North Dakota Air Monitoring Study



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Executive Summary

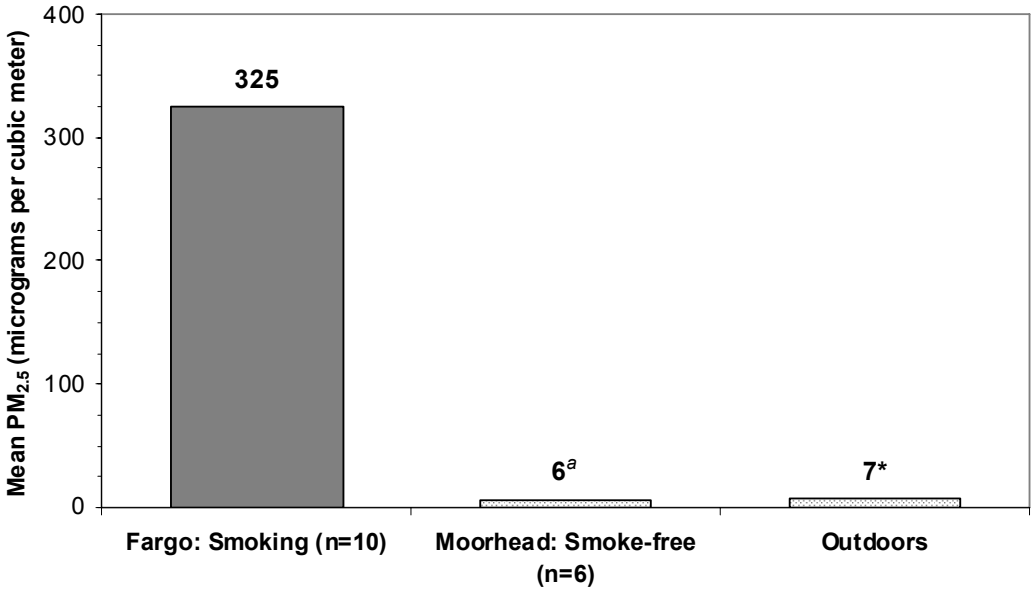
Indoor air quality was assessed in 10 randomly selected Fargo, ND bars where indoor smoking is permitted in May 2008. Six similar establishments were also randomly selected and sampled in Moorhead, MN where indoor smoking is prohibited. The concentration of fine particle air pollution, $PM_{2.5}$, was 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:

- The average level of fine particle indoor air pollution was 54 times higher in places in Fargo compared to the smoke-free places in Moorhead. (Mean $PM_{2.5}$ concentration in Fargo 325 $\mu g/m^3$ versus 6 $\mu g/m^3$ in Moorhead)
- Employees working full-time in the establishment sampled in Fargo are exposed annually to fine particle air pollution levels 5 times higher than the safe annual limit established by the U.S. Environmental Protection Agency (EPA).
- Indoor particle pollution levels in smoke-free Moorhead are low and virtually the same as outdoor air.

Consistent with the findings of the U.S. Surgeon General and the American Society for Heating, Refrigerating, and Air-Conditioning Engineers, 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 the only effective means to eliminate the health risks from these exposures.

Indoor Air Pollution in Fargo and Moorhead Hospitality Venues



[a] 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/

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 measure 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. However, the law exempts bars, separately enclosed bar areas of restaurants, and separately enclosed, adult-only areas in truckstops (ND Century Code §23-12-09). It is hypothesized that levels of indoor fine particle air pollution will be significantly higher in places with indoor smoking compared to those that are smoke-free and that the degree of pollution will be correlated with the amount smoking.

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 from May 2 to May 12, 2008. Most of the sampling was performed on Thursday, Friday, and Saturday evenings between 6:00PM and 1:00AM.

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. 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. 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.

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

The primary goal was to assess the difference in the average level of $PM_{2.5}$ in bars in Fargo compared with Moorhead. Since $PM_{2.5}$ levels are log-normally distributed, all statistical testing was performed using log-transformed $PM_{2.5}$ values. Fargo and Moorhead $PM_{2.5}$ values were compared using an independent samples *t* test. 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 in all 10 locations visited in Fargo. The average $PM_{2.5}$ level in these locations was 325 $\mu g/m^3$. No smoking was observed in the 6 places visited in Moorhead and the average $PM_{2.5}$ level in these places was 6 $\mu g/m^3$. Places in Fargo had fine particle air pollution levels 54 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 ($t(14) = 10.2$, $p<0.001$, $r=0.94$).

The average number of burning cigarettes was 7.6 in Fargo and the average number of burning cigarettes per 100 m^3, or active smoker density (ASD), was 0.57. $PM_{2.5}$ level was significantly correlated with the active smoker density, $r_s=0.64$, $p<0.01$.

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).

Figure 1. Indoor Air Pollution in Fargo and Moorhead Hospitality Venues



[a] 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/

Table 1 shows the results for each location visited.

Table 1. Fine Particle Air Pollution in Fargo and Moorhead Locations Visited

Venue Number	Date Sampled	Smoking Observed?	Size (m^3)	Average # people	Average # burning cigs	Active smoker density*	Average $PM_{2.5}$ level ($\mu g/m^3$)
Smoking (Fargo, ND)							
1	5/2/2008	Yes	1088	78	14.3	1.32	75
2	5/2/2008	Yes	5684	111	13.0	0.23	773
3	5/2/2008	Yes	1019	73	8.0	0.79	527
4	5/2/2008	Yes	454	32	6.0	1.32	106
5	5/3/2008	Yes	1129	72	11.8	1.05	413
6	5/3/2008	Yes	4668	286	2.8	0.06	193
7	5/7/2008	Yes	3127	131	6.3	0.20	577
8	5/8/2008	Yes	1481	41	5.7	0.38	231
9	5/8/2008	Yes	3967	38	3.0	0.08	264
10	5/9/2008	Yes	1984	16	4.7	0.24	88
Average			**2460**	**88**	**7.6**	**0.57**	**325**
Smoke-free (Moorhead, MN)							
11	5/9/2008	No	22218	23	0.0	0.00	10
12	5/10/2008	No	28319	250	0.0	0.00	3
13	5/10/2008	No	3127	35	0.0	0.00	8
14	5/10/2008	No	3967	64	0.0	0.00	7
15	5/11/2008	No	340	7	0.0	0.00	4
16	5/12/2008	No	103	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.

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 325 $\mu g/m^3$ (the average level in all sites with smoking) 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 80 $\mu g/m^3$. The EPA average annual $PM_{2.5}$ limit is exceeded by 5.3 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,[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] 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 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.[25]

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 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 secondhand smoke exposure are detailed in recent reports by the California Environmental Protection Agency[26] and the U.S. Surgeon General[27].

Conclusions

This study documented the substantial difference in indoor air quality between indoor worksites allowing smoking in Fargo, ND and smoke-free worksites in Moorhead, MN. Fine particle indoor air pollution is 54 times higher in Fargo compared to Moorhead.

Workers in Fargo bars are exposed to levels of air pollution in excess of EPA standards in place to protect public health. A comprehensive smoke-free air policy that prohibits indoor smoking in all indoor places is the only proven means to eliminate exposure to toxic tobacco smoke pollution. This reduction in exposure to toxic tobacco smoke will result in improved quality of life and health outcomes for Fargo workers and residents.

Acknowledgments

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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.

Figure 2

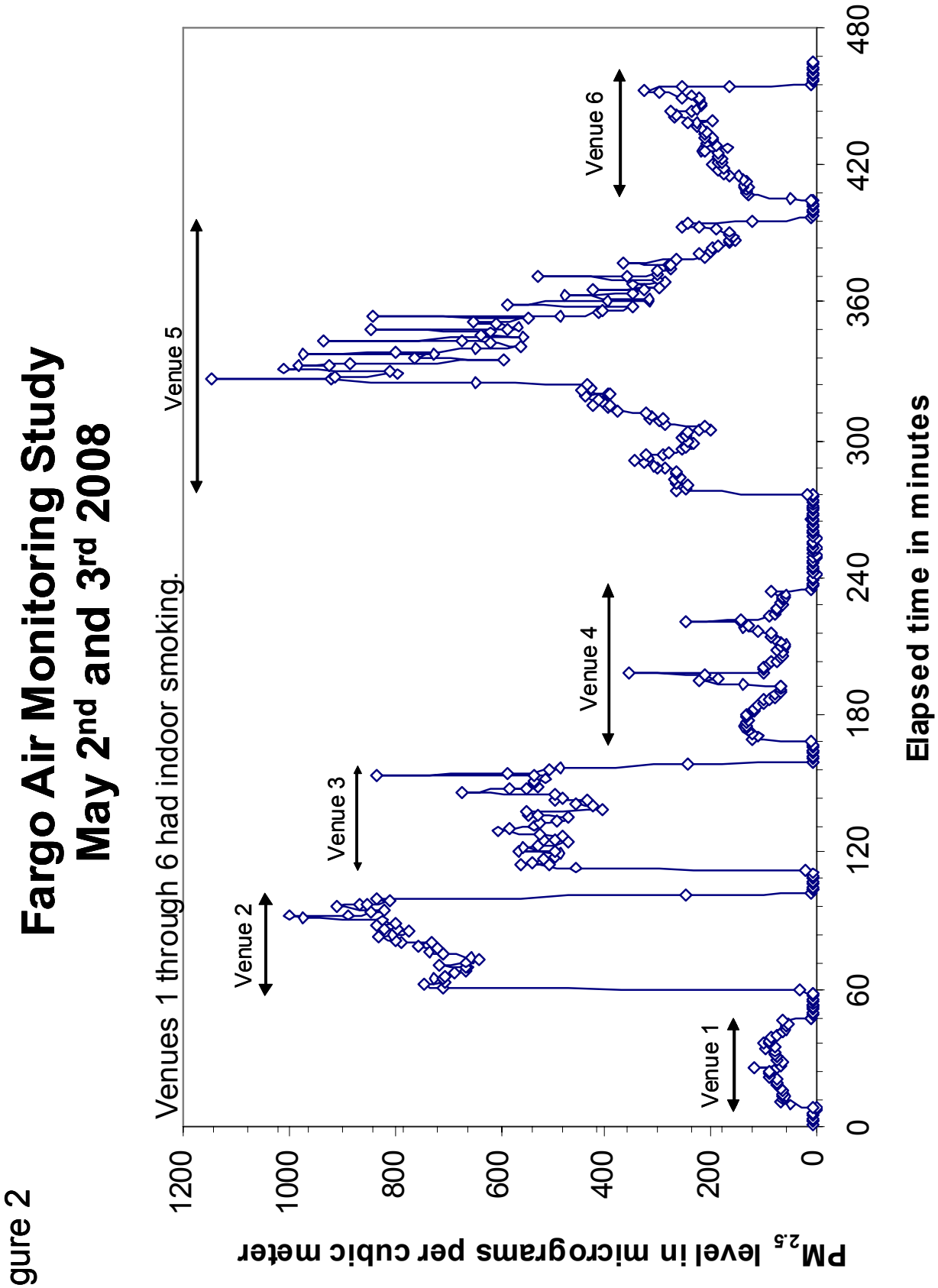

Fargo Air Monitoring Study
May 2nd and 3rd 2008
Venues 1 through 6 had indoor smoking.
Venue 1
Venue 2
Venue 3
Venue 4
Venue 5
Venue 6
PM2.5 level in micrograms per cubic meter
0
200
400
600
800
1000
1200
Elapsed time in minutes
0
60
120
180
240
300
360
420
480

Figure 3

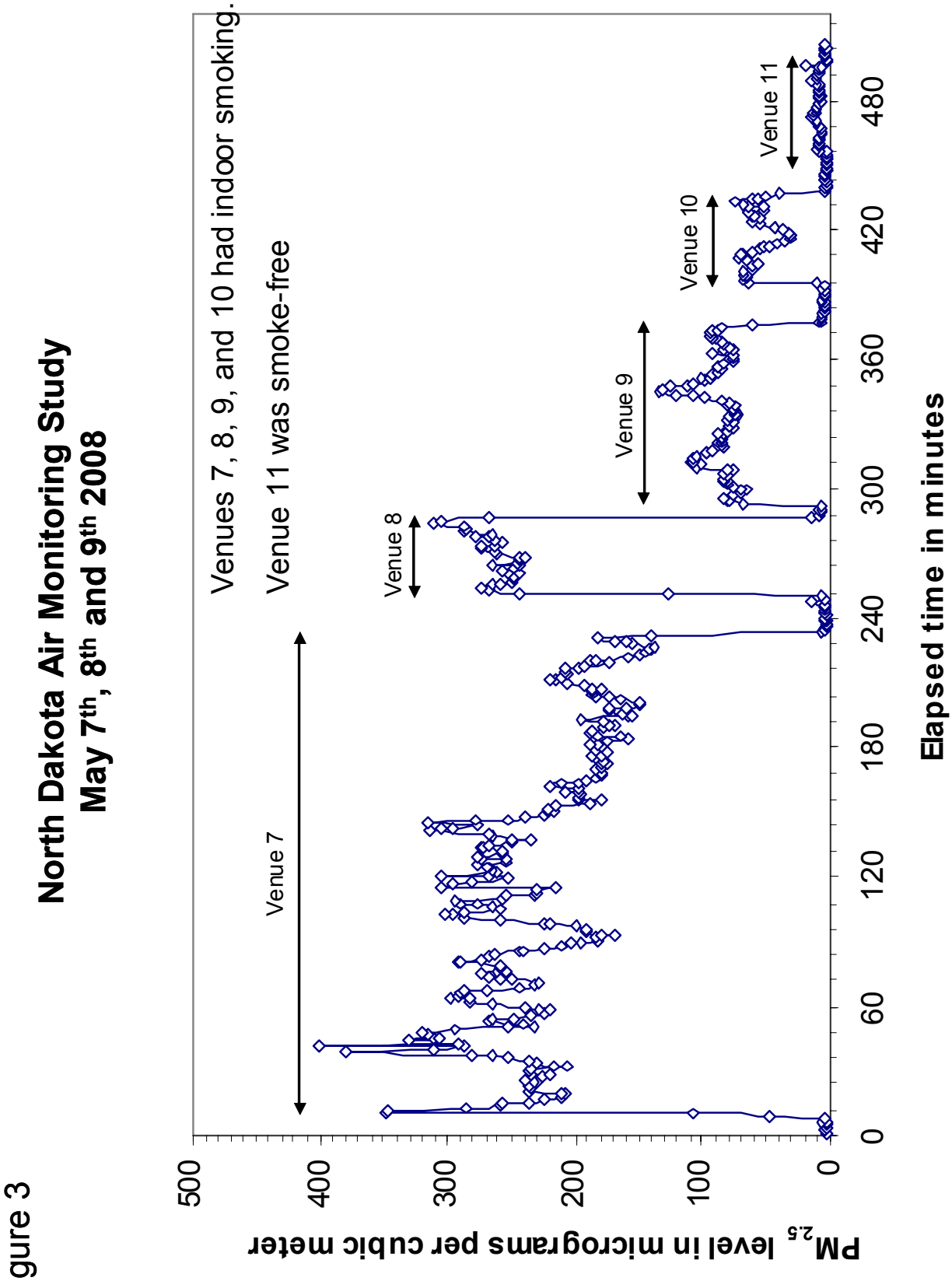
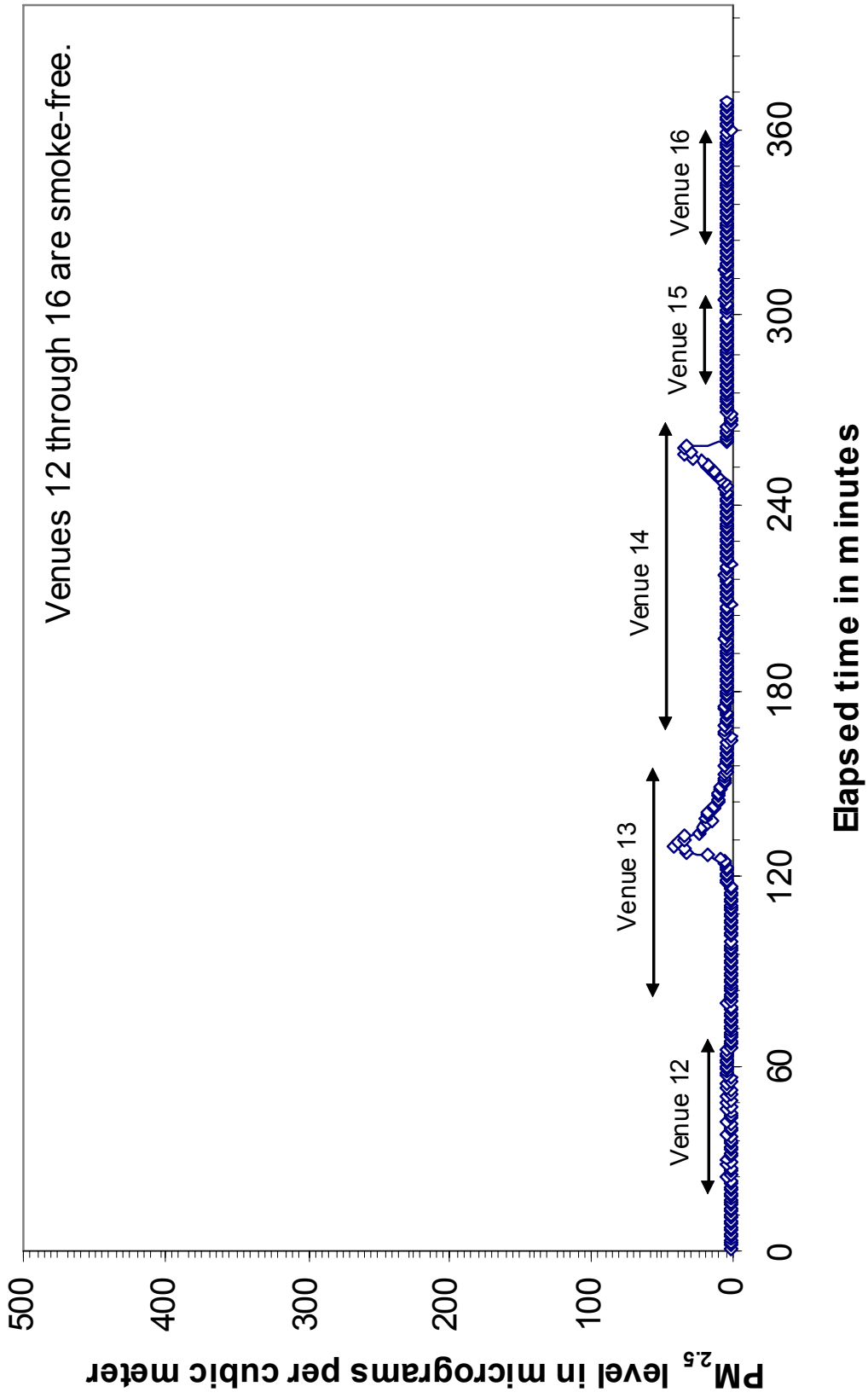

North Dakota Air Monitoring Study
May 7th, 8th and 9th 2008
Venues 7, 8, 9, and 10 had indoor smoking.
Venue 11 was smoke-free
Venue 7
Venue 8
Venue 9
Venue 10
Venue 11
PM2.5 level in micrograms per cubic meter
0
100
200
300
400
500
0
60
120
180
240
300
360
420
480
Elapsed time in minutes

Figure 4


Fargo Air Monitoring Study
May 10th, 11th, and 12th 2008
Venues 12 through 16 are smoke-free.
Venue 12
Venue 13
Venue 14
Venue 15
Venue 16
PM2.5 level in micrograms per cubic meter
0
100
200
300
400
500
0
60
120
180
240
300
360
Elapsed time in minutes

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