

## **Indoor Air Quality After Implementation of Henderson's Smoke-free Ordinance**

Ellen J. Hahn, DNS, RN<sup>1</sup>  
Kiyong Lee, ScD, CIH<sup>2</sup>  
Heather E. Robertson, MPA<sup>1</sup>  
Seongjik Lee, MS, EdS<sup>1</sup>

March 14, 2007

<sup>1</sup>University of Kentucky, College of Nursing

<sup>2</sup>University of Kentucky, College of Public Health, Department of Environmental Health

## Executive Summary

Indoor air quality was assessed in 11 venues in Henderson, Kentucky, including five restaurants, four bars, and two other entertainment venues after a smoke-free workplace and public places law was implemented on October 1, 2006. All venues were to be smoke-free by law; except for one which qualified for an exemption and allowed smoking as per the ordinance. Venues were sampled from February 16, 2007 to February 19, 2007, using the TSI SidePak AM510 Personal Aerosol Monitor. The average PM<sub>2.5</sub> level from all 11 venues including those that were not complying with the law is compared to the average PM<sub>2.5</sub> levels in Lexington, Georgetown, and Louisville pre- and post-law, as well as the National Ambient Air Quality Standard for 24 hours.

Key findings of the study are:

- The level of indoor air pollution in venues sampled in Henderson, Kentucky, post-law (average PM<sub>2.5</sub> = 133 µg/m<sup>3</sup>) was 7.4 higher than Lexington's post-law and 6.7 times higher than Georgetown's post-law average PM<sub>2.5</sub> levels (see Figure 1). Workers and patrons in Henderson venues sampled in this study were exposed to air pollution nearly four times the National Ambient Air Quality Standard for outdoor air.
- The five restaurants, four bars, and two other entertainment venues had average PM<sub>2.5</sub> levels ranging from 7 µg/m<sup>3</sup> to 434 µg/m<sup>3</sup> (see Figure 2). Smoking was observed in five of the 11 venues; one of these is exempt from the smoke-free ordinance and allows smoking by law. In six venues where there was no smoking observed, the average PM<sub>2.5</sub> was 34 µg/m<sup>3</sup> compared to 206 µg/m<sup>3</sup> where smoking was observed (not in compliance with the law), and 434 µg/m<sup>3</sup> in the venue that allowed smoking by law (see Figure 3). In the noncompliant venues, air pollution was six times higher than in venues where smoking was not observed. In the entertainment venue that allowed smoking by law, the air pollution was nearly 13 times higher than in venues where smoking was not observed.
- The average air pollution level in the six venues where smoking was not observed post-law was 34 µg/m<sup>3</sup> below the National Ambient Air Quality Standard for outdoor air. The data suggest that when smoking is completely prohibited inside, air quality is significantly improved.

If Henderson amends its smoke-free law to exempt bars and allow enclosed, ventilated smoking rooms (like Louisville's current law), indoor air quality would be expected to worsen. In Louisville, the average PM<sub>2.5</sub> pre-law was 304 µg/m<sup>3</sup>. After their partial smoke-free law was implemented, the average PM<sub>2.5</sub> level did not improve, rising slightly to 338 µg/m<sup>3</sup> (see Figure 1).

## Introduction

Secondhand smoke (SHS) contains at least 250 chemicals that are known to be toxic.<sup>1,2</sup> There is no safe level of exposure to SHS.<sup>2</sup> SHS exposure is the third leading cause of preventable death in the United States.<sup>3</sup> SHS is a mixture of the smoke from the burning end of tobacco products (sidestream smoke) and the smoke exhaled by smokers (mainstream smoke) and is known to cause cancer in humans.<sup>1,2,3</sup> SHS exposure is a cause of heart disease and lung cancer in

nonsmoking adults.<sup>1-4</sup> An estimated 3,000 nonsmokers die from lung cancer<sup>5</sup> annually and over 46,000 nonsmokers die from heart disease<sup>2</sup> every year in the U.S. It is estimated that approximately 60% of people in the United States have biological evidence of SHS exposure.<sup>6</sup>

Currently in the U.S., 570 local municipalities and 21 states plus the District of Columbia have enacted 100% smoke-free laws in workplaces and/or restaurants and/or bars.<sup>7</sup> It is estimated that approximately 52.9% of the U.S. population are protected by clean indoor air regulations that cover virtually all indoor worksites including bars and restaurants. There are over 2,300 local ordinances or regulations that restrict smoking to some extent in workplaces across the United States and Washington D.C.<sup>8</sup> The extent of protection provided by these laws vary widely from community to community.

Currently in Kentucky, 11 communities have enacted and implemented smoke-free laws. The most comprehensive ordinances, 100% smoke-free workplace *and* 100% smoke-free enclosed public place laws, have been implemented in Georgetown, Morehead, Ashland, and Elizabethtown.. The next most comprehensive ordinances, 100% smoke-free enclosed public place laws, have been implemented in Lexington, Letcher County, and Frankfort. Three communities have enacted partial smoke-free laws, protecting workers and patrons in some public venues: Louisville, Daviess County, and Paintsville. Henderson, Kentucky has implemented a smoke-free law covering most workplaces and public places.

The purpose of this study was to (a) assess air quality in 11 Henderson, Kentucky hospitality venues after implementation of their smoke-free law; and (b) compare the results to Lexington, Georgetown and Louisville, Kentucky air quality data before and after their smoke-free laws took effect.

## Methods

Between February 16 and 19, 2007, indoor air quality was assessed in 11 indoor locations including restaurants, bars, and other entertainment venues in Henderson. Sites were of various sizes; some sites were individually owned establishments and some were part of local or national chain entities.

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 and the particulate matter in the air scatters the light from a laser to assess the real-time concentration of particles smaller than 2.5 $\mu$ m in micrograms per cubic meter, or PM<sub>2.5</sub>. The SidePak was calibrated against a light scattering instrument, which had been previously calibrated and used in similar studies. 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<sub>2.5</sub> concentration within each venue. The Kentucky Center for Smoke-free Policy (KCSP) staff trained staff from the Green River District Health Department, who conducted the sampling and sent the data to KCSP for analysis

### Statistical Analyses

Descriptive statistics including the venue volume, number of patrons, number of burning cigarettes, and smoker density (i.e., average number of burning cigarettes per 100 m<sup>3</sup>) were reported for each venue and averaged for all venues.

### **Results**

The five restaurants, four bars, and two other entertainment venues were visited on Friday, Saturday, Sunday and Monday for an average of 48 minutes (range 42-97 minutes). Visits occurred at various times of the day from 10:34AM to 11:03 PM. The average size of the Henderson venues was 2,255 m<sup>3</sup> (range 146-15,810 m<sup>3</sup>) and the smoker density was 0.26 #bc/100 m<sup>3</sup>. On average, 78 patrons were present per venue and 6.9 burning cigarettes per venue were observed. Descriptive statistics for each venue are summarized in Table 1.

As depicted in Figure 1, the average level of indoor air pollution in the 11 Henderson venues (133 µg/m<sup>3</sup>) was approximately 7.4 higher than Lexington's post-law and 6.7 times higher than Georgetown's post-law average PM<sub>2.5</sub> levels. Workers and patrons in Henderson venues sampled in this study were exposed to air pollution nearly four times the National Ambient Air Quality Standard for outdoor air.

Table 1. Air Quality for 11 Venues in Henderson, Post-Law 2007

<b>Venue</b>	<b>Date Sampled</b>	<b>Average # people</b>	<b>Average # burning cigs</b>	<b>Smoker density (#bc/100m<sup>3</sup>)</b>	<b>Average PM2.5 level</b>
Restaurant A	2/16/2007	83	0.0	0.00	7
Restaurant B	2/17/2007	35	0.0	0.00	14
Restaurant C	2/17/2007	49	0.0	0.00	11
Restaurant D	2/18/2007	33	0.0	0.00	9
Restaurant E	2/18/2007	44	0.0	0.00	8
Bar A*	2/16/2007	35	4.4	0.96	312
Bar B*	2/17/2007	198	11.0	0.87	384
Bar C	2/19/2007	22	0.0	0.00	155
Bar D*	2/17/2007	17	4.0	0.70	95
Other Venue A*	2/16/2007	52	0.4	0.01	31
Other Venue B	2/18/2007	287	56.0	0.35	434

\* Not complying with smoke-free law based on observed smoking.

Note. There were no burning cigarettes observed in Bar C. However, one person entered with an unlit cigarette, noticed strangers, and did not light up. The data suggest that there was smoking in Bar C immediately prior to the monitoring.

Figure 2 shows the average level of indoor air pollution in each of the 11 sampled venues. The average PM<sub>2.5</sub> levels ranged from 7 µg/m<sup>3</sup> to 434 µg/m<sup>3</sup>. Smoking was observed in five of the 11 venues; one of these is exempt from the smoke-free ordinance and allows smoking by law. In six venues where there was no smoking observed, the average PM<sub>2.5</sub> was 34 µg/m<sup>3</sup>, compared to 206 µg/m<sup>3</sup> where smoking was observed (not in compliance with the law), and 434 µg/m<sup>3</sup> in the venue that allowed smoking by law (see Figure 3). In the noncompliant venues, air pollution was six times higher than in venues where smoking was not observed. In the entertainment venue that allowed smoking by law, the air pollution was nearly 13 times higher than in venues where smoking was not observed.

## Discussion

The average PM<sub>2.5</sub> level in the 11 venues in Henderson, Kentucky was 133 µg/m<sup>3</sup>, a level approximately four times higher than the National Ambient Air Quality Standard of 35 µg/m<sup>3</sup>. There were over 80 EPA cited epidemiologic studies in creating a particulate air pollution standard in 1997.<sup>9</sup> To protect the public's health, the EPA set a new limit of 35 µg/m<sup>3</sup> for PM<sub>2.5</sub> on December 17, 2006 as the average level of exposure over 24-hours.

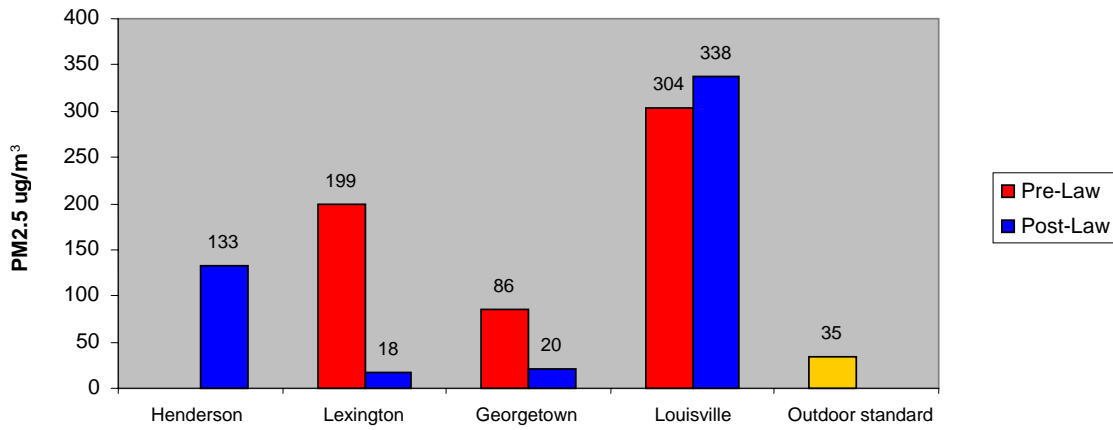
Three Kentucky air quality studies have demonstrated significant improvements in air quality as a result of implementing a comprehensive smoke-free law. Hahn et al. showed a 91% decrease in indoor air pollution after Lexington, Kentucky implemented a comprehensive smoke-free law on April 27, 2004.<sup>10</sup> The average level of indoor air pollution was 199 µg/m<sup>3</sup> pre-law and dropped to 18 µg/m<sup>3</sup> post-law. Average levels of indoor air pollution dropped from 86 µg/m<sup>3</sup> to 20 µg/m<sup>3</sup> after Georgetown, Kentucky implemented a comprehensive smoke-free law on October 1, 2005. Similarly, other studies show significant improvements in air quality after implementing a smoke-free law. One California study showed an 82% average decline in air pollution after smoking was prohibited.<sup>11</sup> When indoor air quality was measured in 20 hospitality venues in western New York, average levels of respirable suspended particle (RSP) dropped by 84% after a smoke-free law took effect.<sup>12</sup>

Other studies have been conducted to assess the effects of SHS on human health. Hahn et al. found a 56% drop in hair nicotine levels in a sample of hospitality workers after Lexington implemented a smoke-free law, regardless of whether workers were smokers or nonsmokers.<sup>13</sup> Workers were also less likely to report colds and sinus infections after the law went into effect. Similarly, Farrelly et al. also showed a significant decrease in both salivary cotinine concentrations and sensory symptoms in hospitality workers after New York State implemented a smoke-free law in their worksites.<sup>14</sup> Smoke-free legislation in Scotland was associated with significant improvements in respiratory symptoms, spirometry measurements, and systemic inflammation in bar workers. The significant improvement in respiratory health was reported only one month after the smoke-free law took effect.<sup>15</sup>

There is no longer any doubt in the medical or scientific communities that SHS is a significant public health problem. In 2006, U.S. Surgeon General Carmona, said "The scientific evidence is now indisputable: secondhand smoke is not a mere annoyance. It is a serious health hazard that can lead to disease and premature death in children and nonsmoking adults." SHS causes coronary heart disease, lung cancer, other cancers, and lung disease in nonsmoking adults.

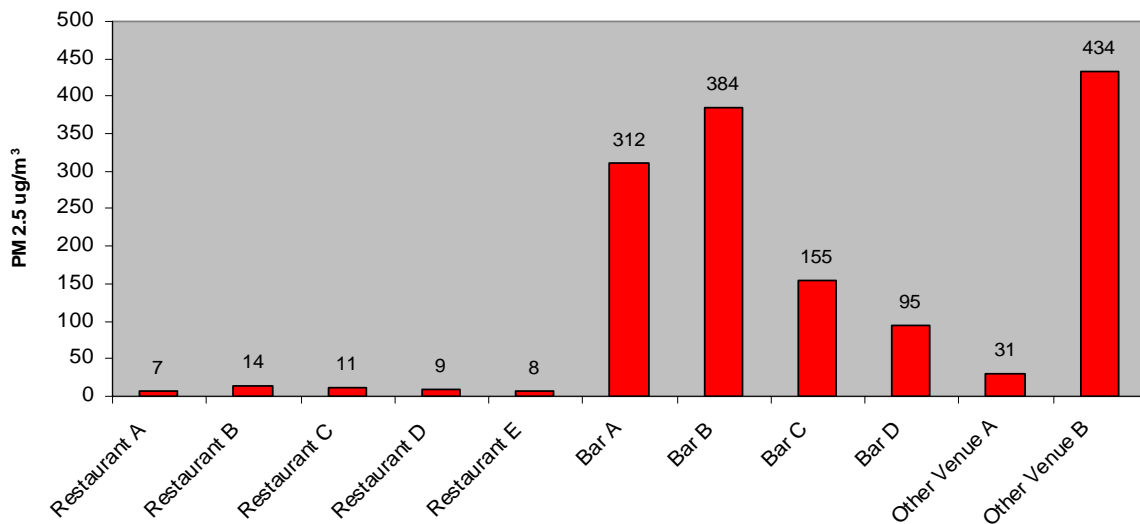
Many millions of Americans, both children and adults, are still exposed to secondhand smoke in their homes and workplaces. Approximately 60% of people in the United States have biological evidence of SHS exposure.<sup>16</sup> U.S. Surgeon General Carmona said, “Eliminating smoking in indoor spaces fully protects nonsmokers from exposure to secondhand smoke. Separating smokers from nonsmokers, cleaning the air, and ventilating buildings cannot eliminate exposure of nonsmokers to secondhand smoke.”

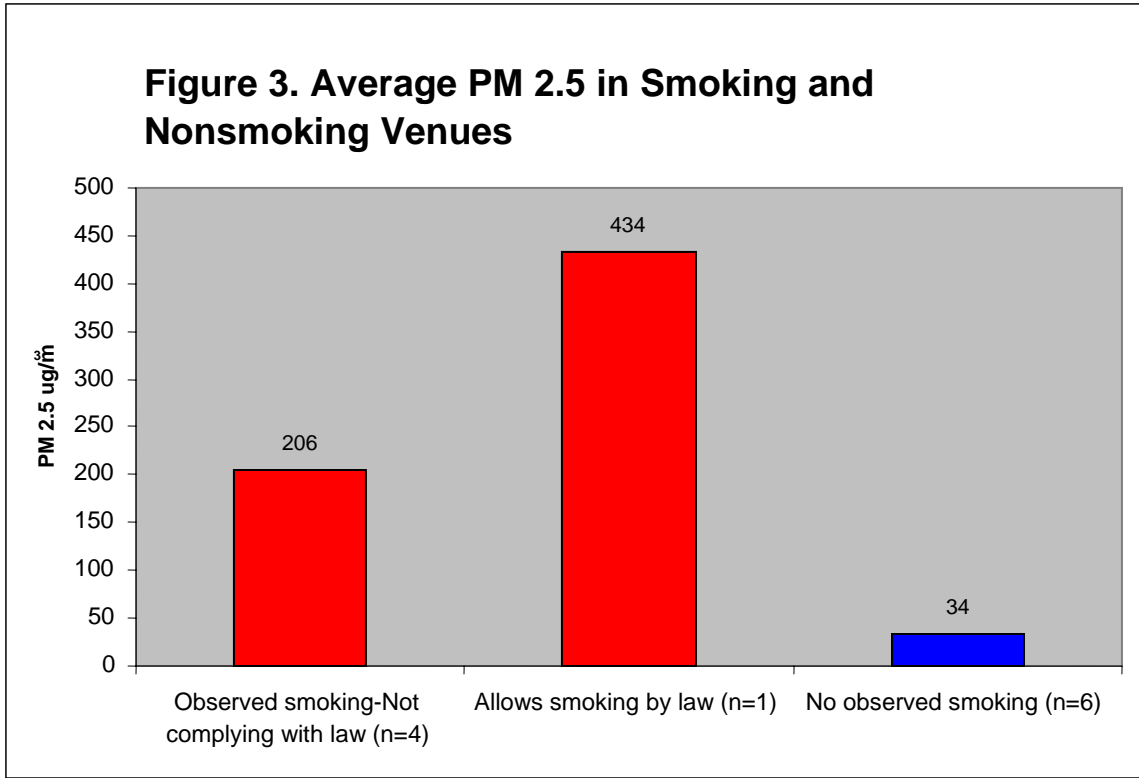
**Figure 1. Average Fine Particle Air Pollution in Four Kentucky Communities**



The National Ambient Air Quality Standard for PM 2.5 is 35 ug/m<sup>3</sup> for 24 hours.  
There is currently no indoor air quality standard.

**Figure 2. Average Fine Particle Air Pollution in 11 Venues in Henderson, Post-Law, 2007**





**Conclusions**

The average air pollution level in the six venues where smoking was not observed post-law was 34  $\mu\text{g}/\text{m}^3$ , below the National Ambient Air Quality Standard for outdoor air. The data suggest that when smoking is completely prohibited inside, air quality is significantly improved. On average, workers and patrons in Henderson were exposed to indoor air pollution levels approximately four times the National Ambient Air Quality Standard, and approximately 7.4 higher than Lexington’s post-law and 6.7 times higher than Georgetown’s post-law average  $\text{PM}_{2.5}$  levels.

If Henderson amends its smoke-free law to exempt bars and allow enclosed, ventilated smoking rooms (like Louisville’s current law), indoor air quality would be expected to worsen. In Louisville, the average  $\text{PM}_{2.5}$  pre-law was 304  $\mu\text{g}/\text{m}^3$ . After their partial smoke-free law was implemented, the average  $\text{PM}_{2.5}$  level did not improve, rising slightly to 338  $\mu\text{g}/\text{m}^3$ . Based on this information as well as difficulties with enforcement, the Louisville Metro Council strengthened their law to include bars and remove ventilation provisions on October 6, 2006 (to go into effect July 1, 2007).



## References

1. National Toxicology Program. *10<sup>th</sup> Report on Carcinogens*. Research Triangle Park, NC: U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program, December 2002.
2. United States Department of Health and Human Services. *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General*. Atlanta, GA: Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Center for Chronic Disease and Prevention and Promotion, Office of Smoking and Health; 2006.
3. National Cancer Institute. *Health Effects of Exposure to Environment Tobacco Smoke*. Smoking and Tobacco Control Monograph No. 10 (PDF – 71k). Bethesda, MD: U.S. Department of Health and Human Services, National Institutes of Health, National Cancer Institute; 1999. NIH Pub. No. 99-4645.
4. U.S. Environmental Protection Agency. *Respiratory Health Effects of Passive Smoking: Lung Cancer and Other Disorders*. Washington, DC: U.S. Environmental Protection Agency; 1992. Pub. No. EPA/600/6-90/006F.
5. Centers for Disease Control and Prevention. Annual smoking-attributable mortality, years of potential life lost, and economic costs—United States, 1995-1999, *MMWR*, 2002;51(14):300-320.
6. Centers for Disease Control and Prevention. *Second National Report on Human Exposure to Environmental Chemicals: Tobacco Smoke*. Atlanta, GA: U.S. Department of Health and Human Services, CDC, National Centre for Environmental Health; 2003:80. NCEH Pub No. 03-0022.
7. Americans for Nonsmokers' Rights. *Summary of 100% smokefree state laws and population protected by state and local laws*. January 12, 2007. Retrieved March 13, 2007 from <http://www.no-smoke.org/pdf/SummaryUSPopList.pdf>.
8. Americans for Nonsmokers' Rights. (2006b). *Overview list – how many smoke-free laws?* July 1, 2006. Retrieved August 11, 2006 from <http://www.no-smoke.org/pdf/mediaordlist.pdf>.
9. U.S. Environmental Protection Agency. *National Ambient Air Quality Standards for Particulate Matter; Final Rule*. Federal Register 1997; 62(138): 38651-38701.
10. Hahn, E, Lee, K, Okoli, Z, Troutman, A, Powell, R. Smoke-free Laws and Indoor Air Pollution in Lexington and Louisville. *Louisville Medicine* 2005; 52(10): 391-392.
11. Ott, W, Switzer, P, Robinson, J. Particle concentrations inside a tavern before and after prohibition of smoking: Evaluating the performance of an indoor air quality model. *J Air Wast Manag Assoc* 1996; 46:1120-1134.

12. Morbidity and Mortality Weekly Report, Indoor Air Quality in Hospitality Venues Before and After implementation of a Clean Indoor Air Law—Western New York, 2003, November 12, 2004, 53(44); 1038-1041.
13. Hahn, E, Rayens, M, York, N, Dignan, M, Al-Delaimy, W. Secondhand Smoke Exposure in Restaurant and Bar Workers Before and After Lexington’s Smoke-Free Ordinance. July 2005.
14. Farrelly, M, Nonnemaker, J, Chou, R, Hyland, A, Peterson, K, Bauer, U. Change in hospitality workers’ exposure to secondhand smoke following the implementation of New York’s smoke-free law. *Tobacco Control* 2005; 14: 236-241.
15. Menzies, D, Nair, A, Williamson, P, Schembri, S, Al-Khairalla, M, Barnes, M, Fardon, T, McFarlane, L, Magee, G, Lipworth, B. Respiratory Symptoms, Pulmonary Function, and Markers of Inflammation Among Bar Workers Before and After a Legislative Ban on Smoking in Public Places. *JAMA*. 2006;296:1742-1748.
16. CDC. *Second National Report on Human Exposure to Environmental Chemicals: Tobacco Smoke*. Atlanta, GA: U.S. Department of Health and Human Services, CDC, National Centre for Environmental Health; 2003:80. NCEH Pub No. 03-0022.