North Dakota Air Monitoring Study: Effect of the Fargo Smoke-Free Air Ordinance

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Executive Summary

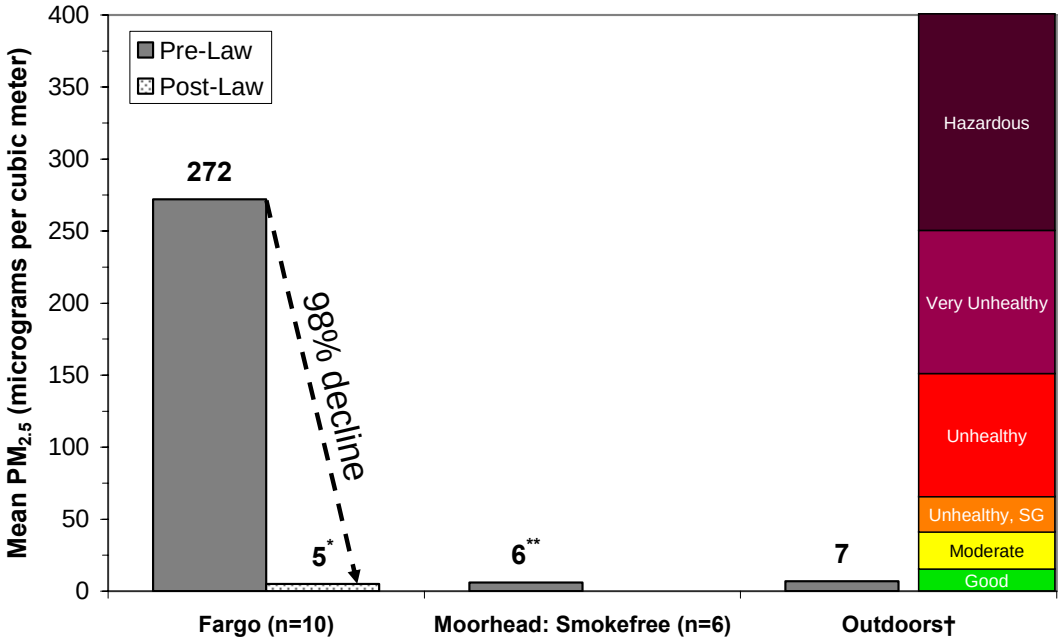
Indoor air quality was assessed in 10 randomly selected Fargo, ND bars both before and after a smoke-free indoor air ordinance. Six similar establishments were also randomly selected and sampled in Moorhead, MN where indoor smoking is prohibited. The concentration of fine particle air pollution, $PM_{2.5}$, 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 disease and death.

Key findings of the study include:

- Before the Fargo smoke-free air ordinance, the average level of fine particle indoor air pollution was 45 times higher in Fargo locations sampled compared to the places in smoke-free Moorhead.
- Employees working full-time in the establishments sampled in Fargo before the law were exposed annually to fine particle air pollution levels 4.5 times higher than the safe annual limit established by the U.S. Environmental Protection Agency (EPA).
- Indoor particle pollution levels declined 98% in Fargo as a result of the smoke-free air law to low levels, similar to those found in outdoor air.

Consistent with the findings of the U.S. Surgeon General, this study provides further evidence that indoor smoking causes exposure to harmful levels of indoor air pollution and that comprehensive smoke-free air policies, prohibiting indoor smoking, are extremely effective in eliminating these exposures.

Effect of Smoke-free Air Ordinance on Indoor Air Pollution in Fargo Hospitality Venues



* p<0.001 for comparison of pre-law to post-law Fargo (paired samples *t* test of log-transformed values)
** p<0.001 for comparison of Fargo to Moorhead (Independent samples *t* test of log-transformed values)
† Used for comparison purposes. Based on the 2007 average $PM_{2.5}$ level from the 5 EPA monitoring sites in North Dakota. http://www.epa.gov/air/data/
Note: The color-coded EPA Air Quality Index is shown to illustrate the magnitude of the measured particle concentrations. (SG=sensitive groups)

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., 24 states, Washington D.C., and Puerto Rico have enacted strong smoke-free laws that include restaurants and bars. The states are Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Illinois, Iowa, Maine, Maryland, Massachusetts, Minnesota, Montana, Nebraska, New Hampshire, New Jersey, New Mexico, New York, Ohio, Oregon, Rhode Island, Utah, Vermont, and Washington (Montana and Utah laws include bars in 2009; the Oregon law goes into effect Jan. 2009 and the Nebraska law goes into effect in June 2009). Well over 50% of the U.S. population is now protected from secondhand smoke in all public places.[7] Florida, Idaho, Louisiana and Nevada have smoke-free laws that cover restaurants but 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, England and France.

The goal of this study was to evaluate the effect of the Fargo smoke-free air ordinance on the level of fine particle indoor air pollution in bars in Fargo, North Dakota and compare these levels to those in nearby Moorhead, Minnesota. North Dakota state law currently prohibits smoking in most workplaces and public places. The State law exempts bars, separately enclosed bar areas of restaurants, and separately enclosed, adult-only areas in truck stops.[1] However, the cities of Fargo[2] and West Fargo[3] both passed smoke-free air ordinances on June 10, 2008, that removed the state exemptions for bars, truck stops, and public access rentals or leases. These comprehensive smoke-free air laws became effective on July 1, 2008.

It is hypothesized that: 1) before the law, levels of indoor fine particle air pollution will be significantly higher in places with indoor smoking compared to those that are smoke-free; 2) particle levels will decline significantly in a cohort of establishments that are sampled before and after the smoke-free air law; and 3) the degree of indoor particle air pollution will be correlated with the amount smoking.

[1] North Dakota Century Code §23-12-09
[2] Article 10-11 of Fargo Municipal Code
[3] City of West Fargo Smoking Ordinance #803

Methods

Overview

A total of 16 bars and restaurants were sampled in May, 2008. Ten of the places visited were in Fargo, ND and permitted indoor smoking. The remaining 6 locations were in Moorhead, MN where indoor smoking is prohibited by law. The places sampled in Fargo were randomly selected from a list of all establishments in Fargo with liquor licenses that permit indoor smoking. The places in Moorhead were randomly selected from a list of all establishments in Moorhead with liquor licenses. The sampling was conducted between May 2 to May 12, 2008. Most of the sampling was performed on Thursday, Friday, and Saturday evenings between 6:00PM and 1:00AM.

The ten locations sampled in Fargo were sampled again between September 17 to October 6, 2008 with the visits occurring in the evenings between 5:30PM and 12:30AM. These visits occurred after the implementation of Fargo's smoke-free air ordinance and all establishments were required to prohibit indoor smoking.

Measurement Protocol

For each visit 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. A sonic measuring device 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.[9, 10] In addition, the SidePak was zero-calibrated prior to each use by attaching a HEPA filter according to the manufacturer's specifications.

TSI SidePak AM510 Personal Aerosol Monitor

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.

> ***$PM_{2.5}$ 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 respiratory and cardiovascular disease and death.***

Roswell Park Cancer Institute staff trained the Fargo testers and analyzed the data.

Statistical Analyses

Since $PM_{2.5}$ levels are log-normally distributed, all statistical testing was performed using log-transformed $PM_{2.5}$ values. To evaluate the first hypothesis, pre-law Fargo and Moorhead $PM_{2.5}$ values were compared using an independent samples *t* test. The second hypothesis was tested by comparing the pre-law Fargo $PM_{2.5}$ levels to the post-law Fargo $PM_{2.5}$ levels using a paired-samples *t* test. The third hypothesis was tested by using all 26 sample visits and correlating the average smoker densities to the $PM_{2.5}$ levels using the Spearman rank correlation coefficient (r_s). Descriptive statistics including the venue volume, number of patrons, and average smoker density (average number of burning cigarettes per 100 m^3) are reported for each venue and averaged for each community as well.

Results

Indoor smoking was observed during all pre-law visits to the 10 locations in Fargo. The mean $PM_{2.5}$ level in these locations was 272 $\mu g/m^3$ (SD[*]=234). No smoking was observed in the 6 places visited in Moorhead and the mean $PM_{2.5}$ level in these places was 6 $\mu g/m^3$ (SD=2.8). Places in Fargo had fine particle air pollution levels 45 times higher than the places in Moorhead. These aggregate results are shown in Figure 1. The difference between $PM_{2.5}$ levels in smoking and smoke-free places is large and statistically significant ($t(14)=9.02$, $p<0.001$, $r=0.92$).

After the Fargo smoke-free air ordinance, the mean $PM_{2.5}$ level in the ten locations in Fargo was 5 $\mu g/m^3$ (SD=2.4). This is a 98% reduction in $PM_{2.5}$ compared to the pre-law levels. This difference is statistically significant ($t(9)=13.1$, $p<0.001$).

The average number of burning cigarettes was 7.6 in Fargo before the law and 0.0 after the law (no burning cigarettes were observed during the post-law sampling). The average number of burning cigarettes per 100 m^3, or active smoker density (ASD), was 0.57 before the law and 0.00 after the law. Looking at all 26 sample visits combined (20 in Fargo and 6 in Moorhead) $PM_{2.5}$ level was significantly correlated with the active smoker density, $r_s=0.68$, $p<0.001$.

[*] SD=standard deviation

There are outdoor air monitoring sites throughout North Dakota that use the EPA's Federal Reference Method for measuring $PM_{2.5}$ in outdoor air. The average $PM_{2.5}$ levels for these monitors for 2007 were found at http://www.epa.gov/air/data/ and were used to determine the average outdoor $PM_{2.5}$ level as a comparison for this study. The average outdoor $PM_{2.5}$ level from these monitors is 7 $\mu g/m^3$ (shown in Figure 1). Indoor $PM_{2.5}$ levels in the absence of smoking in this study are shown to be almost identical to outdoor levels.

The aggregate results showing the $PM_{2.5}$ levels in Fargo pre-law, Fargo post-law, Moorhead, and outdoor levels are shown in Figure 1. The color-coded EPA Air Quality Index (AQI) for $PM_{2.5}$ is also shown for comparison. In Fargo, when indoor smoking was permitted, indoor $PM_{2.5}$ levels were in the "Hazardous" category of the AQI, while post-law levels in Fargo, levels in Moorhead, and outdoor levels are all in the "Good" category.

Table 1 (next page) shows the individual results for each location visited.

Figure 1. Effect of Smoke-free Air Ordinance on Indoor Air Pollution in Fargo Hospitality Venues

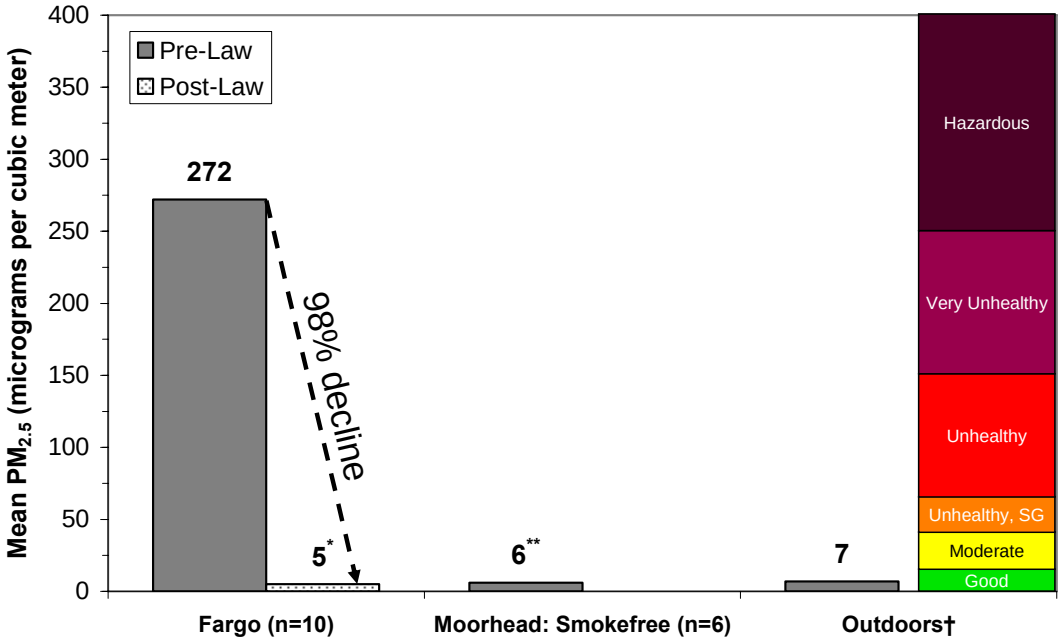


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Table 1. Fine Particle Air Pollution in Fargo, ND and Moorhead, MN Locations Visited Pre- and Post- Smoke-free Air Law

		Pre-Law					Post-Law				
Venue Number	Size (m^3)	Date Sampled	Average # people	Average # burning cigs	Active smoker density*	Average $PM_{2.5}$ level ($\mu g/m^3$)	Date Sampled	Average # people	Average # burning cigs	Active smoker density*	Average $PM_{2.5}$ level ($\mu g/m^3$)
Fargo, ND											
1	1088	5/2/2008	78	14.3	1.32	75	9/17/2008	41	0.0	0.00	5
2	5684	5/2/2008	111	13.0	0.23	773	10/6/2008	21	0.0	0.00	11
3	1019	5/2/2008	73	8.0	0.79	527	9/19/2008	57	0.0	0.00	2
4	454	5/2/2008	32	6.0	1.32	106	9/26/2008	54	0.0	0.00	4
5	1129	5/3/2008	72	11.8	1.05	413	9/26/2008	65	0.0	0.00	7
6	4668	5/3/2008	286	2.8	0.06	193	9/18/2008	214	0.0	0.00	5
7	3127	5/7/2008	131	6.3	0.20	231	9/18/2008	35	0.0	0.00	4
8	1481	5/8/2008	41	5.7	0.38	264	9/26/2008	50	0.0	0.00	4
9	3967	5/8/2008	38	3.0	0.08	88	9/20/2008	250	0.0	0.00	5
10	1984	5/9/2008	16	4.7	0.24	55	9/17/2008	18	0.0	0.00	4
Average	**2460**		**88**	**7.6**	**0.57**	**272**		**80**	**0.0**	**0.00**	**5**
Moorhead, MN (smoke-free at baseline)											
11	22218	5/9/2008	23	0.0	0.00	10					
12	28319	5/10/2008	250	0.0	0.00	3					
13	3127	5/10/2008	35	0.0	0.00	8					
14	3967	5/10/2008	64	0.0	0.00	7					
15	340	5/11/2008	7	0.0	0.00	4					
16	103	5/12/2008	3	0.0	0.00	4					
Average	**9679**		**64**	**0.0**	**0.00**	**6**					

*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 thru 4, starting on page 11. 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 with indoor smoking; 3) peak exposure levels when smoking was occurring can far exceed the average recorded levels in a given venue; 4) indoor fine particle pollution levels are low and similar to outdoor levels in the venues with no observed smoking.

Figures 2 and 3 show the before and after plots for $PM_{2.5}$ levels in the ten locations sampled in Fargo. All of the black shaded area that is visible in these graphs represents $PM_{2.5}$ exposures that were eliminated as a result of the smoke-free air law. In some instances the post-law sampling was of a shorter duration than the pre-law sampling. In these cases the post-law data was repeated to fill in the same duration as the pre-law sampling. This was generally required for only a few minutes of data except for venue 7 where the pre-law sampling was 4 times longer than the post-law sampling. Figure 4, shows the results of the sampling in the 6 locations sampled in smoke-free Moorhead, MN.

Discussion

The EPA cited over 80 epidemiologic studies in creating a particulate air pollution standard in 1997.[11] 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.[11, 12] 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 272 $\mu g/m^3$ (the pre-law mean in Fargo) on the job, and is exposed only to background particle levels of 7 $\mu g/m^3$ during non-work times. For a full-time employee their average annual $PM_{2.5}$ exposure is 68 $\mu g/m^3$. The EPA average annual $PM_{2.5}$ limit is exceeded by 4.5 times due to their occupational exposure. Based on the latest scientific evidence, the EPA staff currently proposes even lower $PM_{2.5}$ standards to adequately protect the public health,[13] 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, similar to $PM_{2.5}$) 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.[14] 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.[15] 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.[16] 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.[17] 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 tobacco smoke pollution (TSP) 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] A recent case report also documented an acute asthma death of a waitress resulting from exposure to tobacco smoke pollution at work.[24]

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 tobacco smoke pollution, of minutes to hours, are associated with many of these cardiovascular effects. The effects of TSP are substantial and rapid, explaining the relatively large health risks associated with TSP exposure that have been reported in epidemiological studies.[25]

The hazardous health effects of exposure to tobacco smoke pollution 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 TSP 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 TSP exposure is also causally associated with stroke, low birthweight, 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 TSP exposure are detailed in recent reports by the California Environmental Protection Agency[26] and the U.S. Surgeon General[27].

Conclusions

Workers in Fargo bars were exposed to levels of air pollution in excess of EPA standards in place to protect public health. The comprehensive smoke-free air policy implemented in Fargo has resulted in a dramatic 98% reduction in fine particle air pollution. Indoor air quality in Fargo bars is now safe and the same as levels in smoke-free Moorhead, MN. This reduction in exposure to toxic tobacco smoke will result in improved quality of life and health outcomes for Fargo workers and residents.

Acknowledgments

Support for this study was provided by the American Heart Association and the Flight Attendant Medical Research Institute.

Appendix

U.S. Environmental Protection Agency Air Quality Index		
Air Quality Index Levels of Health Concern	**$PM_{2.5}$ ($\mu g/m^3$)**	**Meaning**
Good	**≤15**	**Air quality is considered satisfactory, and air pollution poses little or no risk.**
Moderate	**16-40**	**Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.**
Unhealthy for Sensitive Groups	**41-65**	**Members of sensitive groups may experience health effects. The general public is not likely to be affected.**
Unhealthy	**66-150**	**Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.**
Very Unhealthy	**151-250**	**Health alert: everyone may experience more serious health effects.**
Hazardous	**≥251**	**Health warnings of emergency conditions. The entire population is more likely to be affected.**

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

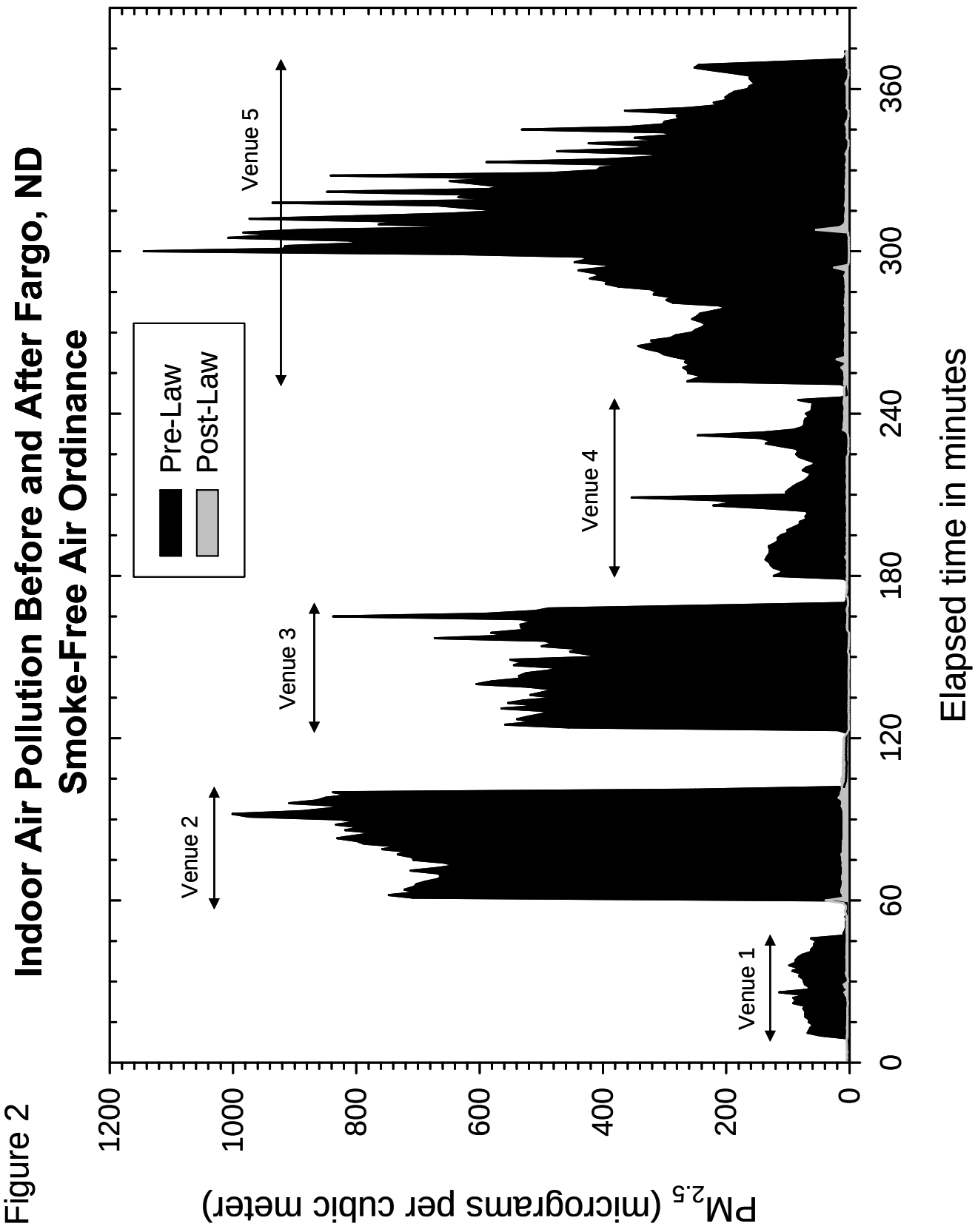
Indoor Air Pollution Before and After Fargo, ND
Smoke-Free Air Ordinance
Pre-Law
Post-Law
Venue 1
Venue 2
Venue 3
Venue 4
Venue 5
PM2.5 (micrograms per cubic meter)
Elapsed time in minutes
0
200
400
600
800
1000
1200
0
60
120
180
240
300
360

Figure 2

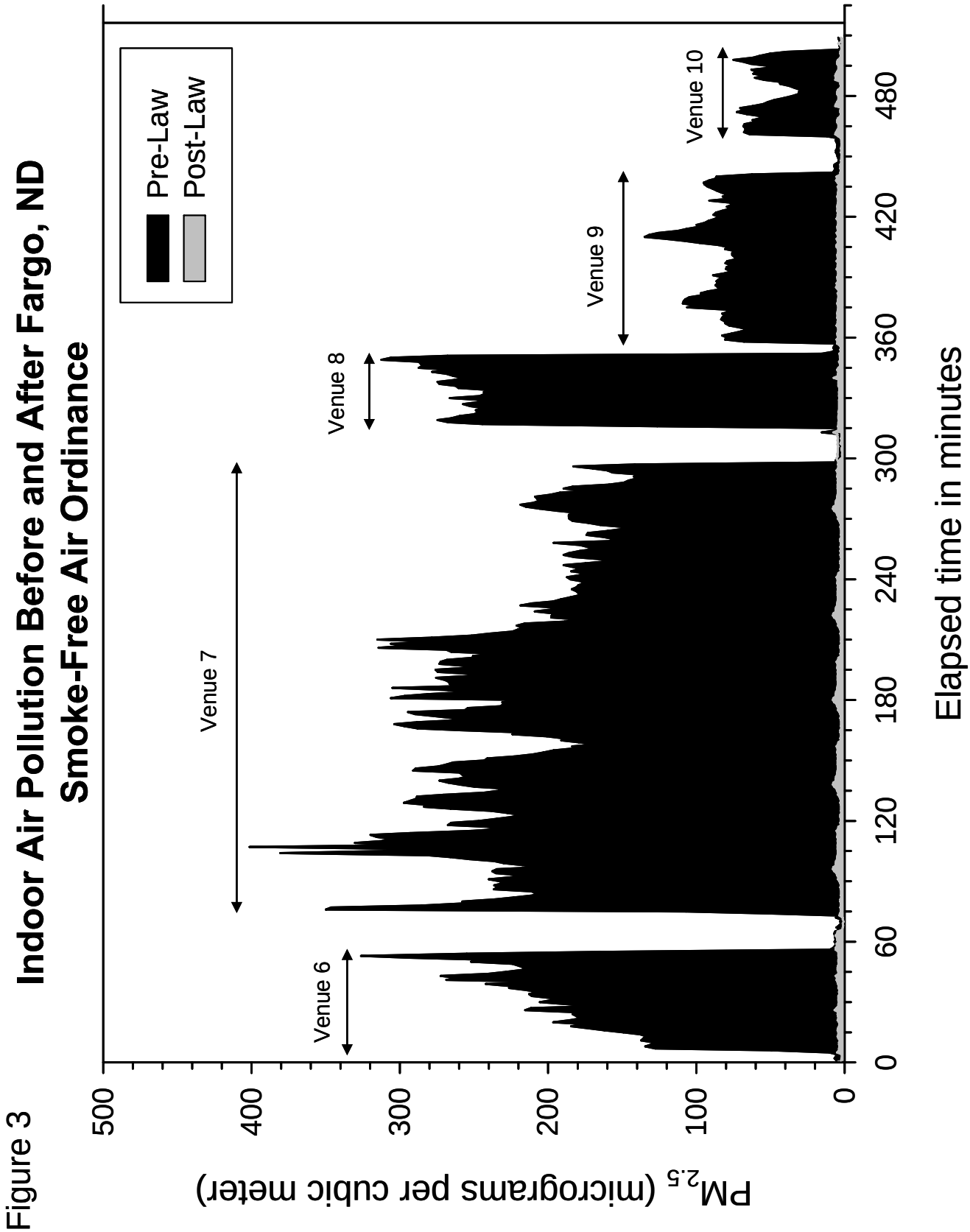
Indoor Air Pollution Before and After Fargo, ND
Smoke-Free Air Ordinance
Pre-Law
Post-Law
Venue 6
Venue 7
Venue 8
Venue 9
Venue 10
PM2.5 (micrograms per cubic meter)
0
100
200
300
400
500
0
60
120
180
240
300
360
420
480
Elapsed time in minutes

Figure 3

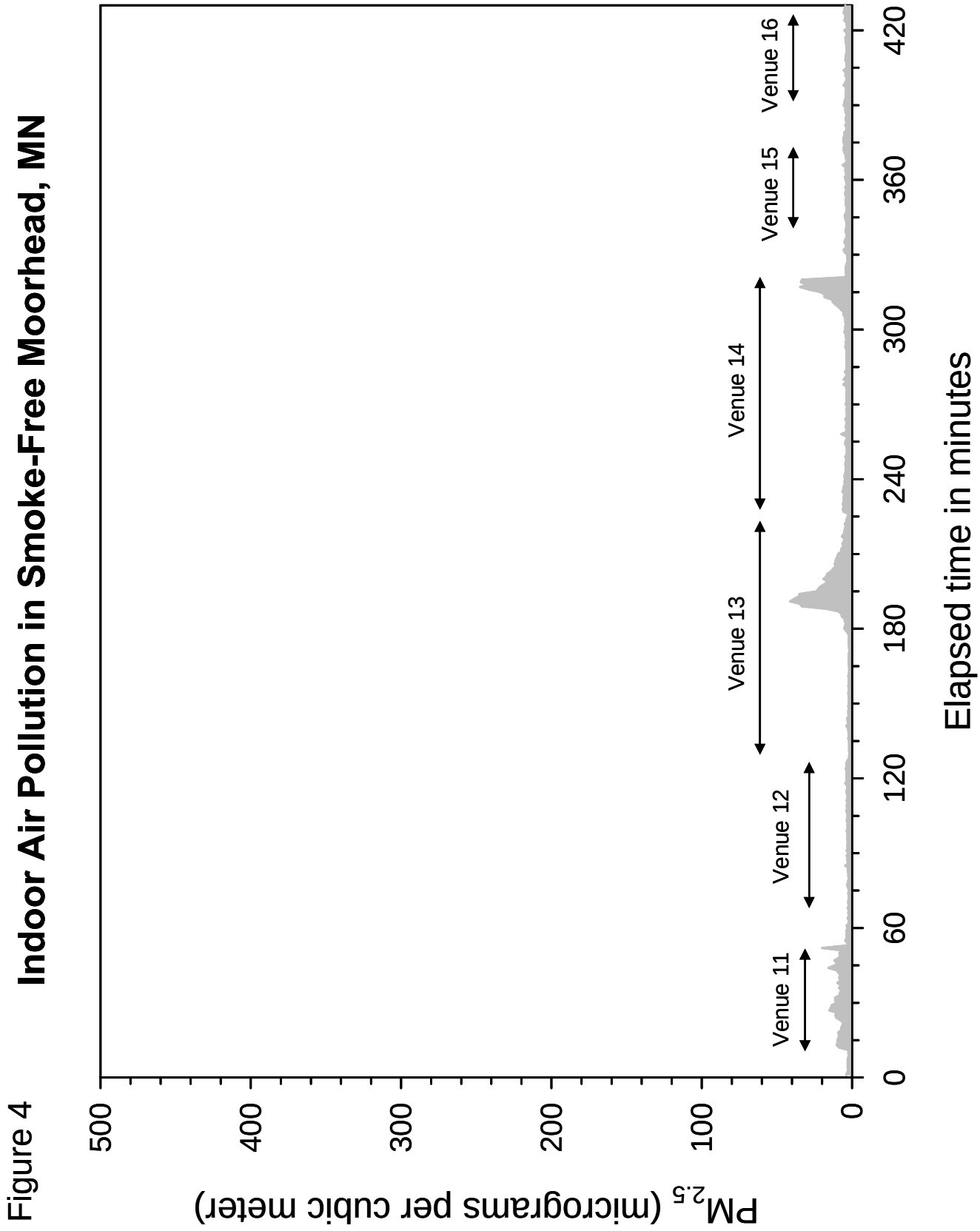
Indoor Air Pollution in Smoke-Free Moorhead, MN
PM2.5 (micrograms per cubic meter)
0
100
200
300
400
500
Elapsed time in minutes
0
60
120
180
240
300
360
420
Venue 11
Venue 12
Venue 13
Venue 14
Venue 15
Venue 16

Figure 4

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