INDIANAPOLIS, INDIANA

INDOOR AIR QUALITY MONITORING STUDY

Mark J. Travers, PhD, MS

Lisa Vogl, MPH

Department of Health Behavior and

Aerosol Pollution Exposure Research Laboratory (APERL)

ROSWELL PARK CANCER INSTITUTE

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EXECUTIVE SUMMARY

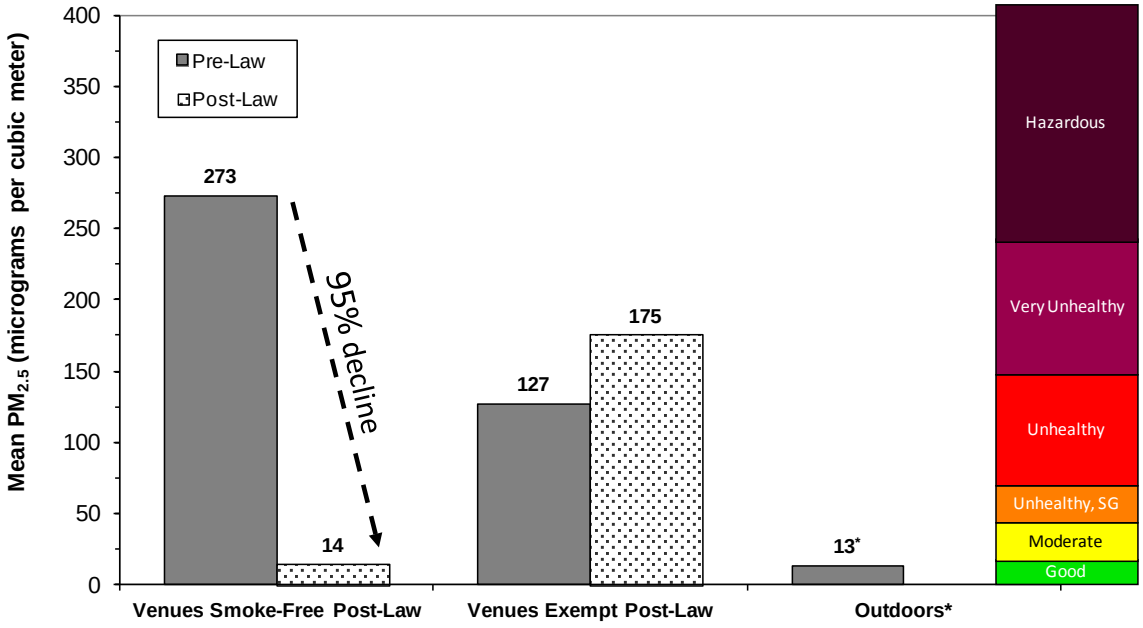
In May, August and November 2012, indoor air quality was assessed in 10 restaurants and bars in Indianapolis, Indiana. Effective June 1st, 2012, the new Indianapolis law prohibits smoking in most public places and places of employment with exemptions for nonprofit clubs, retail tobacco shops and a horse race betting parlor. Prior to the smoke-free air law, all 10 bar and restaurant locations permitted indoor smoking. After the smoke-free air law took effect all bars and restaurants were reassessed to observe the effect of the new smoke-free air law; no smoking was observed in 7 locations, while 3 locations met requirements to be exempt from the smoke-free air law.

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:

- In all 10 locations with observed indoor smoking before the law, the level of fine particle air pollution was "very unhealthy" ($PM_{2.5}$ = 229 µg/m^3). In the 7 locations that went smoke-free after the law, the level of fine particle air pollutions was "hazardous" prior to the law ($PM_{2.5}$ = 273 µg/m^3). This level of fine particle air pollution was 21 times higher than outdoor air in Indianapolis.
- Employees in all 10 locations with indoor smoking before the smoke-free air law went into effect were exposed to levels of air pollution 4.2 times higher than safe annual levels established by the U.S. Environmental Protection Agency due to their occupational exposure to tobacco smoke pollution.
- In the 7 locations that prohibited indoor smoking post-law, indoor particle pollution levels declined 95% as a result of the smoke-free air law to low levels, similar to those found in outdoor air.
- In the 3 locations that met requirements to be exempt from the smoke-free air law, particle pollution levels remained "very unhealthy" even after the smoke-free air law took effect.

Figure 1. Effect of IndianapolisSmoke-free Air Law on Indoor Air Pollution



*Used for comparison purposes. Based on the 2011 average PM2.5 level at Marion County, Indianapolis , Indiana EPA monitoring sites. http://www.epa.gov/airdata/ad_rep_mon.html

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 establishing smoke-free environments is the most effective method for reducing SHS exposure in public places,[5] Healthy People 2020 Objective TU-13 encourages all States, Territories, Tribes and the District of Columbia to establish laws on smoke-free indoor air that prohibit smoking in public places and worksites.[6]

Currently in the U.S., 29 states, Washington D.C., Puerto Rico, and the U.S. Virgin Islands have passed strong smoke-free air laws that include restaurants and bars. The states are Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Illinois, Iowa, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oregon, Rhode Island, South Dakota, Utah, Vermont, Washington, and Wisconsin. 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. Thousands 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 effect of the Indianapolis smoke-free air law on the level of fine particle air pollution in 10 bars and restaurants in Indianapolis, Indiana. The new smoke-free air law prohibits smoking in most public places and places of employment as of June 1st, 2012, with exemptions for nonprofit clubs, retail tobacco shops and a horse race betting parlor. This Indianapolis law is stronger than the recent Indiana State law (effective July 1st, 2012) which allows for more exemptions including all bars and taverns.

It is hypothesized that: 1) particle levels will decline significantly in a cohort of establishments permitting smoking at baseline that are sampled before and after the smoke-free air law; 2) there will be no significant decline in particle pollution levels in a cohort of establishments that are exempt from the smoke-free air law post-law; and 3) the degree of indoor particle air pollution will be correlated with the amount of smoking.

METHODS

> ***$PM_{2.5}$ 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 death.***

In general, a good marker of SHS exposure should be easily and accurately measured at an affordable cost, providing a valid assessment of SHS exposure as a whole. However, SHS is a dynamic and complex mixture of thousands of compounds in vapor and particulate phases and it is not possible to directly measure SHS in its entirety. The two most commonly used and preferred methods of measuring SHS exposure are nicotine and fine particle ($PM_{2.5}$) sampling.[8] These methods are correlated with each other and with other SHS constituents. Nicotine sampling has the advantage of being specific to tobacco smoke, meaning there are no other competing sources of nicotine in the air. Active $PM_{2.5}$ sampling is not specific to tobacco smoke but was chosen for this study due to several advantages of this type of sampling: 1) data can be collected quickly, discreetly, and cost-effectively with a portable battery operated machine; 2) measurements are taken continuously and stored in memory so the changes in particle levels, including peak levels, can be readily observed; 3) the machine is highly sensitive to tobacco smoke, being able to instantly detect particle levels as low as 1 microgram per cubic meter; 4) $PM_{2.5}$ has known direct health effects in terms of morbidity and mortality and there are existing health standards for $PM_{2.5}$ in outdoor air (e.g. US EPA and WHO) that can be used to communicate the relative harm of $PM_{2.5}$ levels in places with smoking.

In May 2012 indoor air quality was assessed in 10 restaurants and bars in Indianapolis, Indiana. After the law took effect on July 1st, 2012, all 10 restaurants and bars were reassessed in August or November to observe the effect of the smoke-free air law.

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 known size such as floor tiles, or estimation. Room volumes were

TSI SIDEPAK AM510 PERSONAL AEROSOL MONITOR

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.[9] The Sidepak was used with a calibration factor setting of 0.32, suitable for secondhand smoke.[10, 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.

Statistical Analyses

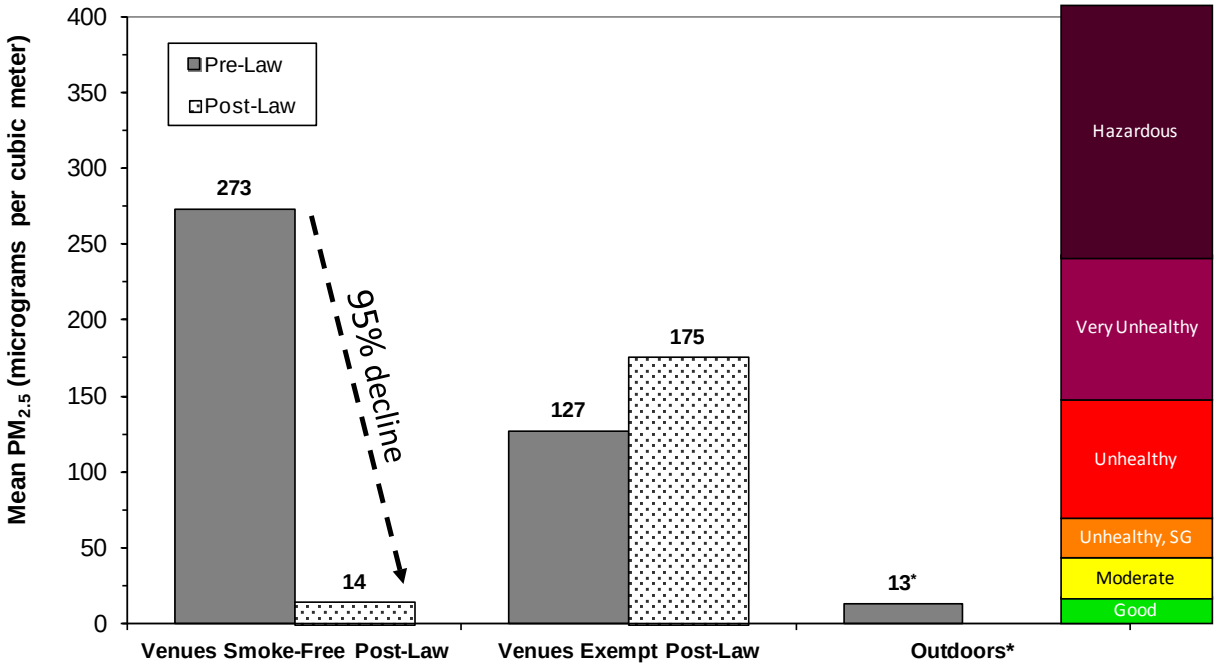
To evaluate the first and second hypotheses, the Wilcoxon signed-rank test was used to compare the difference in the mean levels of $PM_{2.5}$ between establishments with observed smoking and those with no observed smoking before and after the stronger smoke-free air law came into effect in Indianapolis. The third hypothesis is tested by using all 10 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 (i.e., number of burning cigarettes) per $100m^3$ are reported for each venue and averaged for all venues.

RESULTS

A summary of each location visited and tested is shown in Table 1. Prior to the implementation of a stronger law smoke-free air law in Indianapolis, the average $PM_{2.5}$ level in the 7 locations prohibiting indoor smoking post-law was 273 µg/m^3 (Figure 1). After Indianapolis's stronger smoke-free air law took effect, the mean $PM_{2.5}$ level in these 7 locations where smoking was previously observed was 14 µg/m^3. This is a 95% reduction in $PM_{2.5}$ levels compared to the pre-law levels. This difference is statistically significant ($p<0.05$). In the 3 locations exempt from the smoke-free air law there was no significant change in $PM_{2.5}$ levels as the average $PM_{2.5}$ level was 127 µg/m^3 prior to the law and increased to 175 µg/m^3 after the law took effect. These 3 establishments were exempt from the law under its retail tobacco shop provision as 2 operated as cigar bars and one as a hookah bar, all deriving more than 10% of their sales from tobacco products.

In all 10 locations with observed smoking, before the smoke-free air law was passed, the average number of burning cigarettes was 9.0 which correspond to an average smoker density (ASD) of 1.00 burning cigarette per 100 m^3. Looking at all 20 sample visits, pre-law and post-law, $PM_{2.5}$ levels are positively associated with the active smoker density indicating that the amount of indoor smoking is the primary driver of the indoor particle pollution levels. This association was statistically significant (r_s=0.828, $p<0.01$).

Figure 1. Effect of Indianapolis Smoke-free Air Law on Indoor Air Pollution



*Used for comparison purposes. Based on the 2011 average PM2.5 level at Marion County, Indianapolis, Indiana EPA monitoring sites. http://www.epa.gov/airdata/ad_rep_mon.html

The real-time plots showing the level of indoor air pollution in each venue sampled is presented in Figures 2 & 3, starting on page 12. The real-time $PM_{2.5}$ plots 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 observed; and 3) peak exposure levels in some venues where smoking was observed reached levels far in excess of the average recorded level.

Table 1. Fine Particle Air Pollution in Indianapolis Hospitality Venues

		Pre-Law				Post-Law			
Venue Number	**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 ($\mu g/m^3$)**
Venues Smoke-Free Post-Law									
1	576	26	2.8	0.49	70	21	0.0	0.00	8
2	299	28	1.0	0.33	51	46	0.0	0.00	6
3	864	62	3.7	0.42	156	73	0.0	0.00	6
4	1013	143	9.3	0.92	401	32	0.0	0.00	7
5	2305	224	5.0	0.22	93	89	0.0	0.00	8
6	1720	57	5.6	0.33	595	27	0.0	0.00	26
7	665	102	6.6	0.99	546	110	0.0	0.00	35
Average	**1063**	**92**	**4.9**	**0.53**	**273**	**57**	**0.0**	**0.00**	**14**
Venues Exempt Post-Law									
8	3617	21	2.6	0.07	45	12	1.8	0.05	50
9	554	21	10.8	1.94	251	16	9.3	1.69	135
10	544	89	44.8	8.24	86	81	16.8	3.08	340
Average	**1571**	**44**	**19.4**	**3.42**	**127**	**36**	**9.3**	**1.61**	**175**

*Average number of burning cigarettes, cigars, and hookah per 100 cubic meters.

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] 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 229 $\mu g/m^3$ (the average level in all 10 sites with smoking Pre-Law) on the job, and is exposed only to background particle levels of 13 $\mu g/m^3$ during non-work times. For a full-time employee their average annual $PM_{2.5}$ exposure is 62 $\mu g/m^3$. The EPA average annual $PM_{2.5}$ limit is exceeded by 4.2 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) 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.[14] 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.[15] 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.[16] 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%.[17]

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 smoke-free workplace law was implemented in California[18]. 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.[19] 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 air law prohibited smoking in their worksites.[20] A meta-analysis of the 8 published studies looking at the effects of smoke-free air policies on heart attack admissions yielded an estimate of an immediate 19% reduction in heart attack admissions associated with these laws.[21]

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.[22]

The hazardous health effects of exposure to secondhand 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 SHS 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 SHS 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. The health effects of SHS exposure are detailed in recent reports by the California Environmental Protection Agency[23] and the U.S. Surgeon General[24].

CONCLUSIONS

This study demonstrates that employees and patrons in Indianapolis bars and restaurants with observed indoor smoking, prior to the smoke-free air law, were exposed to harmful levels of indoor air pollution resulting from indoor smoking. The new Indianapolis smoke-free air law implemented on June 1st, 2012, that prohibits smoking in most public places and places of employment has been shown to decrease exposure to toxic tobacco smoke pollution by 95%. However, locations meeting requirements to be exempt from the smoke-free air law continue to pose a health risk as demonstrated by the harmful increase in levels of fine particle air pollution before and after the law went into effect. To guarantee a reduction in exposure to toxic tobacco smoke in all public places and places of employment, improvements in the smoke-free air law must be addressed. A 100% smoke-free air law will result in improved quality of life and health outcomes for Indianapolis workers and residents.

ACKNOWLEDGMENTS

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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).

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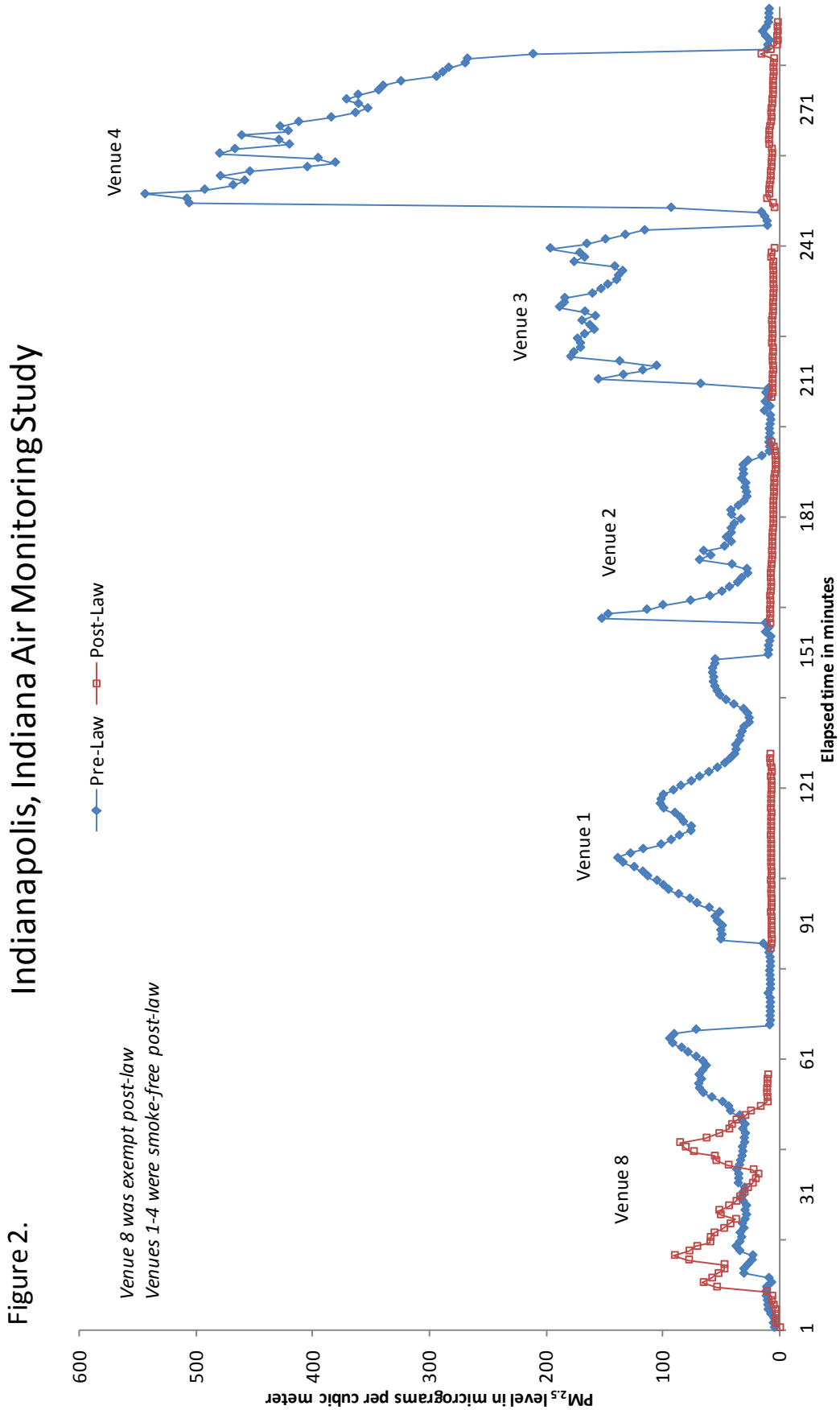
Figure 2.


Indianapolis, Indiana Air Monitoring Study
Pre-Law
Post-Law
Venue 8 was exempt post-law
Venues 1-4 were smoke-free post-law
Venue 4
Venue 3
Venue 2
Venue 1
Venue 8
PM2.5 level in micrograms per cubic meter
Elapsed time in minutes
0
100
200
300
400
500
600
1
31
61
91
121
151
181
211
241
271

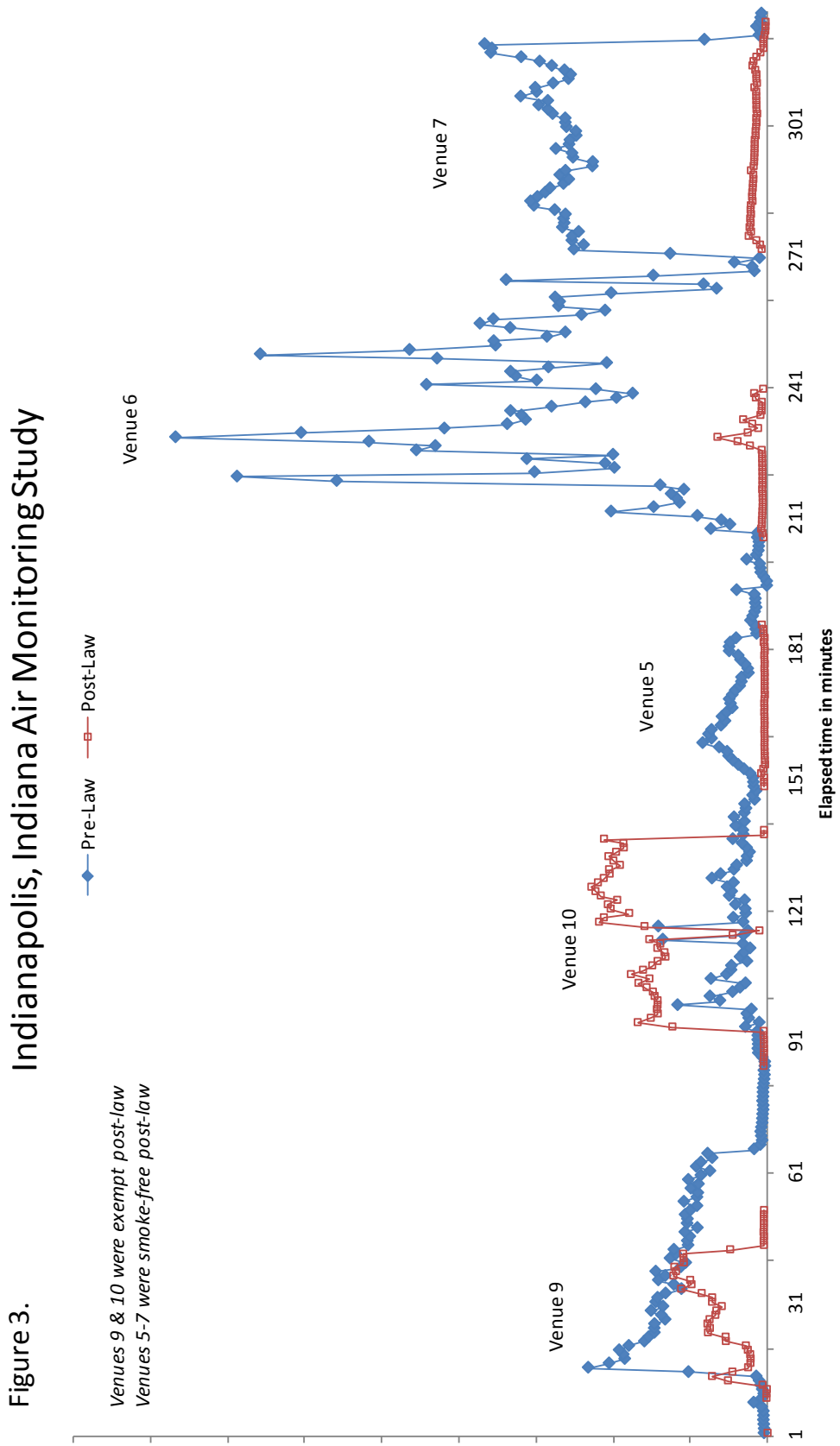

Indianapolis, Indiana Air Monitoring Study
Pre-Law
Post-Law
Venues 9 & 10 were exempt post-law
Venues 5-7 were smoke-free post-law
Venue 9
Venue 10
Venue 5
Venue 6
Venue 7
PM2.5 level in micrograms per cubic meter
Elapsed time in minutes
0
200
400
600
800
1000
1200
1400
1600
1800
1
31
61
91
121
151
181
211
241
271
301

Figure 3.