New Mexico Air Monitoring Study
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Executive Summary

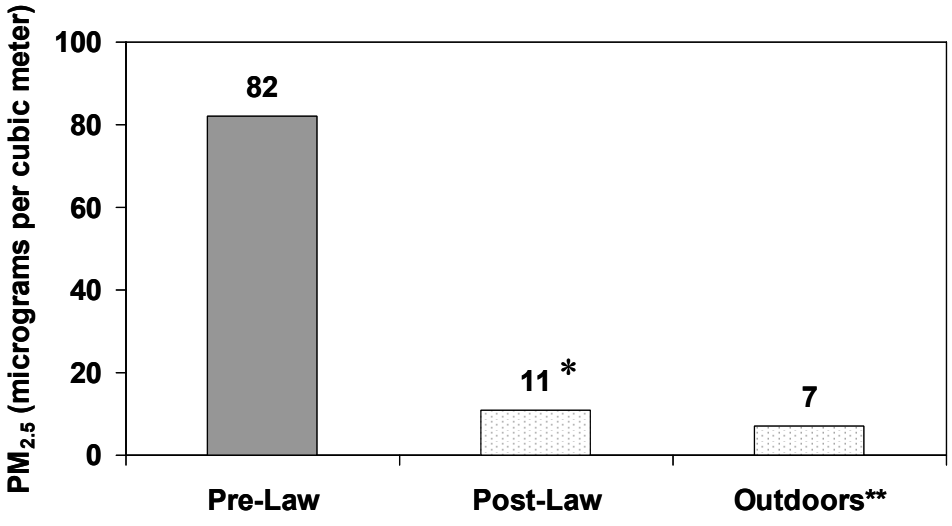
Indoor air quality was assessed in 12 New Mexico hospitality venues including bars, restaurants, and pool halls both before and after the implementation of the New Mexico smoke-free air law on June 15, 2007. The law includes indoor public places and workplaces including stores, offices, bars, and restaurants. The concentration of fine particle air pollution, $PM_{2.5}$, was measured with a TSI SidePak AM510 Personal Aerosol Monitor. $PM_{2.5}$ is 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 cause a variety of adverse health effects including cardiovascular and respiratory morbidity and death.

Key findings of the study include:

- The average level of fine particle indoor air pollution declined 87% after the New Mexico law went into effect.
- Compliance with the law in the twelve places visited was 92%. There was smoking observed in only 1 location after the law went into effect.
- Before the law, employees in sampled locations were exposed to unhealthy air according to U.S. Environmental Protection Agency (EPA) standards. They now work in environments with safe levels of fine particle air pollution.

Before implementation of the New Mexico smoke-free air law, locations allowing indoor smoking were significantly more polluted than indoor smoke-free sites and than outdoor air in New Mexico, with levels of pollution in excess of EPA standards. As a result of the law, air quality is dramatically improved for workers and patrons in New Mexico hospitality venues.

Figure 1. Indoor Air Pollution Before and After New Mexico Clean Indoor Air Law



* Change from pre- to post-law is statistically significant ($p<0.01$)

**2007 average for New Mexico. US EPA AirData Report generated 8/21/07 from http://www.epa.gov/air/data/

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 more than 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 requiring smoke-free environments is 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 and to enforce smoke-free air laws in public places and worksites.[6]

Currently in the U.S., 22 states, Washington, DC, and Puerto Rico have enacted strong smoke-free laws that include restaurants and bars. The states are Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Illinois, Maine, Maryland, Massachusetts, Minnesota, Montana, New Hampshire, New Jersey, New Mexico, New York, Ohio, Oregon, Rhode Island, Utah, Vermont, and Washington (Montana and Utah laws include bars in 2009; Illinois, Maryland, and Oregon laws go into effect in Jan. 2008, Feb. 2008, and Jan. 2009 respectively). Well over 50% of the U.S. population is now protected from secondhand smoke in virtually all public places.[7] Florida, Idaho, Louisiana, Nevada, and North Dakota have smoke-free laws that exempt stand-alone bars. Nine Canadian provinces and territories also have comprehensive smoke-free air laws in effect. Hundreds of cities and counties across the U.S. have also taken action, as have whole countries including Ireland, Scotland, Uruguay, Norway, New Zealand, Sweden, Italy, Spain and England.

On June 15, 2007, New Mexico implemented a comprehensive smoke-free air law. The Dee Johnson Clean Indoor Air Act eliminates smoking in enclosed indoor workspaces including restaurants, bars and other workplaces (retail/office space, etc.) and indoor public places (http://smokefreenm.com/).

The goal of this current study was to evaluate the effect of the new June 15, 2007 law on the level of indoor air pollution in New Mexico worksites that went smoke-free. It was hypothesized that indoor air would be less polluted in venues after the implementation of the law.

Methods

Overview

A total of 12 bars, restaurants, and pool halls were visited both before and after the June 15, 2007 implementation of the New Mexico law prohibiting smoking in indoor public places. The pre-law visits were made in June 2007. Post-law visits were made in July and August, 2007.

Measurement Protocol

Researchers spent a minimum of 30 minutes 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 IntelliMeasure Distance Estimator (Stanley Tools, New Briton, CT) 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 respirable suspended particles in the air. The SidePak uses a built-in sampling pump to draw air through the device where the particulate matter in the air scatters the light from a laser. This portable light-scattering aerosol monitor was fitted with a 2.5 μm impactor in order to measure the concentration of particulate matter with a mass-median aerodynamic diameter less than or equal to 2.5 μm, or $PM_{2.5}$. Tobacco smoke particles are almost exclusively less than 2.5 μm with a mass-median diameter of 0.2 μm.[8] The Sidepak was used with a calibration factor setting of 0.32, suitable for secondhand smoke. 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.[9] Klepeis et al. found a similar SHS calibration factor for the Sidepak when compared to a Piezobalance (Kanomax, Inc.) which provides direct measurements of RSP mass concentrations.[10] This calibration factor has also been confirmed by another researcher who compared Sidepak measurements of SHS to gravimetric measurements using a Personal Environmental Monitor (PEM for PM2.5, MSP Corporation, Shoreview, MN).[11] In addition, the SidePak was zero-calibrated prior to each use by attaching a HEPA filter according to the manufacturer's specifications.

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. 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. Roswell Park Cancer Institute staff analyzed the data.

Statistical Analyses

The primary goal was to assess the change in the average level of $PM_{2.5}$ in worksites and public places after the implementation of a smoke-free air law. Since $PM_{2.5}$ levels are generally log-normally distributed, all statistical testing was performed using log-transformed $PM_{2.5}$ values. Pre- and post-law $PM_{2.5}$ values were compared using a paired samples t-test. Descriptive statistics including the venue volume, number of patrons, and average smoker density (i.e., number of burning cigarettes per 100 m^3) are reported for each venue and averaged for each time period as well.

$PM_{2.5}$ 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.

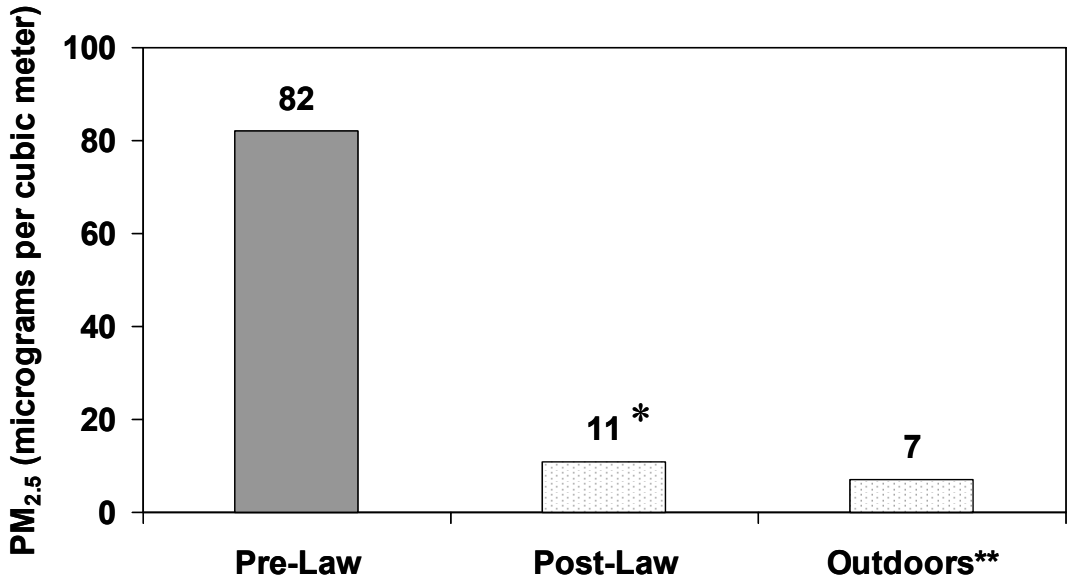
Results

The average $PM_{2.5}$ level in the 12 locations that went smoke-free as a result of the New Mexico law was 82 $\mu g/m^3$ before the law and 11 $\mu g/m^3$ after the law. This was a decrease of 87% in fine particle indoor air pollution. These aggregate results are shown in Figure 1. The average number of burning cigarettes decreased from 6.5 cigarettes to 0.1 and the average active smoker density decreased from 0.70 burning cigarettes per 100 m^3 to 0.01 in these locations.

$PM_{2.5}$ concentrations decreased after the law in all 12 places where data was collected both before and after the law. There was no smoking observed in 11 of the 12 locations after the law (92%). One location had one observed cigarette and this place had the highest post-law $PM_{2.5}$ level.

There are 11 outdoor air monitoring sites in New Mexico that use the EPA's Federal Reference Method for measuring $PM_{2.5}$ in outdoor air. The average $PM_{2.5}$ level for 2007 from each of these sites was found at http://www.epa.gov/air/data/ and they were used to determine the average outdoor $PM_{2.5}$ level as a comparison for this study. This average outdoor $PM_{2.5}$ level is 7.0 $\mu g/m^3$ (shown in Figure 1).

Figure 1. Indoor Air Pollution Before and After New Mexico Clean Indoor Air Law



* Change from pre- to post-law is statistically significant (p<0.01)

**2007 average for New Mexico. US EPA AirData Report generated 8/21/07 from http://www.epa.gov/air/data/

Table 1 shows the results for each establishment visited.

Table 1. Indoor Air Pollution in New Mexico Hospitality Venues

		Pre-Law				Post-Law				
Venue ID	Size (m^3)	Average # people	Average # burning cigs	Active smoker density*	Average $PM_{2.5}$ level ($\mu g/m^3$)	Average # people	Average # burning cigs	Active smoker density*	Average $PM_{2.5}$ level ($\mu g/m^3$)	% reduction in $PM_{2.5}$
1	340	17	2.0	0.59	34	17	0.0	0.00	4	88%
2	1019	76	4.3	0.43	122	108	0.7	0.07	30	75%
3	373	23	1.3	0.36	26	24	0.0	0.00	9	65%
4	598	71	5.2	0.87	108	13	0.0	0.00	10	91%
5	168	28	0.4	0.24	16	10	0.0	0.00	5	69%
6	767	33	4.3	0.55	34	32	0.0	0.00	8	76%
7	1051	16	2.5	0.24	32	17	0.0	0.00	11	66%
8	381	20	4.2	1.09	71	11	0.0	0.00	20	72%
9	1186	23	4.4	0.37	29	53	0.0	0.00	6	79%
10	3540	217	22.3	0.63	257	213	0.0	0.00	7	97%
11	1019	70	9.5	0.93	87	107	0.0	0.00	4	95%
12	866	53	18.0	2.08	162	52	0.0	0.00	13	92%
Mean	*942*	*54*	*6.5*	*0.70*	*82*	*55*	*0.1*	*0.01*	*11*	*87%*

NOTES: * Average number of burning cigarettes per 100 cubic meters.

The real-time plots showing the $PM_{2.5}$ level in each venue minute-by-minute during sampling are presented in the Appendix, Figures 2 through 7, starting on page 13. The real-time plots throughout sampling reveal the following results: 1) low background levels are observed outdoors; 2) much higher levels of fine particle air pollution are measured in venues before the law, when smoking was permitted; 3) peak exposure levels when smoking was permitted can far exceed the average recorded levels in a given venue; 4) indoor fine particle pollution levels are much lower following implementation of the smoke-free air law.

Figures 2, 3 and 4 (pages 13 through 15) show the plots for the pre-law monitoring done in June. $PM_{2.5}$ levels are shown on the left-hand axis. Figures 5, 6 and 7 (pages 16 through 18) show the plots in the same locations but during the post-law monitoring performed in July and August. Smoking was observed in only one of the locations during these post-law visits. The large reduction in indoor fine particle air pollution after the law is apparent in these figures.

Discussion

The EPA cited over 80 epidemiologic studies in creating a particulate air pollution standard in 1997.[12] The EPA has recently updated this standard and, 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 35 $\mu g/m^3$ for 24-hour exposure.[12, 13] In order to compare the findings in this study with the annual EPA $PM_{2.5}$ exposure standard, it was assumed that a full-time employee in the locations sampled that allow smoking works 8 hours, 250 days a year, is exposed to 82 $\mu g/m^3$ (the average level in all sites before the law) on the job, and is exposed only to background particle levels of 7.0 $\mu g/m^3$ during non-work times. For a full-time employee their average annual $PM_{2.5}$ exposure was 24 $\mu g/m^3$. The EPA average annual $PM_{2.5}$ limit is exceeded due to their occupational exposure. After the smoke-free air law, these same workers are now exposed to an average particle concentration of 10 $\mu g/m^3$ and, for a full-time employee in these New Mexico venues, the average annual exposure is 8 $\mu g/m^3$, a safe level according to the EPA. Based on the latest scientific evidence, the EPA staff currently proposes even lower $PM_{2.5}$ standards to adequately protect the public health,[14] making the high $PM_{2.5}$ exposures of people in smoking environments even more alarming.

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. In Indiana, an 89% decrease in $PM_{2.5}$ was documented in Bloomington locations that went smoke-free after that town implemented a smoke-free air ordinance.[15] A similar 85% reduction in $PM_{2.5}$ levels was seen in Indianapolis locations that went smoke-free, however levels were unchanged in the locations that were exempt from the Indianapolis ordinance.[16] 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.[17] 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.[9] 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 a 58% reduction even in locations where only SHS from an adjacent room was observed at baseline.[18] 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%.[19]

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[20], 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.[21] Smoke-free legislation in Scotland was associated with significant early improvements in symptoms, lung function, and systemic inflammation of all bar workers, while asthmatic bar workers also showed reduced airway inflammation and improved quality of life.[22] Farrelly et al. also showed a significant decrease in both salivary cotinine concentrations and sensory symptoms in hospitality workers after New York State's smoke-free law prohibited smoking in their worksites.[23]

The effects of passive smoking on the cardiovascular system in terms of increased platelet aggregability, endothelial dysfunction, increased arterial stiffness, increased atherosclerosis, increased oxidative stress and decreased antioxidant defense, inflammation, decreased energy production in the heart muscle, and a decrease in the parasympathetic output to the heart, are often nearly as large (averaging 80% to 90%) as chronic active smoking. Even brief exposures to SHS, of minutes to hours, are associated with many of these cardiovascular effects. 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.[24]

The hazardous health effects of exposure to second-hand smoke are now well-documented and established in various independent research studies and numerous international reports. The body of scientific evidence is overwhelming: there is no doubt within the international scientific community that second-hand smoke causes heart disease, lung cancer, nasal sinus cancer, sudden infant death syndrome (SIDS), asthma and middle ear infections in children and various other respiratory illnesses. There is also evidence suggesting second-hand smoke exposure is also causally associated with stroke, low birth weight, spontaneous abortion, negative effects on the development of cognition and behavior, exacerbation of cystic fibrosis, cervical cancer, and breast cancer in pre-menopausal women. The health effects of secondhand smoke exposure are detailed in recent reports by the California Environmental Protection Agency[25] and the U.S. Surgeon General[26].

Conclusions

This study documented the substantial improvement in indoor air quality that occurred after the implementation of New Mexico's smoke-free air law. Fine particle air pollution dropped a dramatic 87% in places where smoking was occurring before the law.

Before implementation of the New Mexico law, locations allowing indoor smoking were significantly more polluted than indoor smoke-free sites and than outdoor air in New Mexico, with levels of pollution in excess of EPA standards. As a result of the New Mexico law, air quality is dramatically improved for workers and patrons of these hospitality venues. This reduction in exposure to toxic secondhand smoke will result in improved quality of life and health outcomes for New Mexico workers and residents.

Acknowledgments

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Appendix

Real-time plots of $PM_{2.5}$ levels in this study start on the following page.

Figure 2. New Mexico, Pre-Law
June 9th and 10th, 2007

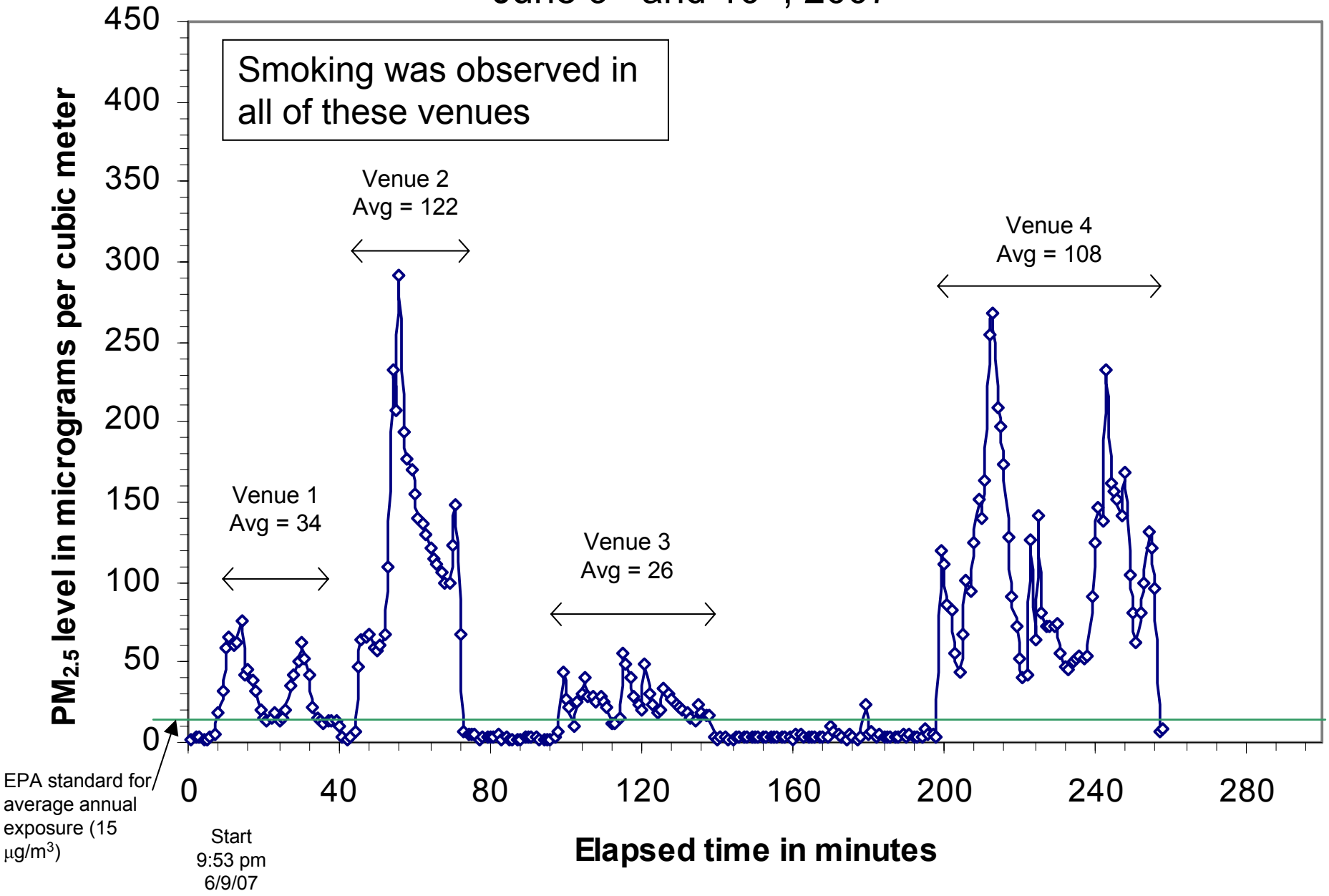

Figure 3. New Mexico, Pre-Law
June 11th and 12th, 2007

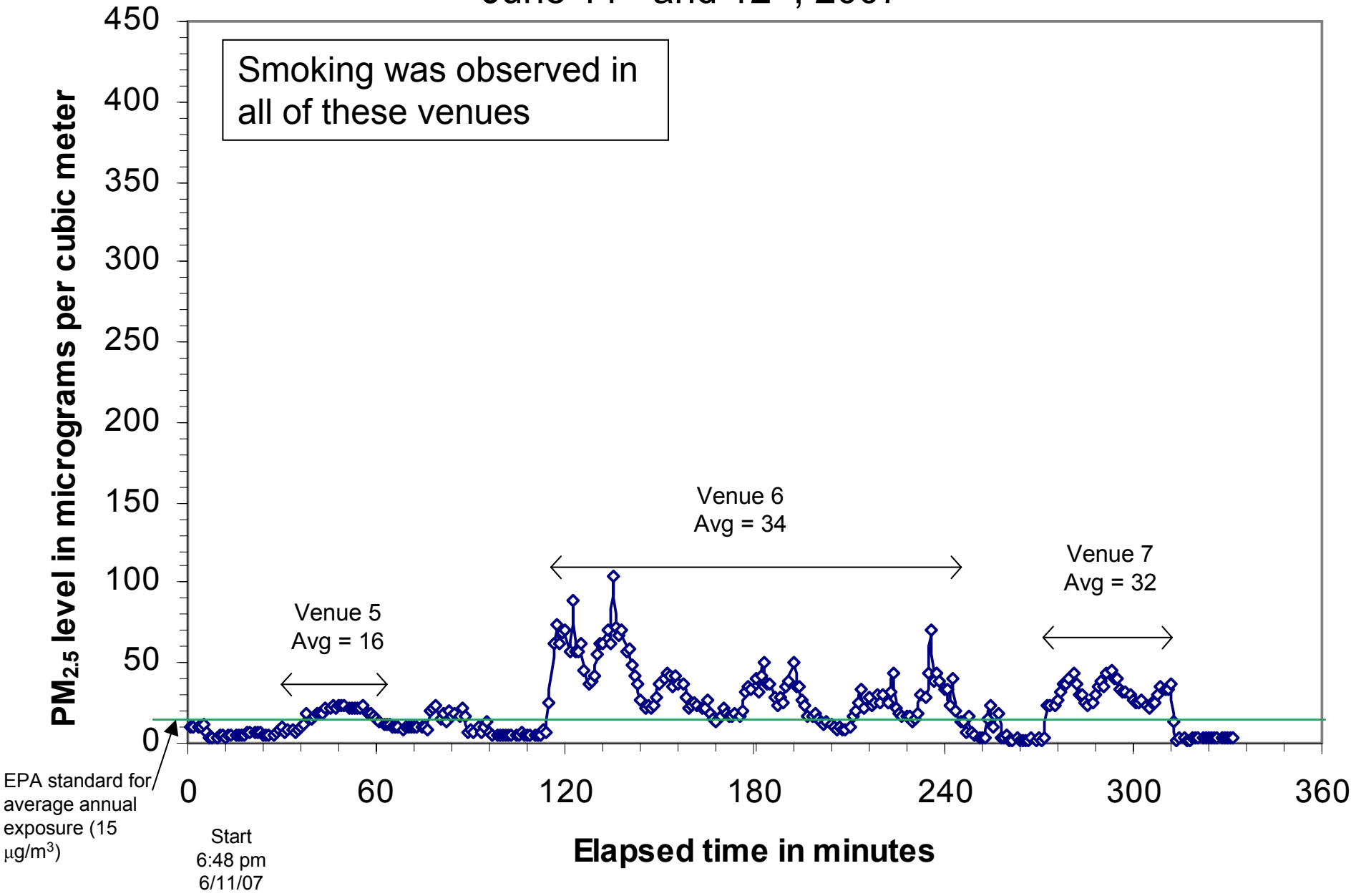

Figure 4. New Mexico, Pre-Law
June 13th and 14th, 2007

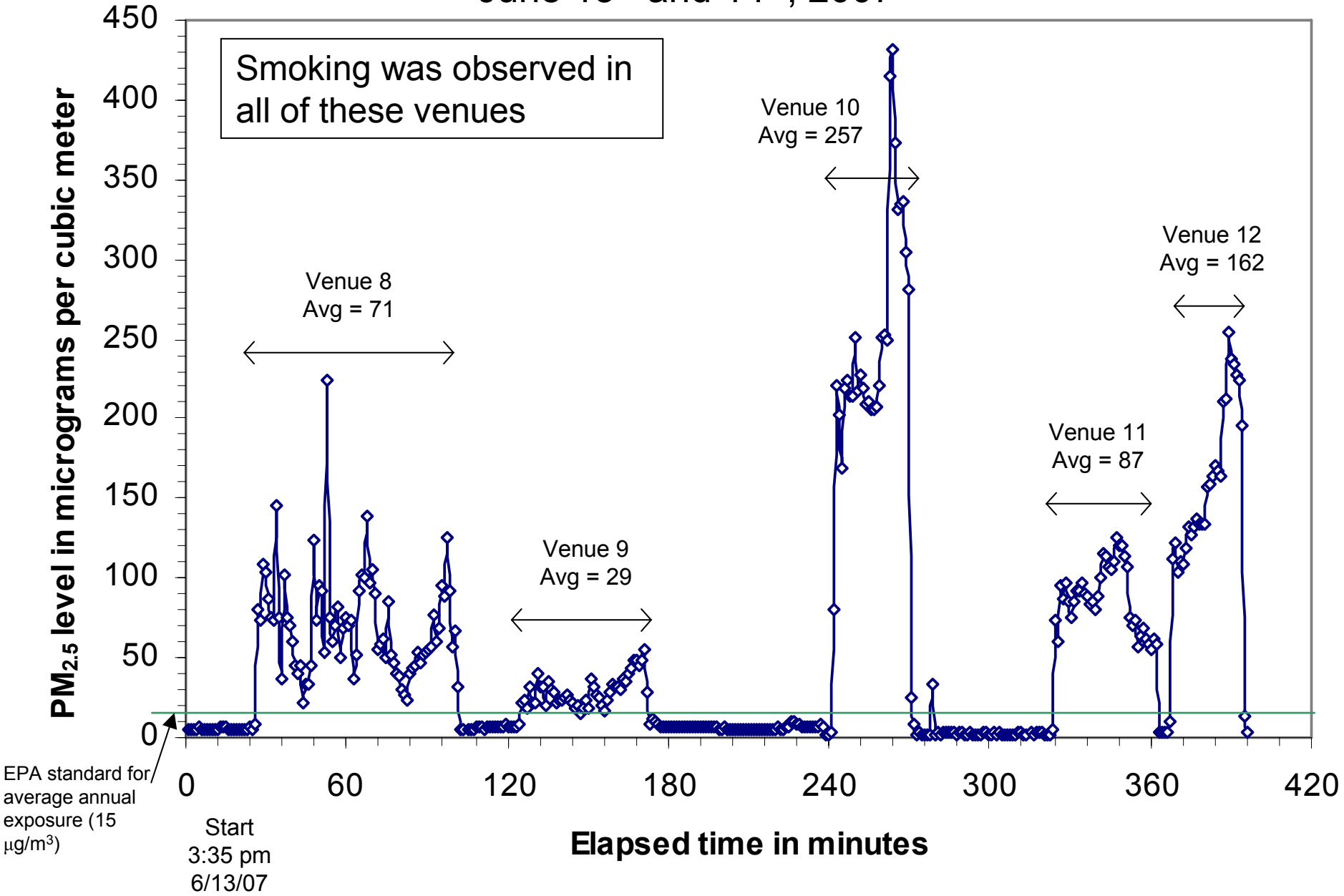

Figure 5. New Mexico, Post-Law
July 18th, 24th, & 25th, 2007

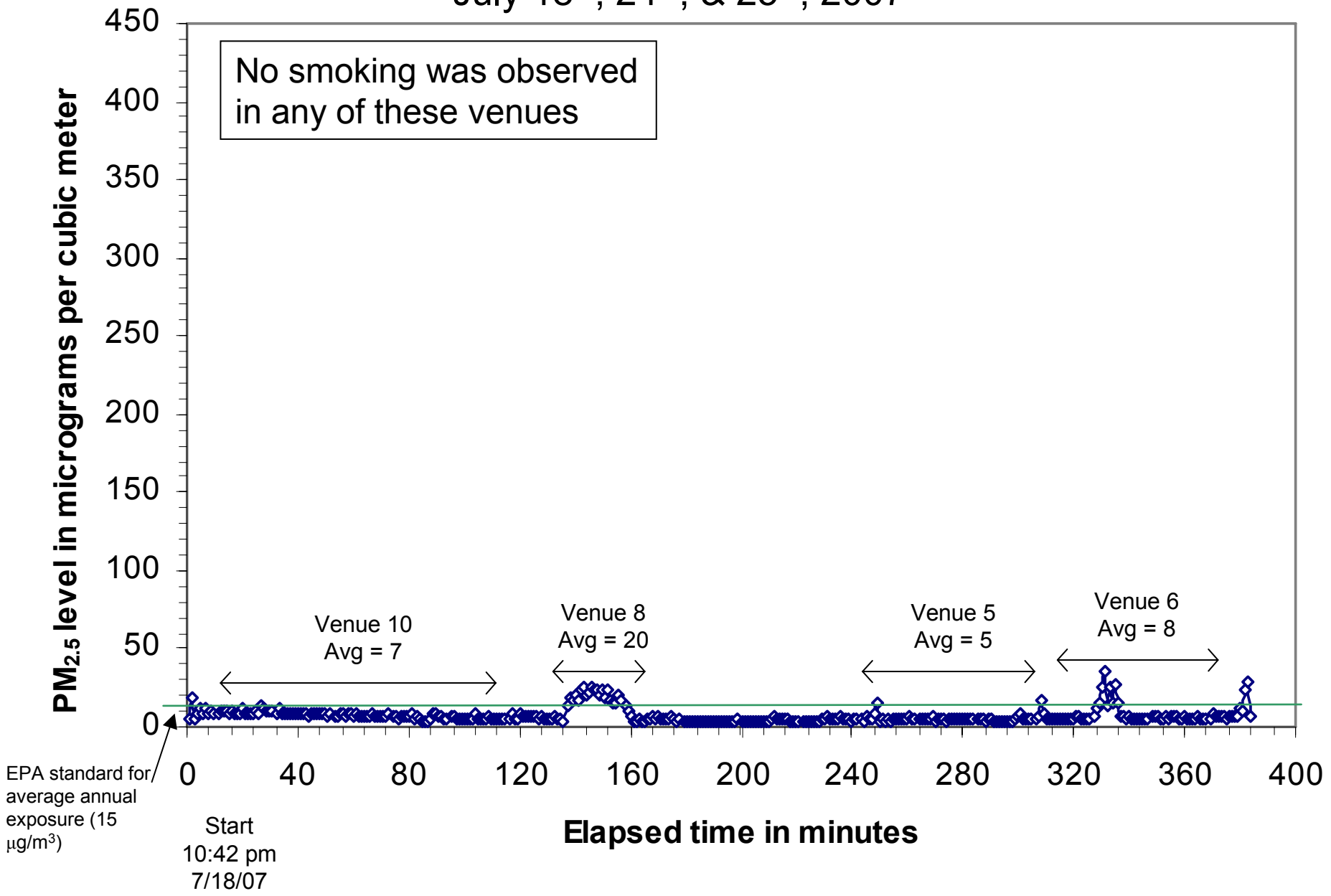

Figure 6. New Mexico, Post-Law
July 26th, 28th, & 29th, 2007

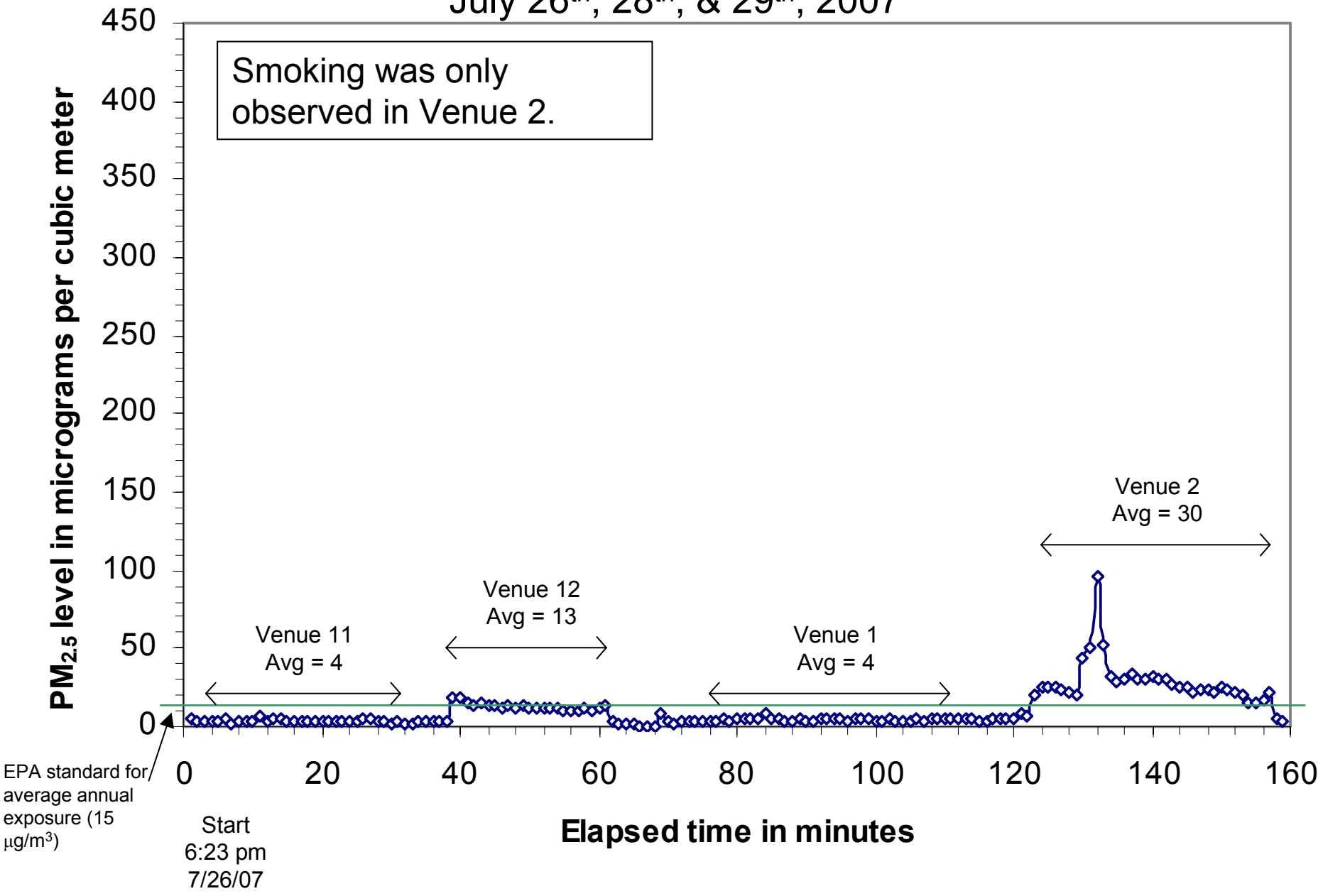

Figure 7. New Mexico, Post-Law
August 1st, 2nd, & 5th, 2007