Indianapolis Air Quality Monitoring Study

Mark J. Travers, PhD, MS

Department of Health Behavior

Roswell Park Cancer Institute

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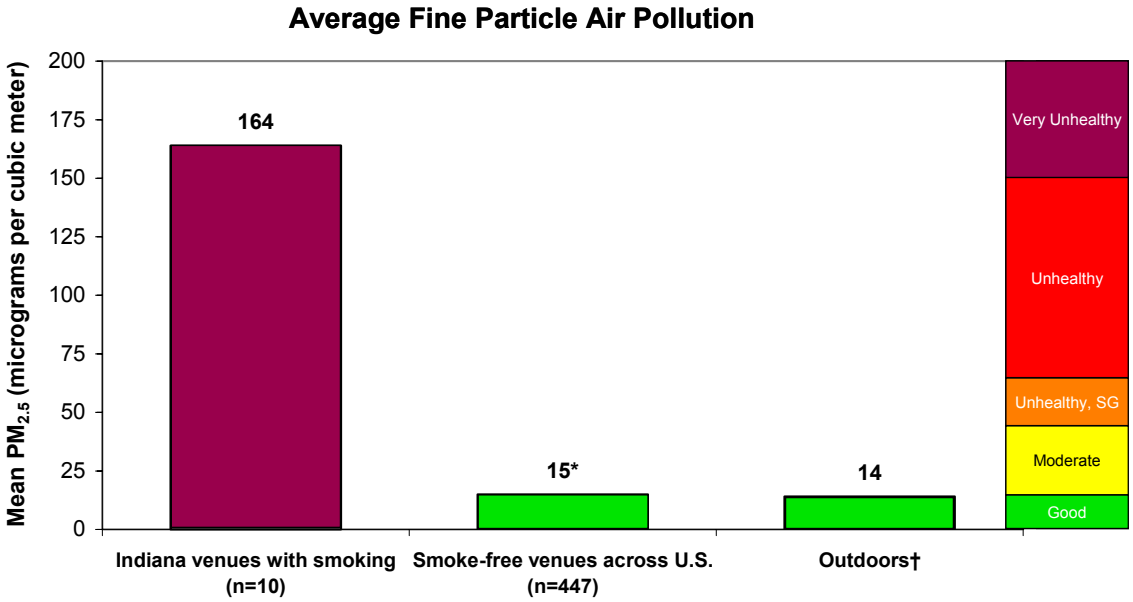
Executive Summary

In March 2009, indoor air quality was assessed in 10 indoor locations in Indianapolis, Indiana. These locations included bars, restaurants, nightclubs, and off-track betting and all locations permitted indoor smoking.

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 level of fine particle air pollution is very unhealthy in Indiana bars permitting smoking ($PM_{2.5}$ = 164 µg/m^3). This level of air pollution is 11 times higher than smoke-free venues in the U.S., and 12 times higher than outdoor pollution levels in Marion County.
- Employees in the Indiana venues permitting indoor smoking are exposed to levels of air pollution 3 times higher than safe annual levels established by the U.S. Environmental Protection Agency due solely to their occupational exposure to tobacco smoke pollution.
- Workers and patrons in the smoking-permitted locations in this study are still exposed to hazardous air contaminants and are at risk for a wide range of adverse health effects including lung cancer, cardiovascular disease and death, and effects on the unborn fetus such as pre-term delivery, low birth weight and spontaneous abortion. Smoke-free air policies are proven to effectively protect the health of workers and patrons from the adverse effects of exposure to tobacco smoke pollution.



* p<0.001 for comparison of smoke-free to smoking-permitted (Independent samples t test of log-transformed values)

† Annual average $PM_{2.5}$ level from USEPA outdoor monitoring sites in Marion County (2008).

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., 27 states, Washington D.C., and Puerto Rico have passed strong smoke-free air 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, North Carolina, Ohio, Oregon, Rhode Island, South Dakota,[1] Utah, Vermont, Washington, and Wisconsin.[2] Well over 50% of the U.S. population is now protected from secondhand smoke in all public places.[7] 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 determine the level of fine particle air pollution in Indianapolis public places that permit indoor smoking and compare that to levels in places where indoor smoking is prohibited. It is hypothesized that indoor particle air pollution levels will be significantly lower in restaurants and bars that do not allow indoor smoking compared to bars where smoking is permitted.

[1] The South Dakota law was passed by state legislators but has not been implemented yet due to a voter petition whose validity is being determined.
(http://www.aberdeennews.com/apps/pbcs.dll/article?AID=/20090703/NEWS10/907039989)
[2] The North Carolina and Wisconsin laws go into effect 1/2/2010 and 7/5/2010 respectively

Methods

Overview

In March 2009, indoor air quality was assessed in 10 indoor locations in Indianapolis, Indiana. These locations included bars, restaurants, nightclubs, and off-track betting and all locations permitted indoor smoking.

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. Room dimensions were also determined using a combination of any or all of the following techniques; a sonic measuring device, counting of construction materials of a know size such as floor tiles, or estimation. Room volumes were calculated from these dimensions. 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 pulmonary and cardiovascular disease and mortality.

Teams of trained testers from Indianapolis did the sampling and researchers from Roswell Park Cancer Institute analyzed the data.

Statistical Analyses

The primary goal was to assess the difference in the average levels of $PM_{2.5}$ between smoke-free and smoking-permitted establishments. Statistical significance is assessed using an independent samples *t* test on the log-transformed $PM_{2.5}$ concentrations. $PM_{2.5}$ concentrations were log-transformed to achieve normality and homogeneity of variances. The 10 locations sampled were compared to a large sample (n=447) of similar venues across the United States that do not permit indoor smoking. The smoke-free comparison data was collected using the exact same protocol and these results have been reported elsewhere.[10]

Results

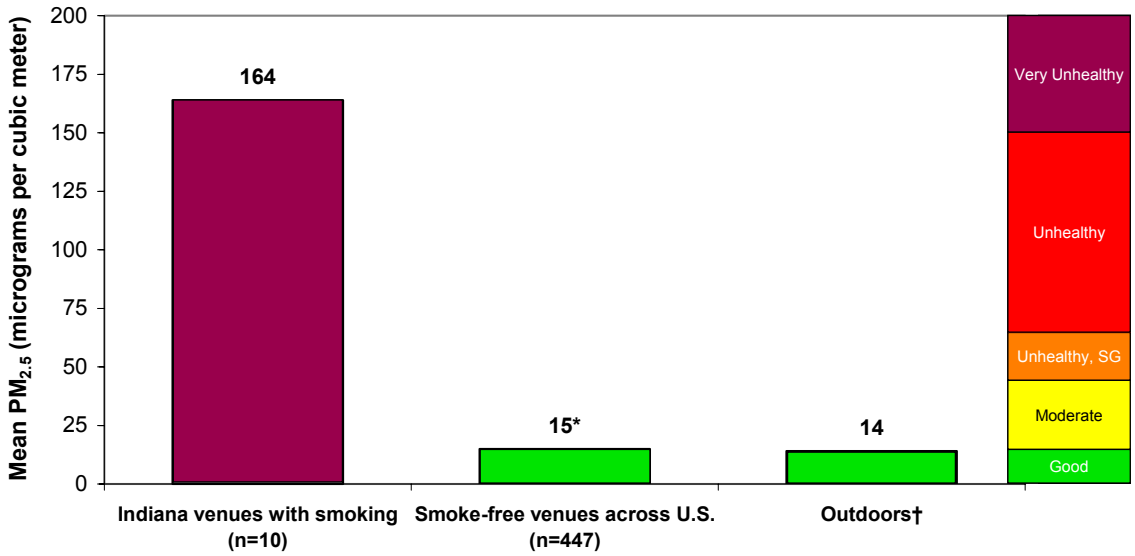
A summary of each location visited is shown in Table 1. The average $PM_{2.5}$ level in the 10 locations permitting indoor smoking was 164 $\mu g/m^3$, compared to 15 $\mu g/m^3$ in smoke-free places around the U.S. (Figure 1). Statistical analysis of the log transformed $PM_{2.5}$ concentrations shows this is a significant 89% difference in fine particle indoor air pollution ($p<0.001$).

Table 1. Fine Particle Indoor Air Pollution in Indiana Venues

Venue Number	Size (m^3)	Average # people	Average # burning cigs	Active smoker density*	Average $PM_{2.5}$ level ($\mu g/m^3$)
1	576	30	1.5	0.26	84
2	847	43	6.7	0.79	145
3	1094	160	9.7	0.88	196
4	6239	193	16.0	0.26	193
5	2610	45	4.5	0.17	30
6	2412	76	7.0	0.29	132
7	1312	126	6.0	0.46	393
8	918	74	5.3	0.58	230
9	672	131	2.3	0.35	121
10	410	92	11.0	2.68	115
Average	**1709**	**97**	**7.0**	**0.67**	**164**

*Average number of burning cigarettes per 100 cubic meters.

Figure 1. **Average Fine Particle Air Pollution**



* p<0.001 for comparison of smoke-free to smoking-permitted (Independent samples t test of log-transformed values)

† Annual average $PM_{2.5}$ level from USEPA outdoor monitoring sites in Marion County (2008).

The real-time plots showing the level of indoor air pollution in each venue sampled are presented in Figures 2 and 3 starting on page 11. The real-time $PM_{2.5}$ plots throughout the duration of sampling reveal the following results: 1) low background levels are observed outdoors; 2) high levels of indoor air pollution are observed in the venues where smoking was permitted; and 3) peak exposure levels in some venues where smoking was permitted reached levels far in excess of the average recorded level.

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] 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 164 $\mu g/m^3$ (the average level in all sites before the law) on the job, and is exposed only to background particle levels of 14 $\mu g/m^3$ during non-work times. For a full-time employee their average annual $PM_{2.5}$ exposure is 48 $\mu g/m^3$. The EPA average annual $PM_{2.5}$ limit is exceeded by over 3 times due to their occupational exposure. In contrast, workers in smoke-free locations are exposed to an average particle concentration of 15 $\mu g/m^3$, 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,[12] 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 smokefree 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.[13] 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.[14] 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.[15] 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 smokefree air laws, even though compliance with the laws was less than 100%.[16]

Other studies have directly assessed the effects SHS exposure has on human health. Rapid improvements in the respiratory health of bartenders were seen after a state smokefree workplace law was implemented in California[17]. Smokefree 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.[18] Farrelly et al. also showed a significant decrease in both salivary cotinine concentrations and sensory symptoms in hospitality workers after New York State's smokefree law prohibited smoking in their worksites.[19] A meta-analysis of the 8 published studies looking at the effects of smokefree air policies on heart attack admissions yielded an estimate of an immediate 19% reduction in heart attack admissions associated with these laws.[20]

The effects of passive smoking on the cardiovascular system in terms of increased platelet aggregation, 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.[21]

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. The health effects of secondhand smoke exposure are detailed in recent reports by the California Environmental Protection Agency[22] and the U.S. Surgeon General[23].

Conclusions

This study demonstrates that employees and patrons in Indianapolis places allowing indoor smoking are exposed to harmful levels of indoor air pollution resulting from indoor smoking. A comprehensive smoke-free air policy that prohibits indoor smoking in all indoor places is the only proven means to eliminate this exposure to toxic tobacco smoke pollution. This type of policy will result in improved quality of life and health outcomes for Indianapolis workers and residents.

Acknowledgments

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Special thanks go to volunteers from the American Heart Association, Smoke Free Indy, and Indiana Tobacco Prevention and Cessation who collected the data for this study.

Thanks to Cheryl Rivard, Roswell Park Cancer Institute, who helped process the data.

Roswell Park Cancer Institute (RPCI) is America's first cancer center founded in 1898 by Dr. Roswell Park. RPCI is the only upstate New York facility to hold the National Cancer Center designation of "comprehensive cancer center" and to serve as a member of the prestigious National Comprehensive Cancer Network.

Over its long history, Roswell Park Cancer Institute has made fundamental contributions to reducing the cancer burden and has successfully maintained an exemplary leadership role in setting the national standards for cancer care, research and education.

The campus spans 25 acres in downtown Buffalo and consists of 15 buildings with about one million square feet of space. A new hospital building, completed in 1998, houses a comprehensive diagnostic and treatment center. In addition, the Institute built a new medical research complex and renovated existing education and research space to support its future growth and expansion.

For more information about Roswell Park and cancer in general, please contact the Cancer Call Center at 1-877-ASK-RPCI (1-877-275-7724).

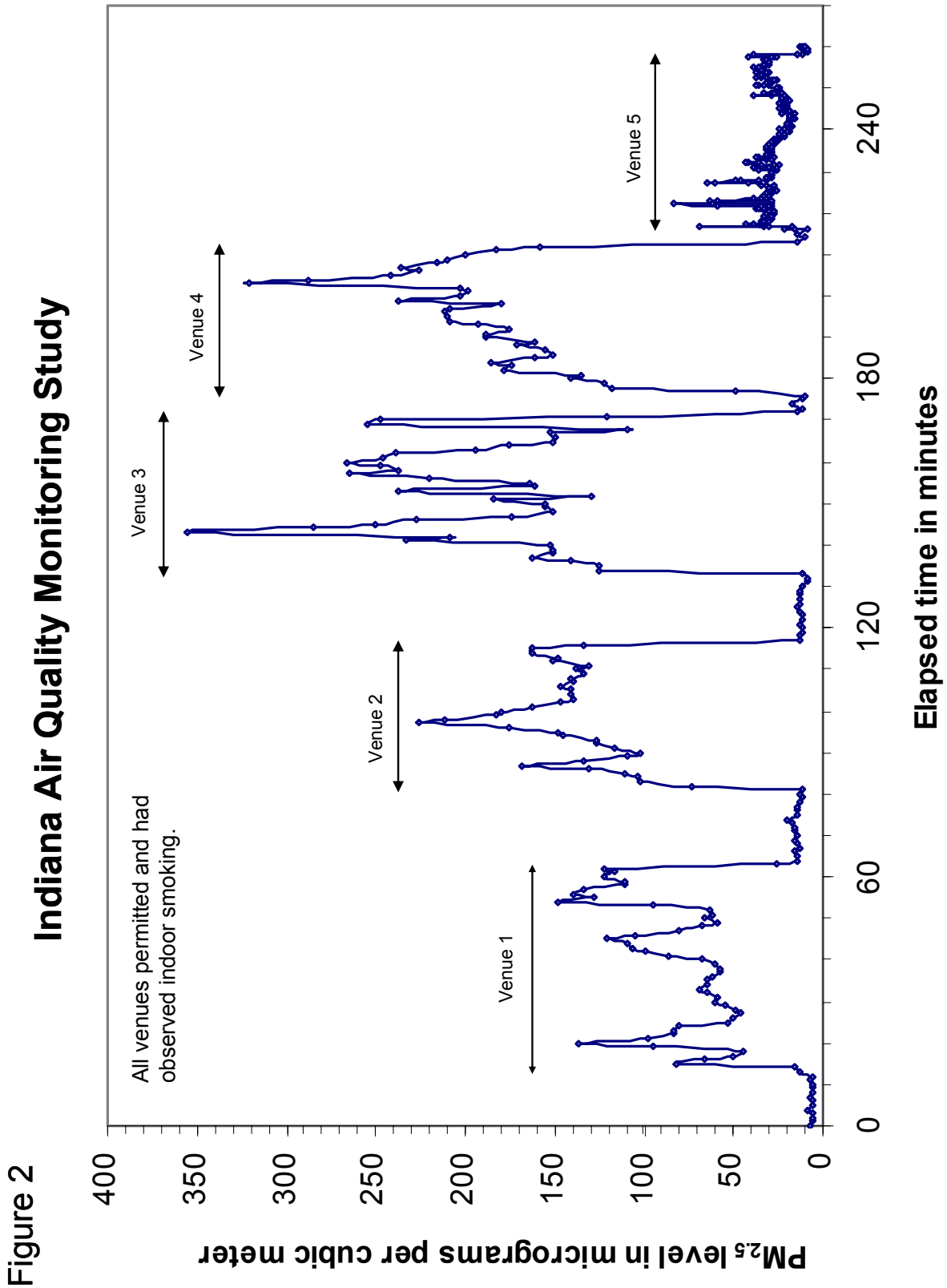
Indiana Air Quality Monitoring Study
All venues permitted and had observed indoor smoking.
Venue 1
Venue 2
Venue 3
Venue 4
Venue 5
PM2.5 level in micrograms per cubic meter
Elapsed time in minutes
0
50
100
150
200
250
300
350
400
0
60
120
180
240

Figure 2

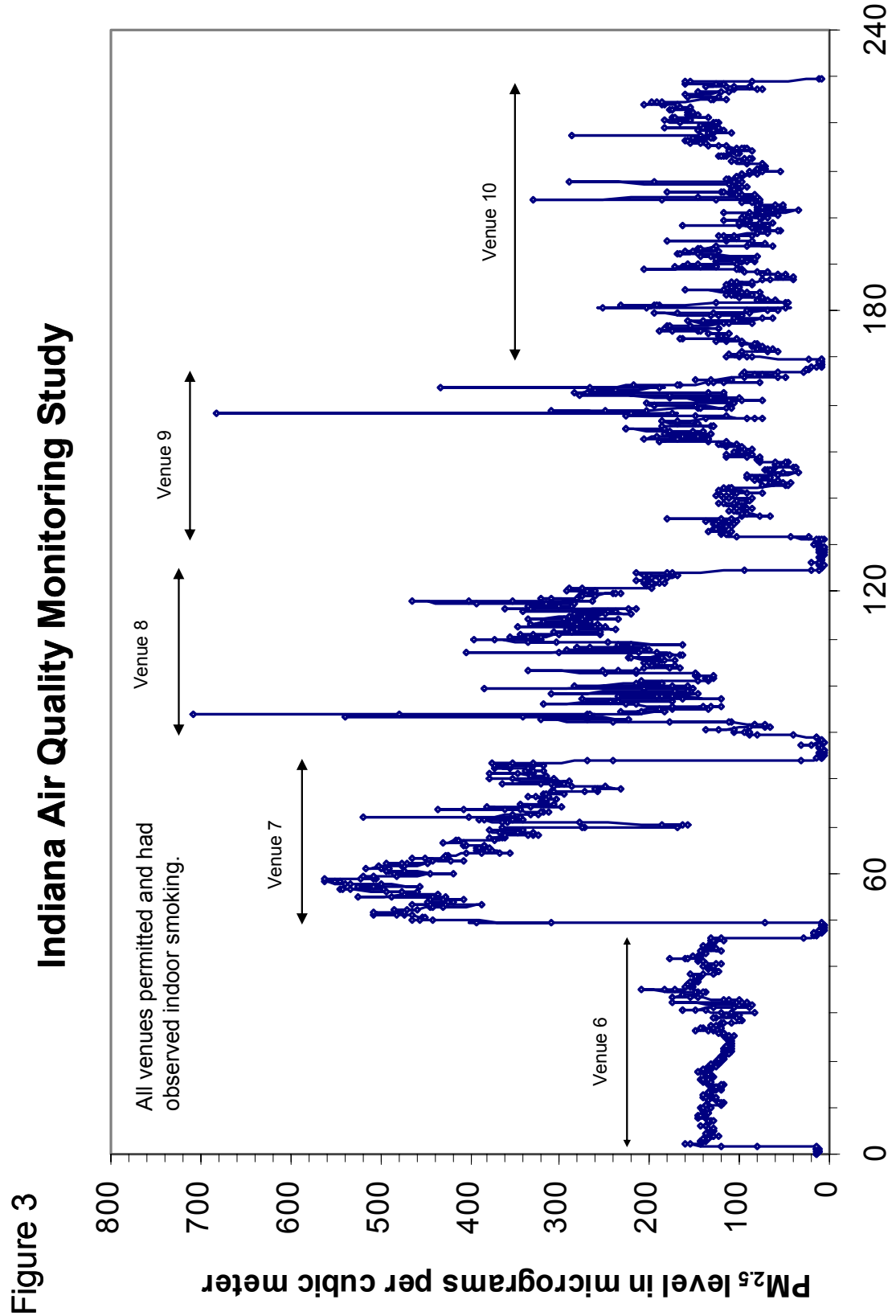
Indiana Air Quality Monitoring Study
All venues permitted and had observed indoor smoking.
Venue 6
Venue 7
Venue 8
Venue 9
Venue 10
PM2.5 level in micrograms per cubic meter
0
100
200
300
400
500
600
700
800
Elapsed time in minutes
0
60
120
180
240

Figure 3

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