Indoor Air Quality Before and After Implementation of Laurel County's Smoke-free Ordinance

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Executive Summary

Indoor air quality was assessed in nine locations before and 10 locations after the city of London's smoke-free workplace ordinance was implemented on August 10, 2009. Of the 10 venues tested after London's law went into effect, five were located within London city limits, and five were outside London city limits. Locations were sampled using the TSI SidePak AM510 Personal Aerosol Monitor from March 14 to March 21, 2008 before the ordinance was in effect and from August 13 to October 16, 2010, after London's smoke-free law was implemented. The average $PM_{2.5}$ levels in London pre- and post-law were compared in five venues. We also compared the air quality in venues covered by London's law to those located in the county without a law, as well as to the average $PM_{2.5}$ levels in Georgetown and Lexington pre- and post-law and to the National Ambient Air Quality Standard (NAAQS) for 24 hours.

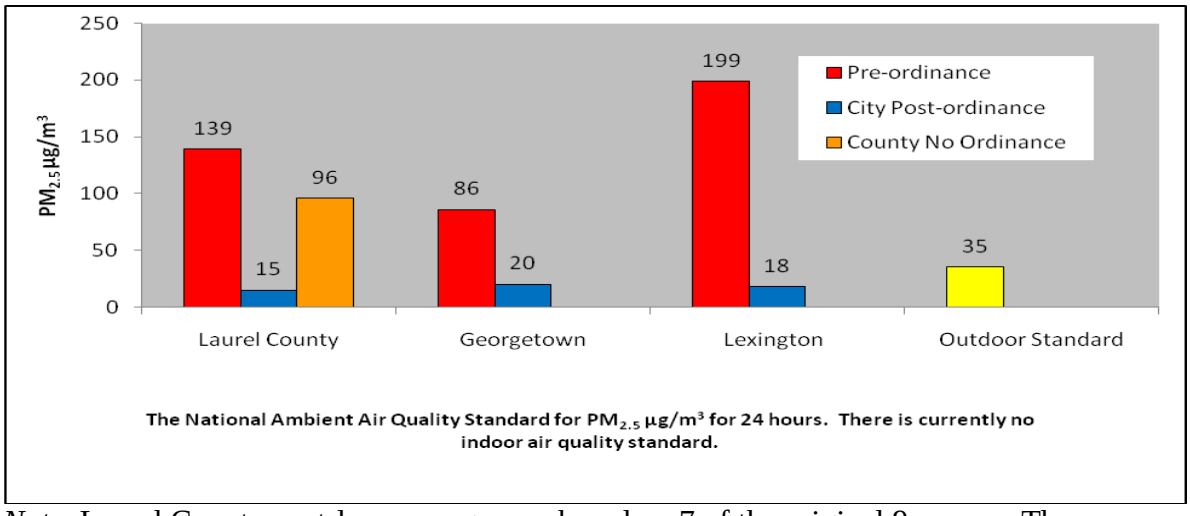
Key findings of the study are:

- Before London's ordinance, the average $PM_{2.5}$ in the nine venues tested was 139µg/m.^{3} After London's smoke-free law, air pollution dropped to 15µg/m^3 in the city venues. Air pollution remained high in venues located outside the city limits and not covered by the city's smoke-free law (96µg/m^3).

- Of the five venues tested within London city limits, the average $PM_{2.5}$ decreased from 172 µg/m^3 before the smoke-free law to 15 µg/m^3 after the law, representing a 91.3% decline in indoor air pollution. The venues observed within the London city limits were well below the National Ambient Air Quality Standard (35µg/m^3).

- Of the five venues tested in the county after London's ordinance took effect, the average $PM_{2.5}$ was 96 µg/m^3 which is 6.4 times greater than London's venues, and 2.7 times greater than the National Ambient Air Quality Standard (35µg/m^3).

Figure 1. Average Fine Particle Air Pollution in Three Kentucky Communities, Pre- and Post- Ordinance



Note. Laurel County post-law averages are based on 7 of the original 9 venues. Three new venues were added to the post-law study**.**

Introduction

Secondhand smoke (SHS) contains at least 250 chemicals that are known to be toxic.[1] There is no safe level of exposure to SHS.[2,3] SHS damages the DNA, blood vessels, and lung tissue, causing cancer, heart, and lung disease.[3] SHS exposure is the third leading cause of preventable death in the United States.[2] SHS is a mixture of the smoke from the burning end of tobacco products (sidestream smoke) and the smoke exhaled by smokers (mainstream smoke). An estimated 3,000 nonsmokers die from lung cancer and over 46,000 nonsmokers die from heart disease[2] every year in the U.S due to SHS exposure. It is estimated that 40.1% of nonsmokers in the United States have biological evidence of SHS exposure.[4]

Currently in the U.S., 21,884 local municipalities are covered by either local or state 100% smoke-free laws in workplaces and/or restaurants and/or bars.[5] It is estimated that approximately 48% of the U.S. population is protected by clean indoor air regulations that cover virtually all indoor worksites including bars and restaurants. There are 3,487 local ordinances or regulations that restrict smoking to some extent in workplaces across the United States and Washington D.C.[5] The extent of protection provided by these laws varies widely from community to community.

As of January 2, 2012, 31 Kentucky communities had implemented smoke-free laws or adopted smoke-free regulations. The most comprehensive ordinances/regulations, 100% smoke-free workplace and 100% smoke-free enclosed public place laws, have been implemented in 19 communities: Ashland, Bardstown, Bowling Green, Campbellsville, Clark County (Board of Health regulation), Corbin, Danville, Elizabethtown, Georgetown, Glasgow, Hardin County (unincorporated areas), Lexington-Fayette County, London, Louisville, Madison County (Board of Health regulation), Morehead, Prestonsburg, Radcliff, and Woodford County (Board of Health regulation), Kentucky. Bullitt County's Board of Health has adopted a comprehensive regulation but it is delayed pending court action. Manchester, KY passed a comprehensive smoke-free law which will go into effect January 29, 2012. The next most comprehensive ordinances, 100% smoke-free enclosed public place laws, have been implemented in three communities: Frankfort, Letcher County, and Paducah. Nine communities have enacted partial smoke-free laws, protecting workers and patrons in some public venues: Beattyville, Daviess County, Henderson, Hopkins County, Kenton County, Oak Grove, Oldham County, Paintsville, and Pikeville.

The purpose of this study was to (a) assess air quality in Laurel County, Kentucky venues before and after implementation of London's comprehensive smoke-free workplace ordinance on August 10, 2009; (b) compare London venues post-ordinance with Laurel County venues outside the city limits; and (c) compare the results to Georgetown and Lexington, Kentucky air quality data before and after their smoke-free laws took effect. It was hypothesized that the average level of indoor air pollution sampled post-ordinance in London venues would be significantly lower than pre-ordinance levels, lower than venues outside the city limits, and lower than the National Ambient Air Quality Standard (NAAQS).

Methods

Between March 14 and March 21, 2008 before London's smoke-free ordinance took effect, indoor air quality was assessed in 9 hospitality venues in Laurel County. Sites were of various sizes; some sites were individually owned establishments and some were part of local or national chain entities.

All venues tested pre-ordinance allowed smoking before London's ordinance went into effect. Two of the original nine venues tested pre-ordinance were not tested post-ordinance because they had closed. Three venues were added for the post-ordinance study and were considered in this analysis. Between August 13 and October 16, 2010, two years after London's ordinance took effect, indoor air quality was assessed in the seven Laurel County venues that remained from the original sample and in three additional venues for a total of 10 venues post-ordinance. Five of these venues were in London and 5 venues were located outside the city limits.

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 2.5μm in micrograms per cubic meter, or $PM_{2.5}$. 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.

Aerosol TSI SidePak AM510 Personal 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 outdoor and entryway air. The remaining data points were summarized to provide an average $PM_{2.5}$ concentration within each venue. The Clean Indoor Air Partnership (CIAP) staff trained researchers from the Laurel County Health Department who conducted the sampling. CIAP analyzed the data.

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^3) were reported for each venue and averaged for all venues.

Results

Before the smoke-free ordinance, nine Laurel County hospitality venues were visited from March 14 to March 21, 2008. The average size of the venues pre-law was 676 m^3 (range 49-1712 m^3). On average, 55 patrons were present per venue and 9.1 burning cigarettes (bc) per venue

were observed. The smoker density was 1.06 #bc/100 m^3. The average $PM_{2.5}$ level pre-law was 139μg/$m.^3$ Descriptive statistics for the nine venues tested before London's smoke-free ordinance are shown in Table 1.

Table 1. Air Quality Data for Nine Venues in Laurel County, Kentucky, Before London's Smoke-free Workplace Ordinance, March 2008

Venue	Date Sampled	Size (m^3)	Average # people	Average # burning cigs	Smoker density (#bc/100m^3)	Average $PM_{2.5}$ level (μg/m^3)
Venue A	3/14/2008	477	58	3.7	0.78	139
Venue B	3/15/2008	49	35	0.1	0.20	9
Venue C	3/16/2008	907	97	5.6	0.62	233
Venue D	3/17/2008	82	19	0.8	0.98	35
Venue E	3/19/2008	1712	47	2.7	0.16	76
Venue F	3/21/2008	74	22	0.7	0.95	127
Venue G	3/21/2008	446	44	2.8	0.63	264
Venue H	3/23/2008	1262	136	64.0	5.07	204
Venue I	3/21/2008	1073	41	1.7	0.16	160
Averages		676	55	9.1	1.06	139

Post-ordinance measurements were obtained from August 13, 2010 to October 16, 2010 in 10 Laurel County venues after London's smoke-free ordinance took effect. Venues were visited for an average of 51 minutes (range 46-57 minutes) per venue. Visits occurred at various times of the day from 11:00 AM to 10:20 PM. On average, 42 people were present per venue. In the city of London, the average $PM_{2.5}$ level post-ordinance was 15 μg/m^3. Descriptive statistics for the five city venues covered by London's smoke-free ordinance are shown in Table 2.

The remaining five venues tested post-law were located outside London city limits and were not covered by the smoke-free ordinance. These venues were visited for an average of 51 minutes (range 47-56 minutes). On average, 61 people were present per venue. The average $PM_{2.5}$ level post-ordinance was 96 μg/m^3. Descriptive statistics for the five venues outside city limits and not covered by the smoke-free ordinance are shown in Table 3.

Table 2. Air Quality Data for Five Venues within the City Limits After London's Smoke-free Ordinance, August 2010 –October 2010

Venue	Date Sampled	Size	Average # of People	Average # burning cigs	Smoker density (#bc/100m3)	Average $PM_{2.5}$ level (μg/m3)
Venue C	8/15/2010	153	107	0.0	0.00	12
Venue E	9/8/2010	1708	27	0.0	0.00	21
Venue F	8/13/2010	75	18	0.0	0.00	35
Venue G	8/20/2010	486	33	0.0	0.00	13
Venue I	9/3/2010	1016	23	0.0	0.00	6
Averages		842	42	0.0	0.00	15

Table 3. Air Quality Data for Five Venues in Laurel County Outside London City Limits, August 2010 – October 2010

Venue	Date Sampled	Size (m^3)	Average # people	Average # burning cigs	Smoker density (#bc/100m^3)	Average $PM_{2.5}$ level (µg/m^3)
Venue B*	8/21/2010	49	20	0.0	0.00	8
Venue H	8/19/2010	959	160	62.6	6.53	325
Venue J	10/15/2010	591	7	1.4	0.24	43
Venue K	10/16/2010	75	13	1.7	2.21	83
Venue L	10/8/2010	931	104	11.0	1.18	20
Averages		521	61	15.3	2.03	96

*<u>*Note*</u>. This county venue had gone voluntarily smoke-free.

Figure 1 shows a decline in fine particle air pollution from the nine venues pre-ordinance (139µg/m^3) to post-ordinance (15µg/m^3) in the five London venues. Analyzing just the five venues tested within London city limits pre- and post-law, the average $PM_{2.5}$ decreased from 172 µg/m^3 before the smoke-free law to 15 µg/m^3 after the law, representing a 91.3% decline in indoor air pollution. The venues observed within the London city limits were well below the National Ambient Air Quality Standard (35µg/m^3). After the smoke-free ordinance took effect, the indoor air pollution was similar to Georgetown and Lexington after their comprehensive laws took effect, while venues in Laurel County outside of London remained higher than in Georgetown and Lexington.

Of the five venues tested outside the city limits after London's ordinance took effect, the average $PM_{2.5}$ was (96 µg/m^3) which is 6.4 times greater than venues in London and 2.7 times greater than the National Ambient Air Quality Standard (35µg/m^3; see Figure 1), and the level of indoor air pollution in these venues was 4.8 times higher than Georgetown and 5.3 times higher than Lexington's $PM_{2.5}$ levels after implementation of their comprehensive smoke-free laws.

Figure 2 shows the average level of indoor air pollution in nine Laurel County venues pre-ordinance. The average $PM_{2.5}$ levels in the nine venues ranged from 9 to 264µg/m^3.

Figure 3 shows the average level of indoor air pollution post–ordinance and compares the venues in the city of London (smoke-free) with the venues in the rest of the county which allow smoking. The average $PM_{2.5}$ levels in the 10 Laurel County venues ranged from 6 to 325 µg/m^3 post-ordinance. Venues A and D were closed during the post-law measurement period.

Figure 2. Air Pollution in Laurel County Pre-Ordinance by Venue

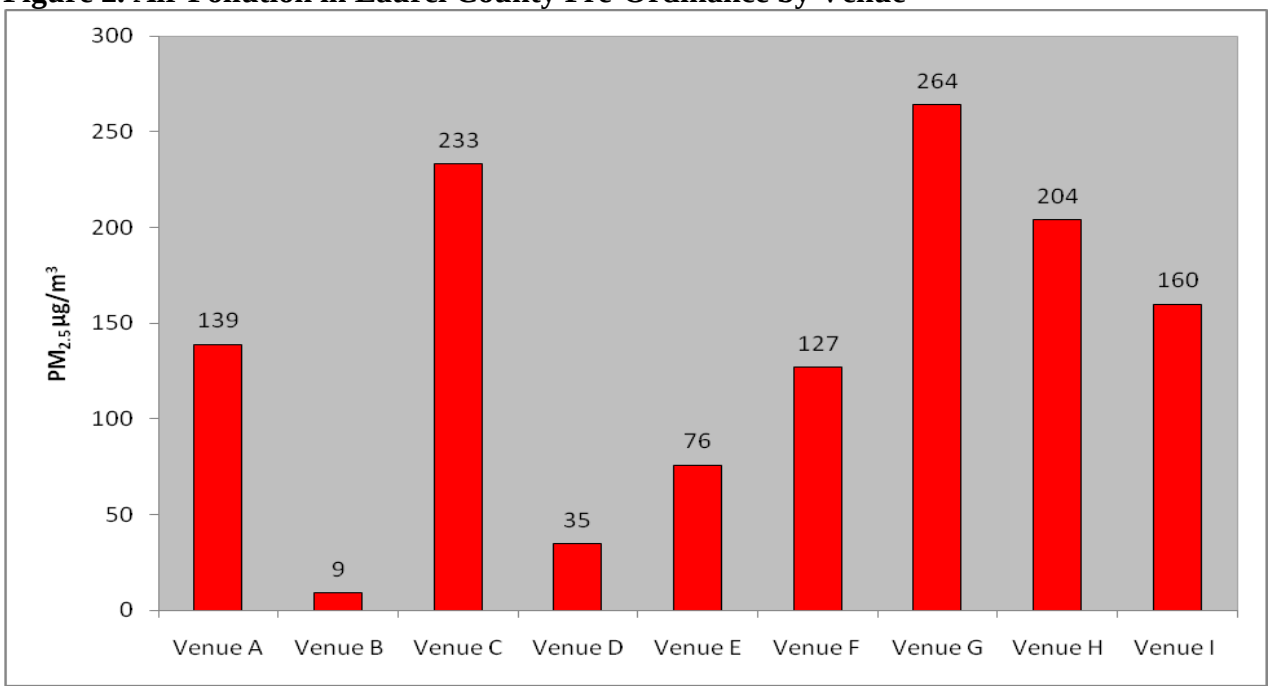
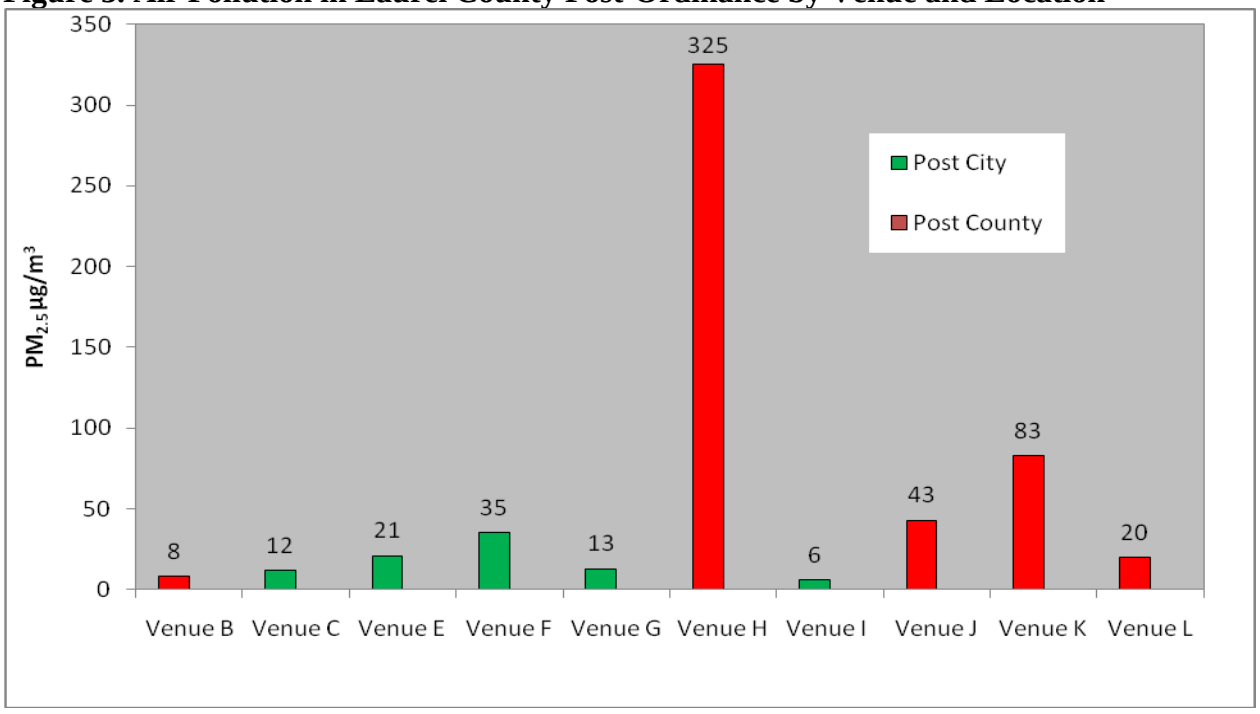


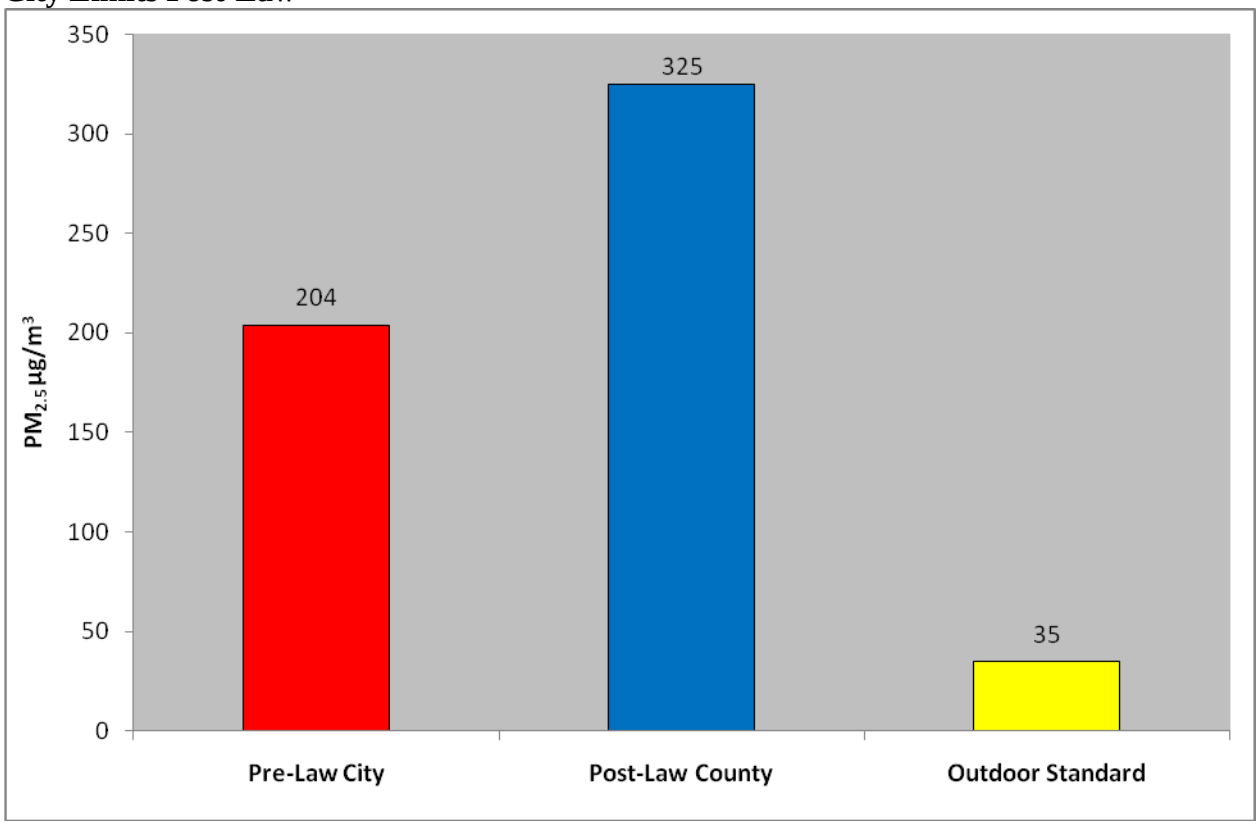
Figure 3. Air Pollution in Laurel County Post-Ordinance by Venue and Location



Note. Venues A and D were closed and were not available for re-testing. Venue B, located outside the city limits, had gone voluntarily smoke-free.

Venue H was located within London city limits during pre-ordinance testing and was re-located to outside London city limits during post-ordinance testing (see Figure 4). Pre-ordinance testing measured $PM_{2.5}$ at 204 µg/m^3 which is 5.8 times higher than the NAAQS for 24 hours (35 µg/m^3). During post-ordinance testing outside the London city limits, the $PM_{2.5}$ was 325 µg/m^3 or 9.3 times higher than the NAAQS for 24 hours.

Figure 4. Air Pollution in Venue H Located in the City Pre-Law and Moved Outside the City Limits Post-Law



Discussion

The average $PM_{2.5}$ levels in five venues tested pre- and post-law in London, Kentucky decreased from 172µg/m^3 before the smoke-free regulation to 15µg/m^3 after implementation, representing a 91.3% drop in indoor air pollution. However, in the venues located outside the city limits and not covered by the ordinance, the average $PM_{2.5}$ was 96 µg/m^3. The average $PM_{2.5}$ level (15 µg/m^3) in London was well below the National Ambient Air Quality Standard (35 µg/m^3) for *outdoor* air set by the EPA. The average $PM_{2.5}$ level (96 µg/m^3) outside the city limits was 2.8 times higher than the National Ambient Air Quality Standard (35 µg/m^3). There were over 80 EPA cited epidemiologic studies in creating a particulate air pollution standard in 1997.[6] To protect the public's health, the EPA set a new limit of 35µg/m^3 on December 17, 2006 as the average level of exposure over 24-hours in *outdoor environments*. There is no EPA standard for indoor air quality.

At least two 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 smoke-free law on April 27, 2004.[7] The average level of indoor air pollution was 199 $\mu g/m^3$ pre-law and dropped to 18$\mu g/m^3$ post-law. Average levels of indoor air pollution dropped from 86 $\mu g/m^3$ to 20 $\mu g/m^3$ after Georgetown, Kentucky implemented a comprehensive smoke-free law on October 1, 2005.[8] 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.[9] 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.[10]

Other studies have assessed the effects of SHS on human health. Hahn et al. found a 56% drop in hair nicotine levels in a sample of workers after Lexington implemented a smoke-free law, regardless of whether workers were smokers or nonsmokers.[11] 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.[12] Smoke-free legislation in Scotland was associated with significant improvements in symptoms, spirometry measurements, and systemic inflammation of bar workers. The significant improvement of respiratory health was reported in only one month after smoke-free law.[13]

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."[2] In 2010, U.S. Surgeon General Benjamin reported that tobacco smoke causes immediate blood vessel, lung tissue, and DNA damage causing heart disease, lung disease, and cancer.[3]

Many millions of Americans, both children and adults, are still exposed to secondhand smoke in their homes and workplaces. Approximately 40.1% nonsmokers in the United States have biological evidence of SHS exposure.[4] 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."[2]

Conclusions

The average level of indoor air pollution in Laurel County, Kentucky dropped from 139$\mu g/m^3$ pre-ordinance to 15 $\mu g/m^3$ post-ordinance in London and 96 $\mu g/m^3$ outside the city limits. In London, there has been a 91.3% reduction in indoor air pollution. The level of indoor air pollution in London venues post-ordinance was similar to Georgetown and Lexington's post-law average $PM_{2.5}$ levels. In the county, air pollution was 2.8 times the NAAQS, and the level of indoor air pollution in these venues was 4.8 times higher than Georgetown and 5.3 times higher than Lexington's $PM_{2.5}$ levels after implementation of their comprehensive smoke-free laws.

These findings show significant improvement in air quality for the venues in the city limits and covered by London's smoke-free ordinance.

This study demonstrates that Laurel County workers and patrons outside the city limits of London are exposed to harmful levels of SHS. Extending London's smoke-free protections to the entire county would significantly improve indoor air quality for all workers and patrons in the county.

References

1. National Toxicology Program. *10th 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. U.S. Department of Health and Human Services. *How Tobacco Smoke Causes Disease: The Biology and Behavioral Basis for Smoking-Attributable Disease: A Report of the Surgeon General.* Atlanta, GA: U.S. Department of Health and Human Services, Center for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, 2010.

4. Centers for Disease Control and Prevention. "Vital signs: Nonsmokers' exposure to secondhand smoke---United States, 1999-2008." *MMWR*, 2010;59(35): 1141-1146.

5. Americans for Nonsmokers' Rights. Overview list: How many smoke-free laws. January 2, 2012. Retrieved January 10, 2012 from http://no-smoke.org/pdf/mediaordlist.pdf.

6. U.S. Environmental Protection Agency. National Ambient Air Quality Standards for Particulate Matter; Final Rule. Federal Register 1997; 62(138): 38651-38701.

7. Hahn, E, Lee, K, Okoli, Z, Troutman, A, Rowan, R. Smoke-free Laws and Indoor Air Pollution in Lexington and Louisville. *Louisville Medicine,* 2005; 52(10): 391-392.

8. Lee, K., Hahn, E.J., Riker, C., Head, S. Seithers, P. Immediate impact of smoke-free laws on indoor air quality. *Southern Medical Journa*l, 2007; 100(9): 885-889.

9. 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. *Journal of the Air Waste Management Association,* 1996; 46:1120-1134.

10. Centers for Disease Control and Prevention. Indoor air quality in hospitality venues before and after implementation of a clean indoor air law—Western New York, *MMWR*, 2003, November 12, 2004, 53(44); 1038-1041.

11. Hahn, E.J., Rayens, M.K., York, N., Okoli, C.T.C., Zhang, M., Dignan, M., Al-Delaimy, W.K. Effects of a smoke-free law on hair nicotine and respiratory symptoms of restaurant and bar workers. *Journal of Occupational and Environmental Medicine*, 2006; 48(9): 906-913

12. 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.

13. 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.