in eighteen locations before and after the implementation of Laramie's smoke-free air law. Four of these locations were smoke-free during the first visit. All eighteen of the places were smoke-free during the second visit in accordance with the smoke-free air law. In the four places that were smoke-free at baseline the average $\text{PM}_{2.5}$ level was $8 \mu\text{g}/\text{m}^3$. In these same four places after the law the average $\text{PM}_{2.5}$ level was $11 \mu\text{g}/\text{m}^3$. In the fourteen places where smoking was observed during the baseline pre-law visit the average $\text{PM}_{2.5}$ level was $223 \mu\text{g}/\text{m}^3$. In these same fourteen places the average $\text{PM}_{2.5}$ level was $10 \mu\text{g}/\text{m}^3$ after the law went into effect. This is a 96% reduction in the level of fine particle air pollutants. Figure 11 shows the real-time plots from Figures 5 and 8 on the same scale. Figure 12 shows the real-time plots from Figures 6 and 9 on the same scale.

Cheyenne, WY – April 8-9, 2005 (Figures 13,14,15)

Eighteen locations were sampled on April 8 and 9, 2005 in Cheyenne, WY. There was no law restricting smoking in indoor public places in effect for Cheyenne. Smoking was observed in seventeen of the eighteen locations sampled. Nine establishments were sampled on the evening of Friday, April 8 from 6:25PM to 1:20AM. Nine more establishments were sampled on the evening of Saturday, April 9 from 4:45PM to 12:40AM. Seventeen of the establishments, including six restaurants with bars, six bars, two restaurants, one pool hall, two dance halls and one bowling alley, allowed smoking and smoking was observed in all of these places. One of the locations, a restaurant with a bar, had a smoke-free policy in effect and no smoking was observed in this establishment. The average volume of the nineteen locations was 768 m^3 and the average smoker density was 1.09 burning cigarettes per 100 m^3 . The average number of people in the venues was 45. Average $\text{PM}_{2.5}$ level was $197 \mu\text{g}/\text{m}^3$ for all nineteen venues. The average $\text{PM}_{2.5}$ level ($223 \mu\text{g}/\text{m}^3$) in the eighteen places with smoking was 26-fold higher than in the one establishment prohibiting indoor smoking ($8 \mu\text{g}/\text{m}^3$).

Figure 4. Pre-Law RSP Levels in bars and restaurants sampled in Laramie, WY, April 1-2, 2005



Venue Number	Size (m ³)	# people in venue	Active smoker density*	Average PM _{2.5} level (µg/m ³)
Bars/Restaurants Where Smoking Was Occuring During Sampling				
2a	1397	42	0.55	363
3a	3471	90	0.10	56
4a	452	55	0.88	193
5a	917	119	1.89	603
6a	228	23	1.46	453
8a	487	97	0.75	185
9a	1284	70	0.34	23
10a	322	26	1.24	28
11a	706	22	0.19	156
13a	331	31	1.11	180
14a	147	15	0.91	87
15a	218	14	1.07	146
17a	875	18	0.42	416
18a	2358	108	0.25	422
19a	729	22	0.00	38
Average	928	50	0.74	223
Smoke-free Bars/Restaurants				
1a	771	149	0.00	8
7a	554	17	0.00	7
12a	292	22	0.00	10
16a	373	21	0.00	6
Average	498	52	0.00	8
Overall	837	50	0.59	178

NOTES: * Average number of burning cigarettes per 100m³

Figure 5.

Wyoming Air Monitoring Study: Laramie, WY, April 1, 2005

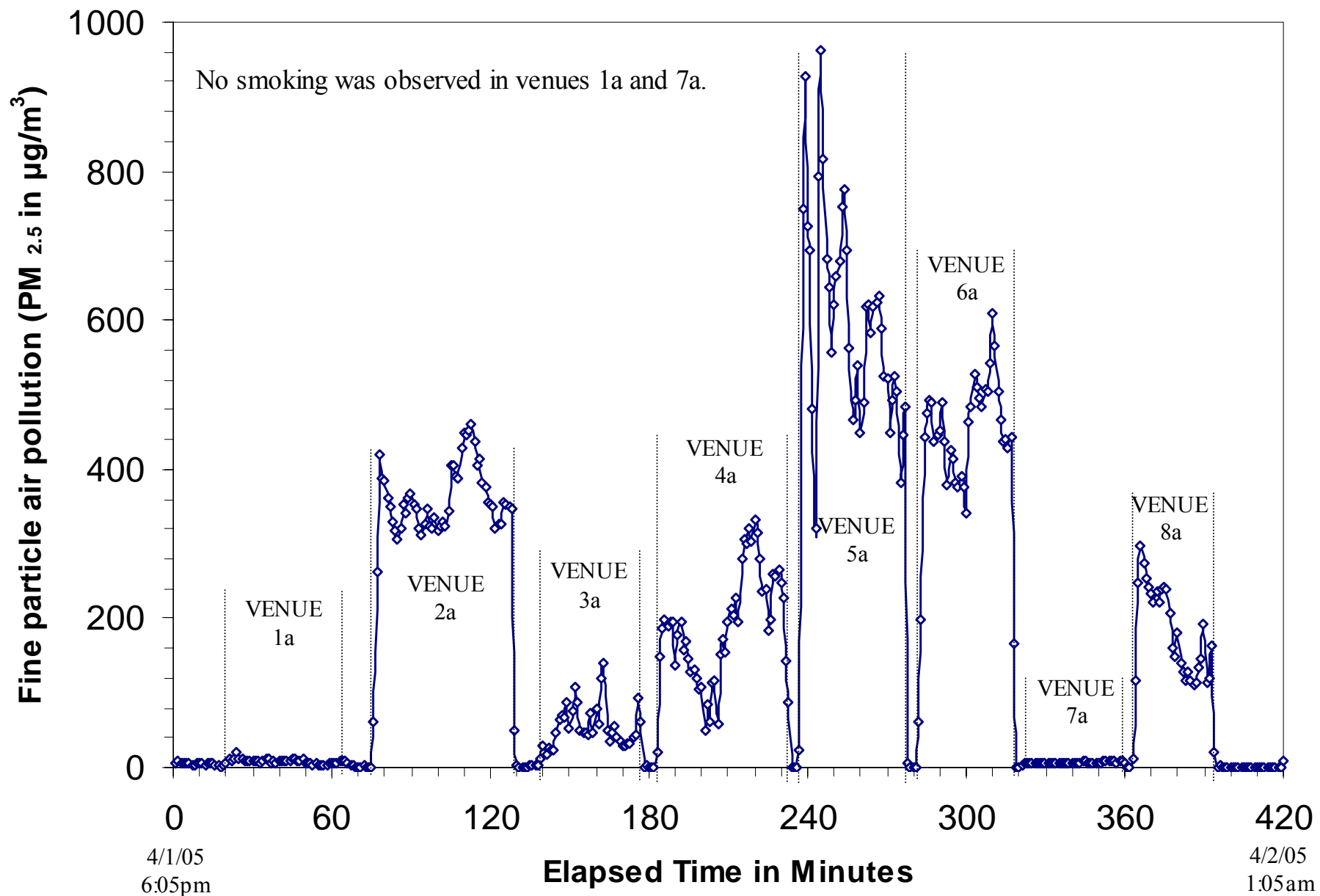


Figure 6.

Wyoming Air Monitoring Study: Laramie, WY, April 2, 2005

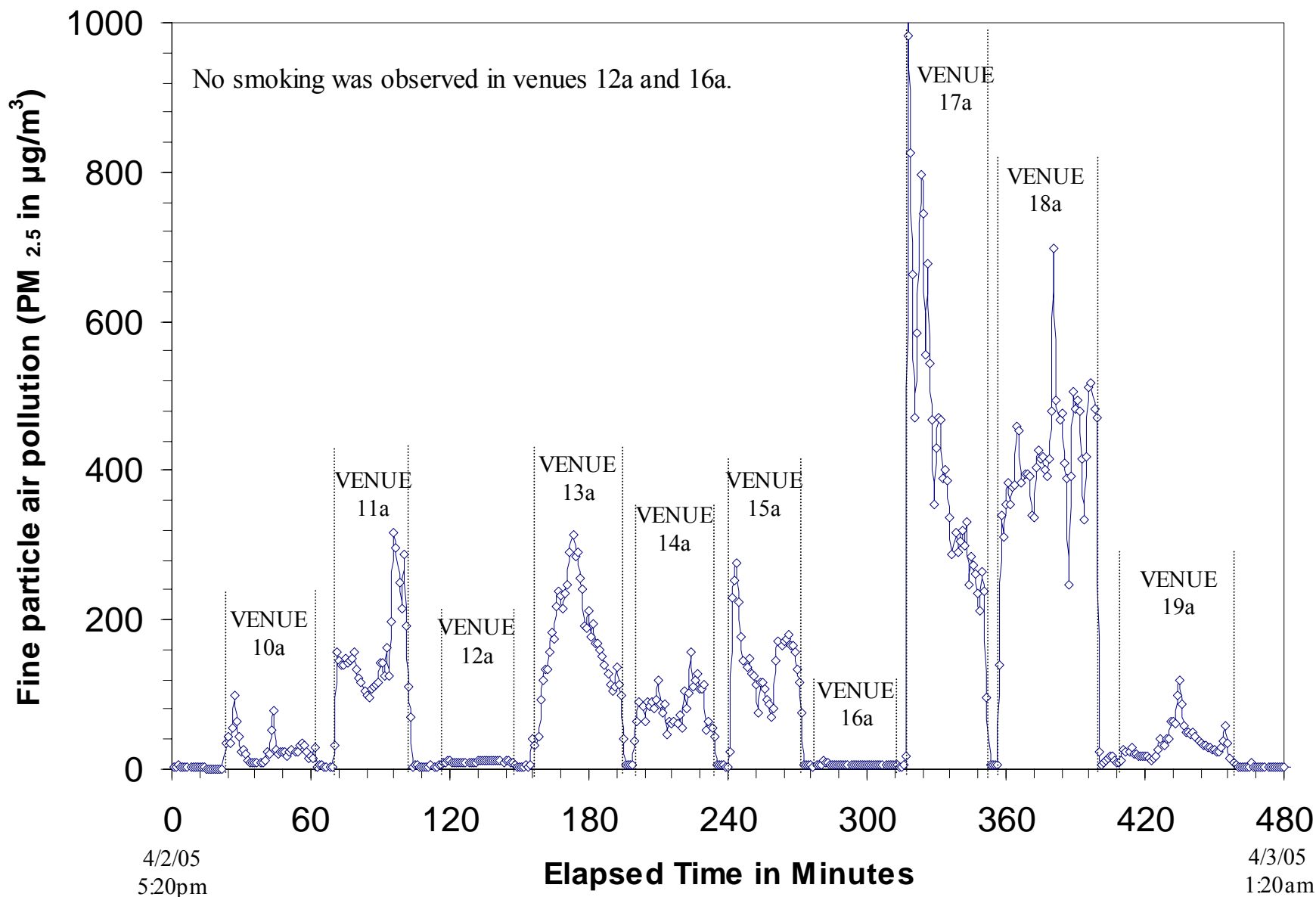
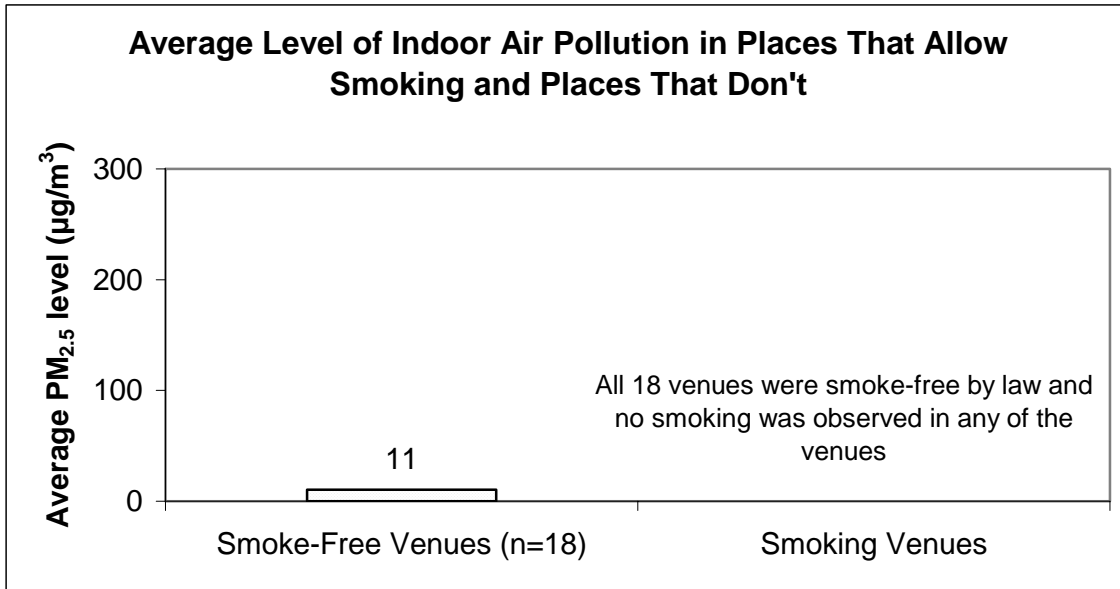


Figure 7. Post-Law RSP Levels in bars and restaurants sampled in Laramie, WY on April 22-23, 2005



Venue Number	Size (m ³)	# people in venue	Active smoker density*	Average PM _{2.5} level (µg/m ³)
All venues were smoke-free by law				
1b	771	149	0.00	8
2b	1397	52	0.00	12
3b	3471	122	0.00	7
4b	452	36	0.00	5
5b	917	120	0.00	24
6b	228	20	0.00	18
7b	554	42	0.00	9
8b	487	122	0.00	9
9b	NA	NA	NA	NA
10b	322	18	0.00	10
11b	706	22	0.00	6
12b	292	13	0.00	15
13b	331	23	0.00	7
14b	147	27	0.00	11
15b	218	7	0.00	9
16b	373	44	0.00	12
17b	875	123	0.00	13
18b	2358	92	0.00	8
19b	729	36	0.00	4
Average	815	54	0.00	11

NOTES:

* Average number of burning cigarettes per 100m³

Figure 8.

Wyoming Air Monitoring Study: Laramie, WY, April 22, 2005

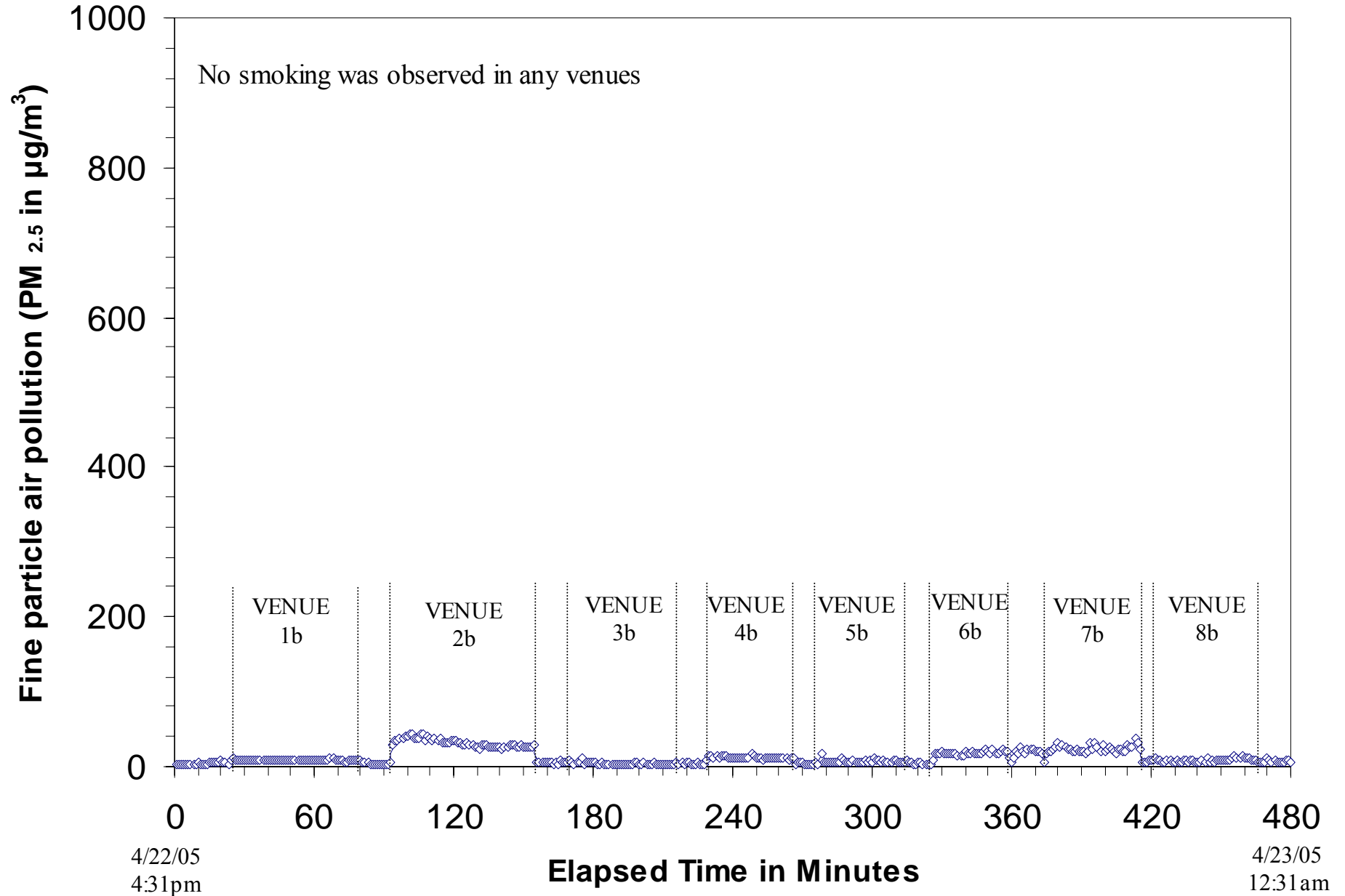


Figure 9.

Wyoming Air Monitoring Study: Laramie, WY, April 23, 2005

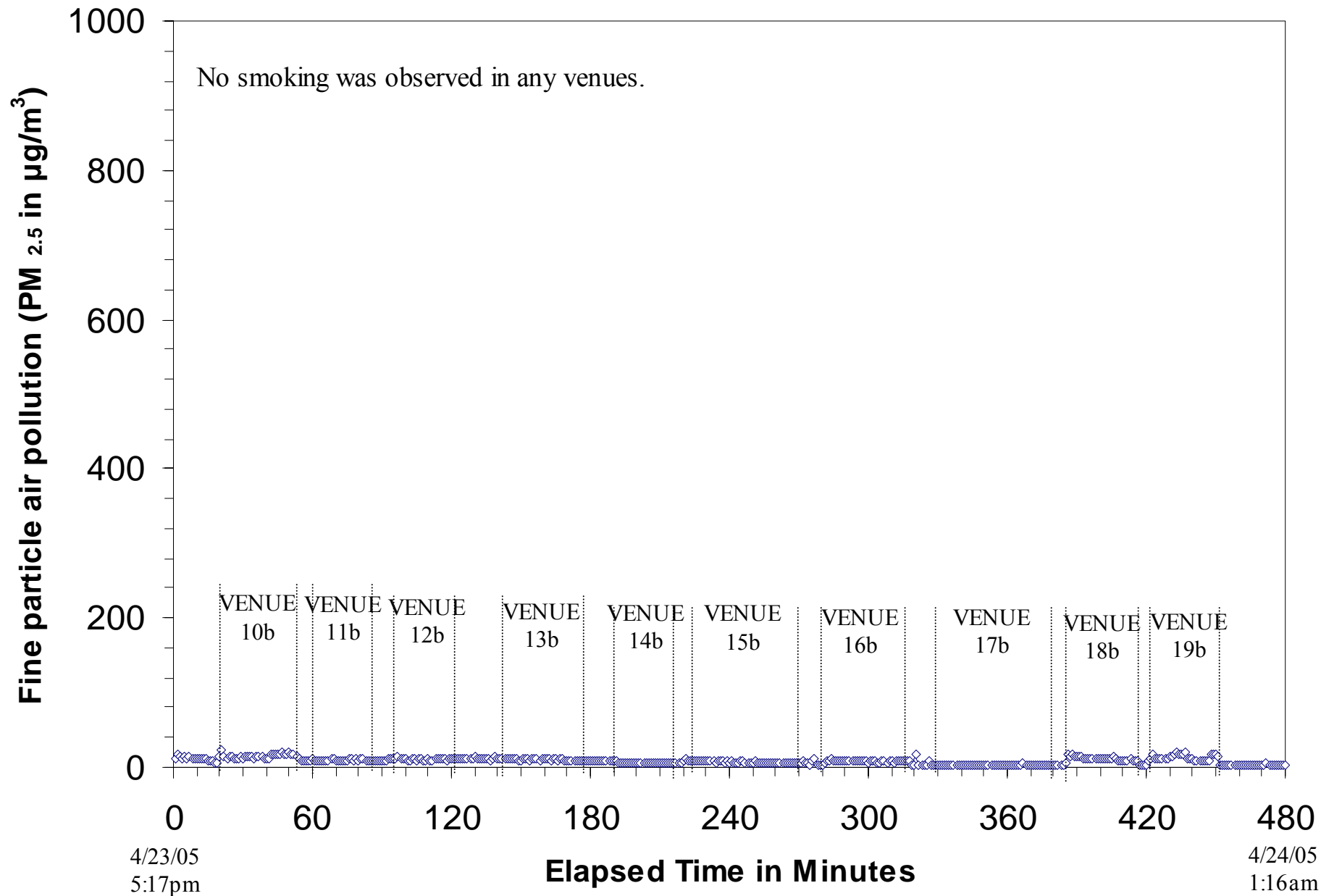
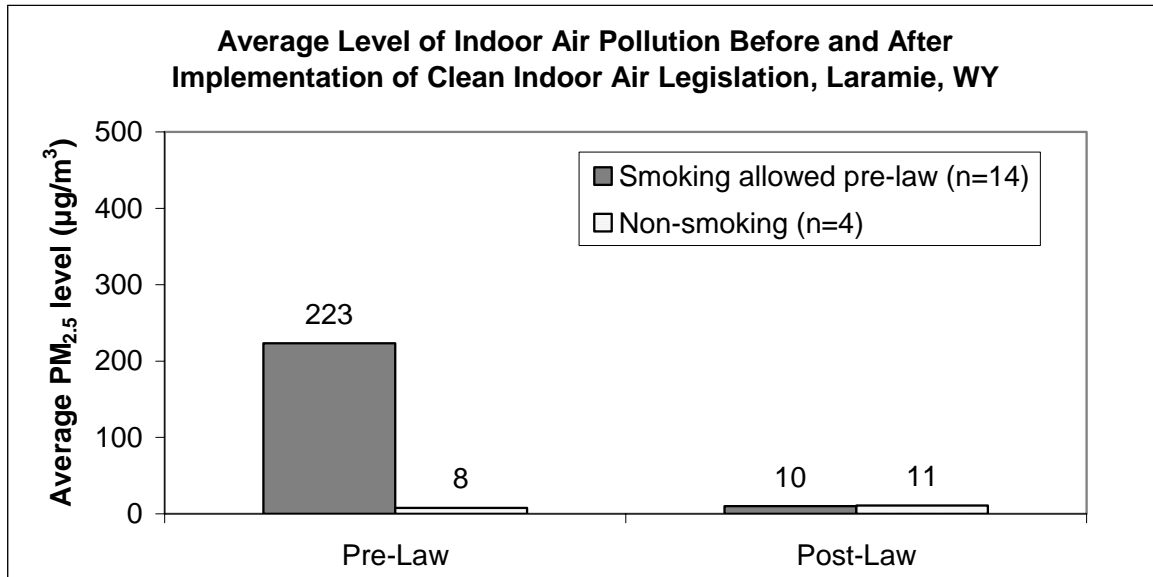


Figure 10. Change in RSP Levels in bars and restaurants sampled in Laramie, WY before and after implementation of a clean indoor air law



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 (µg/m ³) pre-law	Average PM _{2.5} level (µg/m ³) post-law	% Reduction in PM _{2.5}
Non-smoking locations at baseline								
1	771	149	149	0.00	0.00	8	8	
7	554	17	42	0.00	0.00	7	9	
12	292	22	13	0.00	0.00	10	15	
16	373	21	44	0.00	0.00	6	12	
Average	498	52	62	0	0	8	11	
Smoking allowed at baseline								
2	1397	42	52	0.55	0.00	363	12	97%
3	3471	90	122	0.10	0.00	56	7	88%
4	452	55	36	0.88	0.00	193	5	97%
5	917	119	120	1.89	0.00	603	24	96%
6	228	23	20	1.46	0.00	453	18	96%
8	487	97	122	0.75	0.00	185	9	95%
9	1284	70	NA	0.34	NA	23	NA	NA
10	322	26	18	1.24	0.00	28	10	64%
11	706	22	22	0.19	0.00	156	6	96%
13	331	31	23	1.11	0.00	180	7	96%
14	147	15	27	0.91	0.00	87	11	87%
15	218	14	7	1.07	0.00	146	9	94%
17	875	18	123	0.42	0.00	416	13	97%
18	2358	108	92	0.25	0.00	422	8	98%
19	729	22	36	0.00	0.00	38	4	89%
Average	928	50	59	1	0	223	10	92%**

NOTES:

* Average number of burning cigarettes per 100m³

** p < 0.001 (Wilcoxon signed-rank test)

Figure 11.

Laramie, WY Before and After Clean Indoor Air Law (1 of 2)

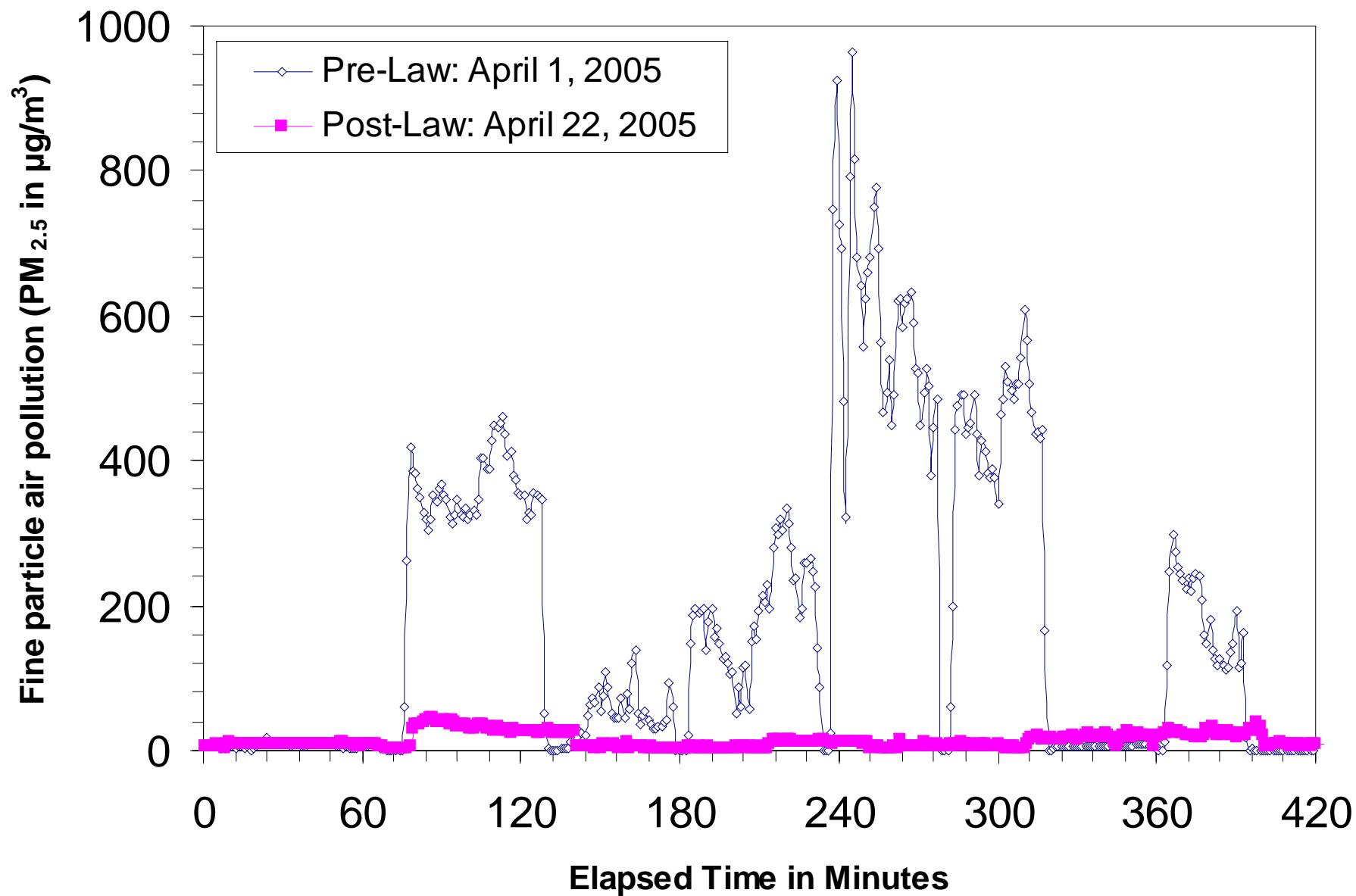


Figure 12.

Laramie, WY Before and After Clean Indoor Air Law (2 of 2)

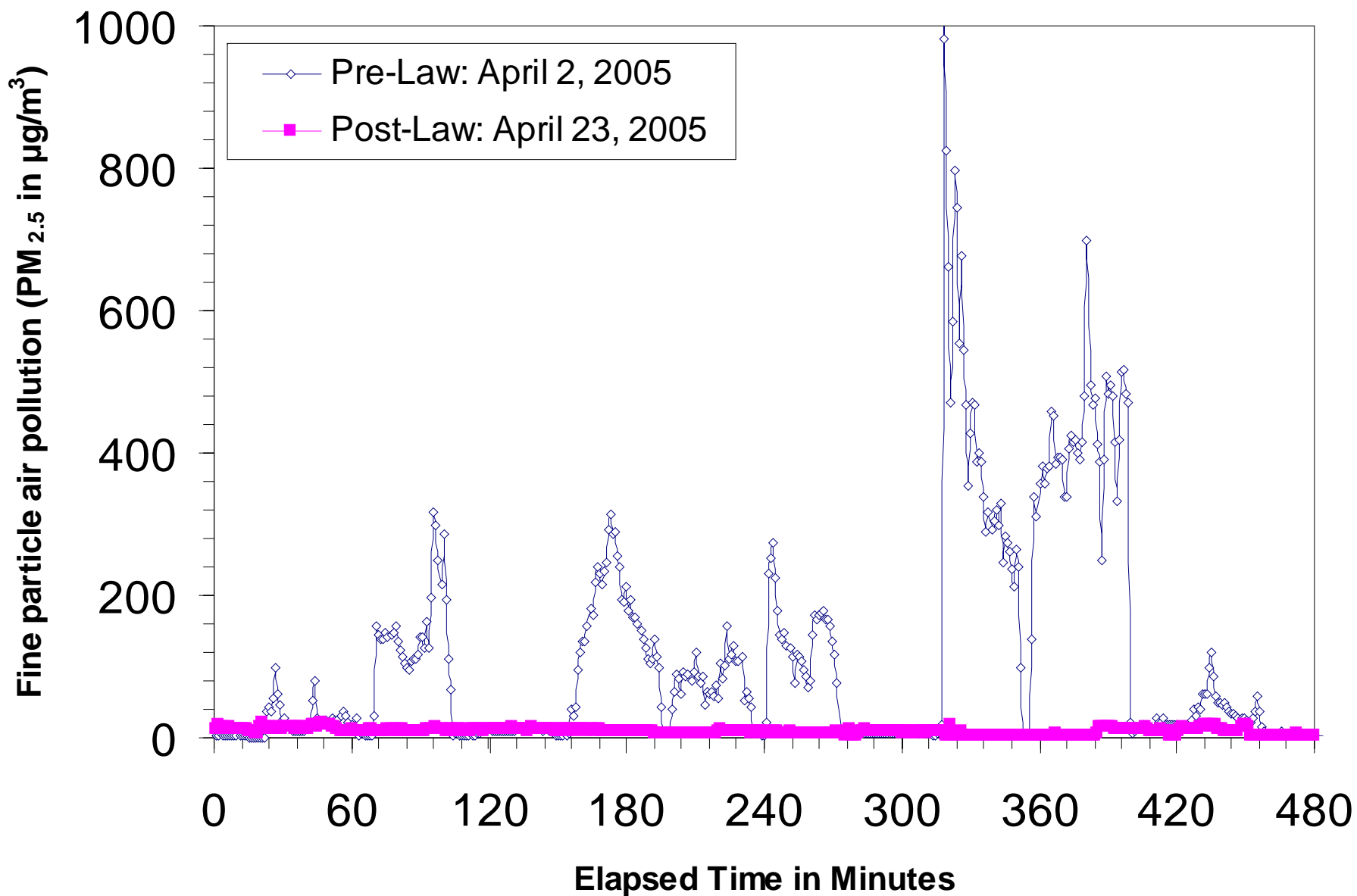
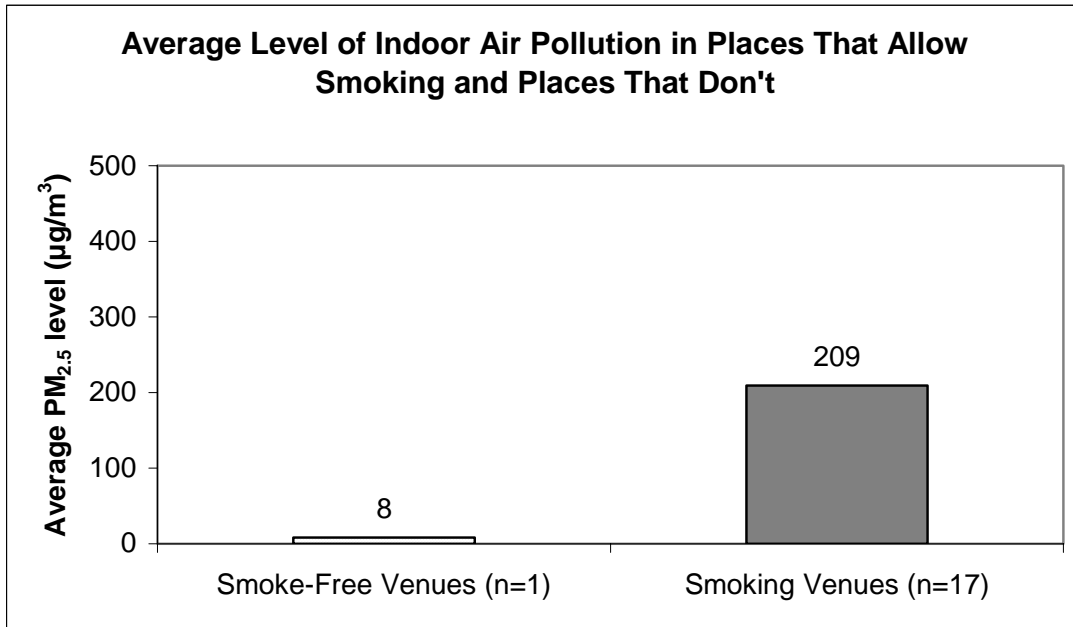


Figure 13. Pre-Law RSP Levels in bars and restaurants sampled in Cheyenne, WY, April 8-9, 2005



Venue Number	Size (m ³)	# people in venue	Active smoker density*	Average PM _{2.5} level (µg/m ³)
Bars/Restaurants Where Smoking Was Occuring During Sampling				
20	112	30	0.89	36
21	1312	28	0.33	147
22	561	58	1.19	279
24	602	47	1.33	288
25	700	64	1.05	395
26	84	20	3.95	77
27	231	78	4.34	781
28	812	18	0.04	43
29	1133	103	0.15	25
30	2309	32	0.14	144
31	202	14	0.50	15
32	195	12	1.71	378
33	668	59	1.00	295
34	1203	25	0.33	81
35	1464	92	0.48	155
36	1620	250	1.85	457
37	1231	29	0.38	198
Average	772	45	1.16	209
Smoke-free Bars/Restaurants				
23	702	41	0.00	8
Average	702	41	0.00	8
Overall	768	45	1.09	197

NOTES: * Average number of burning cigarettes per 100m³

Figure 14.

Wyoming Air Monitoring Study: Cheyenne, WY, April 8, 2005

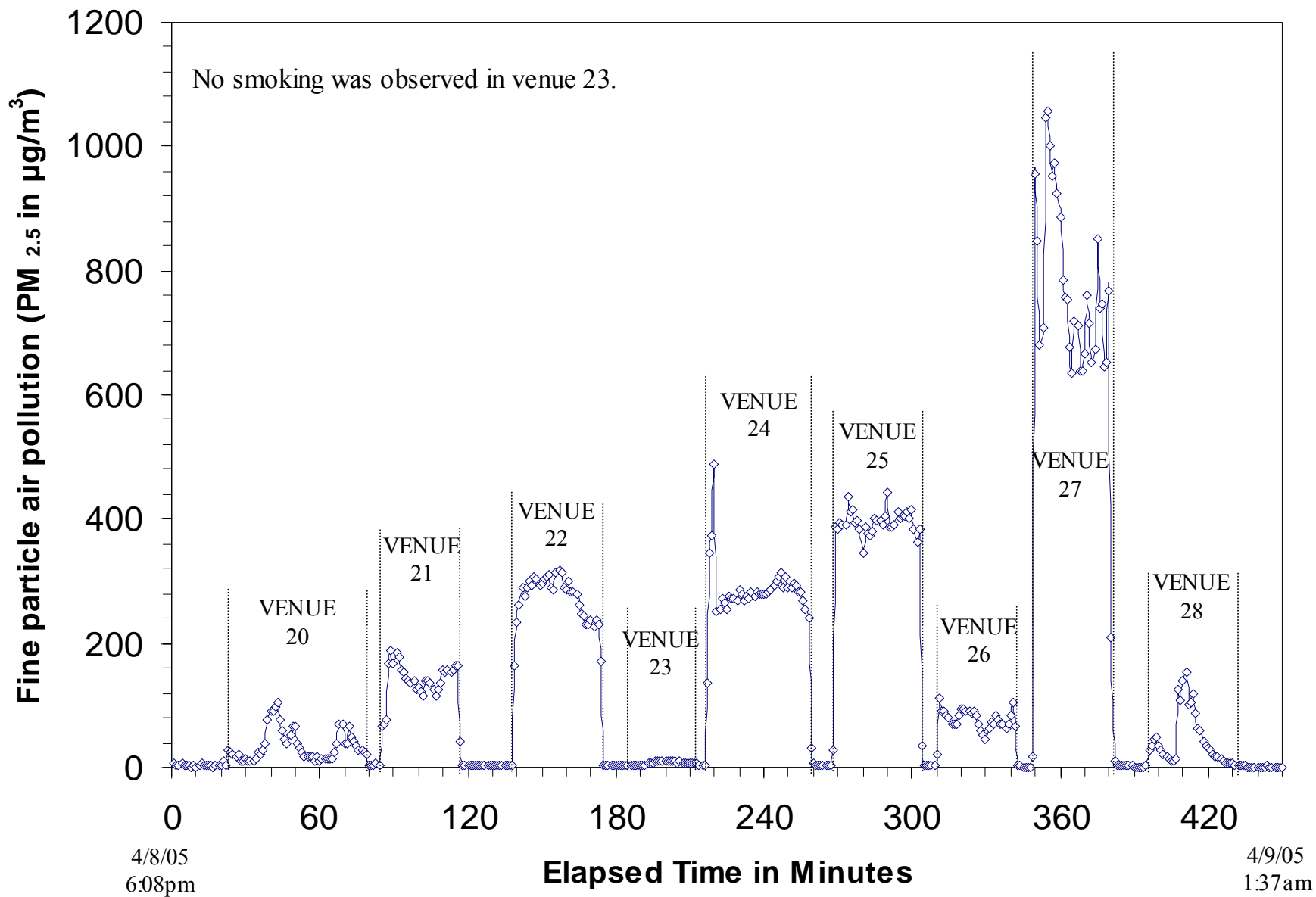
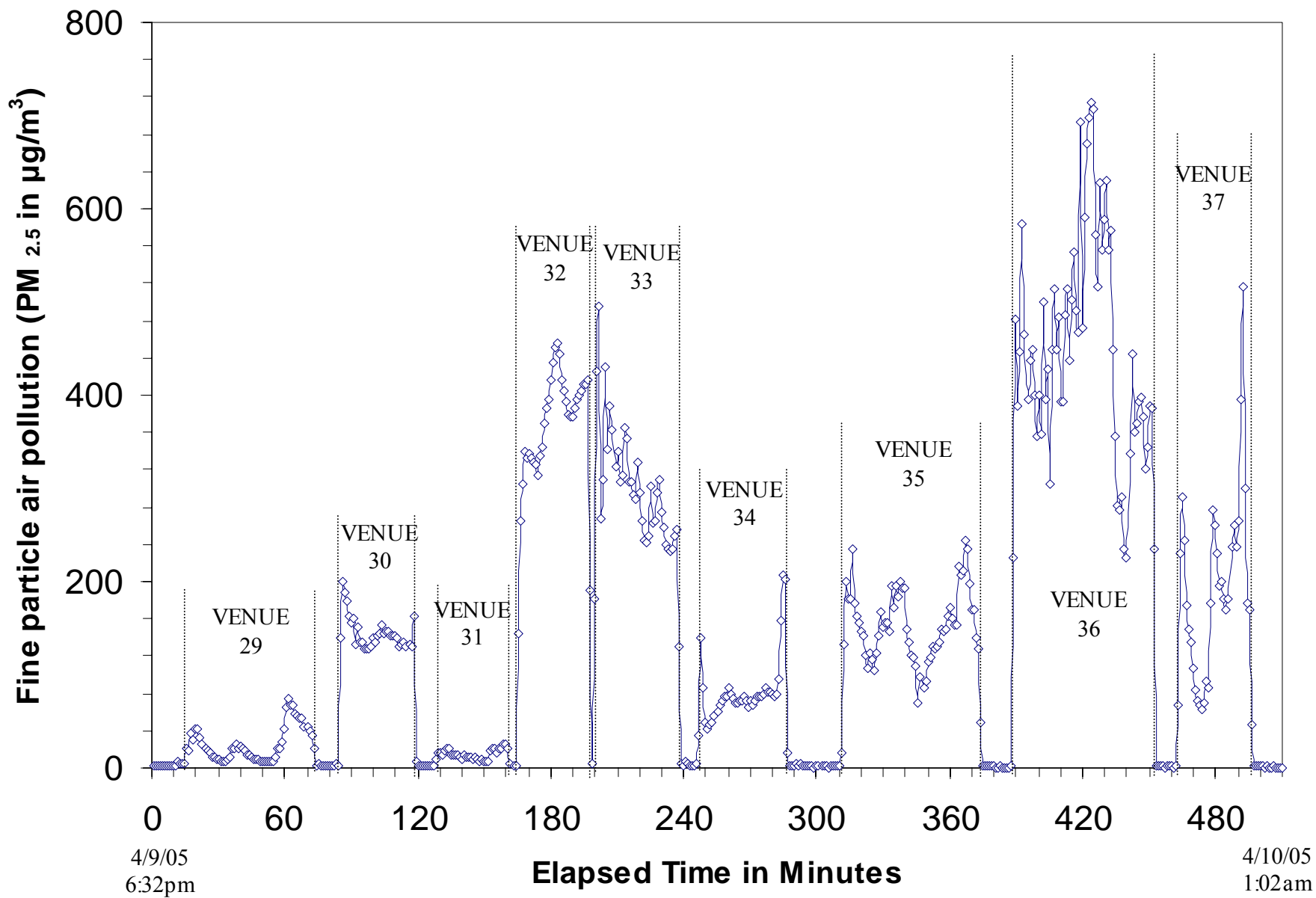


Figure 15.

Wyoming Air Monitoring Study: Cheyenne, WY, April 9, 2005



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 Laramie providing a completely smoke-free indoor work environment led to a 96% reduction in average PM_{2.5} level. This difference is statistically significant ($p < 0.001$) according to the Wilcoxon signed-rank test.

In contrast to the low levels of indoor air pollution found post-law in Laramie hospitality venues, the levels were dramatically higher in Cheyenne, WY. Cheyenne, which has no clean indoor air legislation, had average PM_{2.5} levels that were 20-fold higher than in smoke-free Laramie. This result is statistically significant ($p < 0.001$) according to the Mann Whitney U-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^{viii}. 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 showed an even greater improvement in air quality (96%) in Laramie establishments than in New York and Delaware. This can be explained by the perfect compliance (100%) with the provisions of the smoke-free air law in this study and the very low background concentrations of PM_{2.5} in Laramie.

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^x, 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^{xi}. Indeed, the most recent review article showed that the effects on the cardiovascular system of even brief (minutes to hours) exposure to secondhand smoke are often nearly as large (averaging 80% to 90%) as chronic active smoking.^{xii} 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 $\mu\text{g}/\text{m}^3$ as the average annual level of PM_{2.5} exposure and 65 $\mu\text{g}/\text{m}^3$ 24-hour exposure in order to protect the public health^{vi}. The average PM_{2.5} level observed in venues where smoking was permitted without restriction was 223 $\mu\text{g}/\text{m}^3$. For a full-time employee in such a venue, the average annual limit is exceeded by 4-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,^{xiii} 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. Also, in Laramie air monitoring was done in 15 of the 27 total bars and restaurants (56%) allowing indoor smoking in Laramie. 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 different 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 implementation of a clean indoor air law reduced the levels of harmful indoor air pollution by 96% in a wide range of hospitality venues in Laramie, Wyoming. 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.

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