



**Indoor air pollution at work and play:**  
A study of air quality in hospitality venues  
before and after the Colorado Clean Indoor Air Act

### **About the study**

The Colorado Clean Indoor Air Act was enacted by the 2006 General Assembly and took effect on July 31. The law enables most employees to breathe smoke-free air at their workplaces. The current study assessed the change in air quality that the law produced for employees of hospitality venues such as bars and taverns, restaurants, pool halls, bingo parlors, and family entertainment businesses.

This report was prepared in October 2006 by the Tobacco Program Evaluation Group (TPEG), University of Colorado at Denver & Health Sciences Center. The air quality monitoring protocol was developed by Mark J. Travers at the Roswell Park Cancer Institute, Buffalo NY. We are grateful to the volunteers who conducted air quality tests across Colorado. The study was funded by the State Tobacco Education and Prevention Partnership, Colorado Department of Public Health and Environment.

## Summary of Results

Secondhand exposure to cigarette smoke is a known, serious health hazard. In 2006, Colorado became the 13<sup>th</sup> state to enact a statewide policy making all indoor workplaces smoke-free, including hospitality venues such as bars and restaurants. The University of Colorado assessed the air quality in hospitality venues before and after the policy was implemented, using public health ratings of the Environmental Protection Agency (EPA) as standards for comparison. The key findings are these:

- Overall, air pollution in Colorado hospitality venues improved by an estimated 70% when Colorado's smoke-free air law took effect.
- Before the smoke-free air law, the average employee and patron of a Colorado bar or tavern was exposed to a level of indoor air pollution rated *unhealthy*. Once the law went into effect, bar and tavern air quality was 90% better and met the EPA's *good* rating.
- In restaurants that allowed smoking, air quality in the nonsmoking sections improved by 25% after the law went into effect.
- In family entertainment venues (such as bowling alleys, arcades, etc.), air quality improved by 52% after the law went into effect.
- In casinos, which are exempt from the smoke-free law, air quality remained *unhealthy* after the law took effect.

## **Introduction**

Secondhand smoke (SHS) from cigarettes contains at least 250 chemicals that are known to be toxic or carcinogenic, and SHS itself is a known human carcinogen.<sup>1</sup> SHS is responsible each year for an estimated 3,000 lung cancer deaths and more than 35,000 heart disease deaths in U.S. *never smokers*.<sup>2</sup> SHS also causes respiratory infections, wheezing, sudden infant death syndrome (SIDS), and other illnesses in children, and may cause asthma.<sup>3</sup> SHS exposure remains a major public health concern that is entirely preventable,<sup>4</sup> and smoke-free environmental policies are the most effective method for reducing SHS exposure in public places.<sup>5</sup>

National health objectives encourage clean indoor air laws in public places and worksites,<sup>6</sup> and 14 states plus the District of Columbia and Puerto Rico have enacted such laws. In addition to Colorado, the states are California, Connecticut, Delaware, Hawaii, Maine, Massachusetts, Montana, New Jersey, New York, Rhode Island, Utah, Vermont and Washington (the DC law extends to bars on January 2, 2007, and the Montana and Utah laws extend to bars in 2009). Another three states – Arkansas, Florida and Idaho – have smoke-free laws which exempt stand-alone bars. Hundreds of U.S. cities and counties have also adopted smoke-free laws, as have the nations of Ireland, Scotland, Uruguay, Norway, New Zealand, Sweden, and Italy.

The current study examined indoor air quality in a random statewide sample of Colorado hospitality venues before and after July 1, 2006, when the Colorado Clean Indoor Air Act took effect. The purposes were (1) to measure indoor air quality where on-premise smoking was allowed, and (2) to estimate the improvement in indoor air quality attributable to the smoke-free workplace law.

## **Methods**

### Overview

Forty-nine hospitality venues (bars, restaurants, pool halls, family entertainment venues, bingo parlors and casinos) were chosen representatively from lists of all such establishments that allowed indoor smoking across Colorado. Each venue was assessed before and after implementation of the smoke-free workplace law. For each venue, pre- and post-law visits were made on the same day of the week and approximately the same time of day.

### Sampling

The Group to Alleviate Smoking Pollution (GASP) of Colorado provided lists of hospitality venues that allowed smoking.<sup>7</sup> Using systematic selection, separate ("stratified") samples were drawn for bars, restaurants, casinos, bingo parlors, family entertainment venues, and pool halls. Bars and restaurants were selected from the entire state; all other venues were selected from the entire Denver metropolitan area. Restaurants were eligible for sampling if they had a smoking section, allowed smoking throughout the dining area, or shared indoor air with an adjoining bar. Most testing was done in the evening, from about 5:00 p.m. through midnight or later. Some restaurants were tested during busy lunch hours. Business names and locations are withheld from this report to maintain the privacy of the sampled venues.

Measurement Protocol

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 light from a laser to measure the real-time concentration of particles. A choice of intake nozzles allows the monitor to track only particles of the desired size. Results are reported in micrograms (millionths of grams) of particles per cubic meter.



TSI SidePak AM510 Personal Aerosol Monitor

To monitor cigarette smoke, an intake nozzle was used that tracks particles smaller than 2.5 microns (millionths of a meter). Monitoring of these ultra-fine particles is highly sensitive to secondhand smoke, which is by far the largest contributor to indoor air pollution.<sup>8</sup> The monitor automatically collects an air sample every second and calculates an average pollution level for each minute.

Teams of two trained volunteers conducted air monitoring measurements. Visits lasted an average of 43 minutes each (range: 22 to 77 minutes). The air monitor was carried in a knapsack or purse, with the intake valve at tabletop level or higher to measure air quality within the general breathing zone. Every 15 minutes, the teams manually recorded the total number of people inside the venue and the number of burning cigarettes. These observations were averaged over the time to determine the average number of people on the premises and the average number of burning cigarettes. Room size was measured using an ETP006 Sonic Measure (Ryobi Technologies, Inc.). This measure was used to calculate cigarette density, or the average number of burning cigarettes divided by the volume of the room. During data analysis, the first and last minute of logged data were dropped to exclude measurement of outdoor or entryway air.

Average indoor pollution levels were rated using Environmental Protection Agency (EPA) standards for particulate matter in outdoor air (chart at right). Overall levels before and after the Colorado Clean Indoor Air Act were compared using the Wilcoxon Matched-Pair Signed-Rank Test, which rules out chance differences caused by sampling.

Air Quality Index Levels of Health Concern	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	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.

Source: US Environmental Protection Agency, 1997. National ambient air quality standards for particulate matter; final rule.

## Results

Before the law, the average PM<sub>2.5</sub> level in Colorado hospitality venues was 60.9 µg/m<sup>3</sup>, *unhealthy for sensitive groups*. After the law went into effect, the average level was 18.1 µg/m<sup>3</sup>, a 70% reduction and no health concern except for "a very small number of people who are unusually sensitive to air pollution." The difference is highly unlikely to be a sampling error (p<0.0001).

***PM<sub>2.5</sub> is the amount of particles smaller than 2.5 microns (millionths of a meter) that are suspended in a cubic meter of air. Particles of this size are released in significant amounts from burning cigarettes. They are easily inhaled deep into the lungs and are associated with lung and heart disease and death.***

In bars and taverns, air quality improved by 90.3%. Before the smoke-free law, air quality on average was *unhealthy* or worse – in an estimated 15% of bars and taverns, the pollution level was *hazardous*. After the law, overall air quality in bars and taverns was *good*, and every establishment was *good* or *moderate*.

In bingo parlors, overall air quality went from *unhealthy* – and *very unhealthy* in some parlors – to entirely *good*, a 95.5% improvement.

In nonsmoking sections of restaurants, average air quality improved by 25.9%; the overall rating remained *moderate*. In family entertainment venues such as bowling alleys, arcades and indoor miniature golf courses, the overall rating improved by 57.1% and went from *unhealthy for sensitive people* to *moderate*.

In casinos, air quality remained *unhealthy*. Particle pollution levels were lower post-law than pre-law because about one-third fewer cigarettes were being smoked at the time of the second measurement.

The table on the next page displays air quality ratings in each establishment monitored before and after the law.

**Air quality in a representative sample of Colorado hospitality venues,  
measured before and after the Colorado Clean Indoor Air Act took effect**

	average PM <sub>2.5</sub> level		
	before	after	change
<b>bars, taverns, lounges</b>			
A	81 u	3 g	-96.1%
B	87 u	15 g	-82.5%
C	89 u	17 m	-80.7%
D	843 h	7 g	-99.2%
E	292 h	12 g	-95.8%
F	17 m	2 g	-89.4%
G	22 m	–	–
H	75 u	6 g	-92.5%
I	116 u	7 g	-94.3%
J	227 v	6 g	-97.4%
K	48 s	31	-36.2%
L	123 u	6 g	-95.1%
M	14 g	5 g	-66.0%
N	80 u	37 m	-53.7%
O	73 u	19 m	-73.4%
P	31 m	17 m	-45.1%
Q	58 s	2 g	-95.9%
R	454 h	16 m	-96.5%
<b>all</b>	<b>133.7 U</b>	<b>13.0 G</b>	<b>-90.3%</b>
<b>bingo parlors</b>			
OO	220 v	11 g	-95.2%
PP*	7 g	0 g	-100.0%
QQ	148 u	7 g	-95.6%
<b>all</b>	<b>130.7 U</b>	<b>5.9 G</b>	<b>-95.5%</b>
<b>pool halls</b>			
V V	85 u	5 g	-94.4%
WW	54 s	8 g	-84.4%
<b>all</b>	<b>69.2 U</b>	<b>6.6 G</b>	<b>-90.5%</b>
<b>casinos</b>			
RR	125 u	80 u	-36.4%
SS	52 s	43 s	-18.1%
TT	271 h	154 v	-43.1%
UU	174 v	102 u	-41.4%
<b>all</b>	<b>155.6 U</b>	<b>94.6 U</b>	<b>-39.2%</b>

(continued at right)

	before	after	change
<b>nonsmoking dining areas with secondhand smoke exposure</b>			
S	5 g	2 g	-57.7%
T	13 g	1 g	-91.6%
U	68 u	96 u	+41.5%
V	17 m	–	–
W	5 g	3 g	-31.4%
X	21 m	4 g	-79.0%
Y	8 g	20 m	+153.5%
Z	8 g	6 g	-27.2%
AA	8 g	7 g	-12.4%
BB	12 g	2 g	-78.7%
CC	16 m	15 g	-5.4%
DD	5 g	15 g	+224.7%
EE	52 s	42 s	-18.4%
FF	64 s	12 g	-81.7%
GG	82 u	44 s	-46.0%
<b>all</b>	<b>26.0 M</b>	<b>19.3 M</b>	<b>-25.9%</b>
<b>family entertainment venues</b>			
HH	37 m	–	–
II	42 s	21 m	-49.8%
JJ	4 g	11 g	+180%
KK	6 g	6 g	-3%
LL	33 m	6 g	-83%
MM	54 s	7 g	-86.3%
NN	127 u	3 g	-98.0%
<b>all</b>	<b>43.8 s</b>	<b>18.8 m</b>	<b>-57.1%</b>
<b>overall mean</b>	<b>62.3 S</b>	<b>18.1 M</b>	<b>-70.9%</b>

– not rechecked

\* physically separated nonsmoking area

Letter codes:

g = good

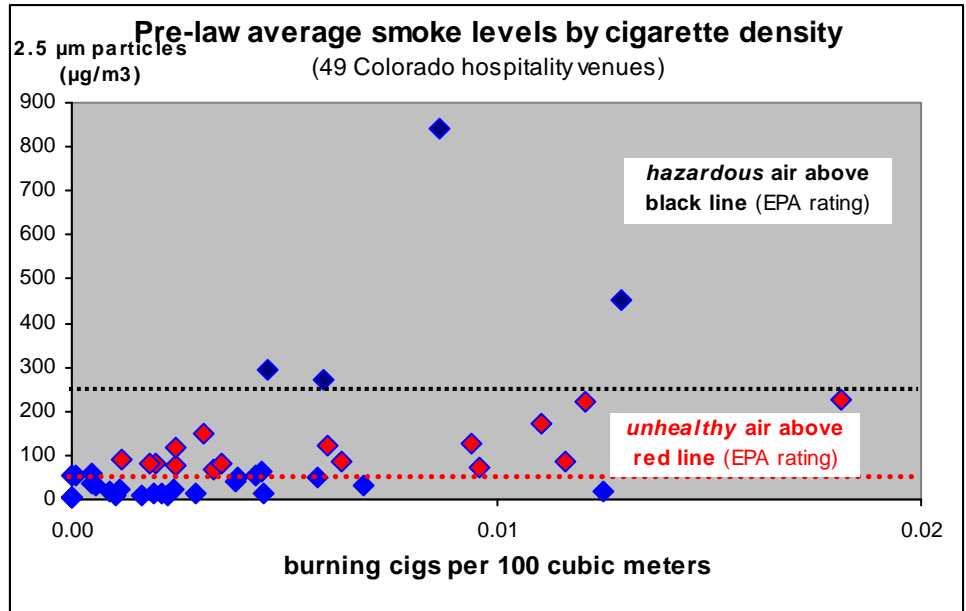
s = unhealthy for sensitive people

u = unhealthy

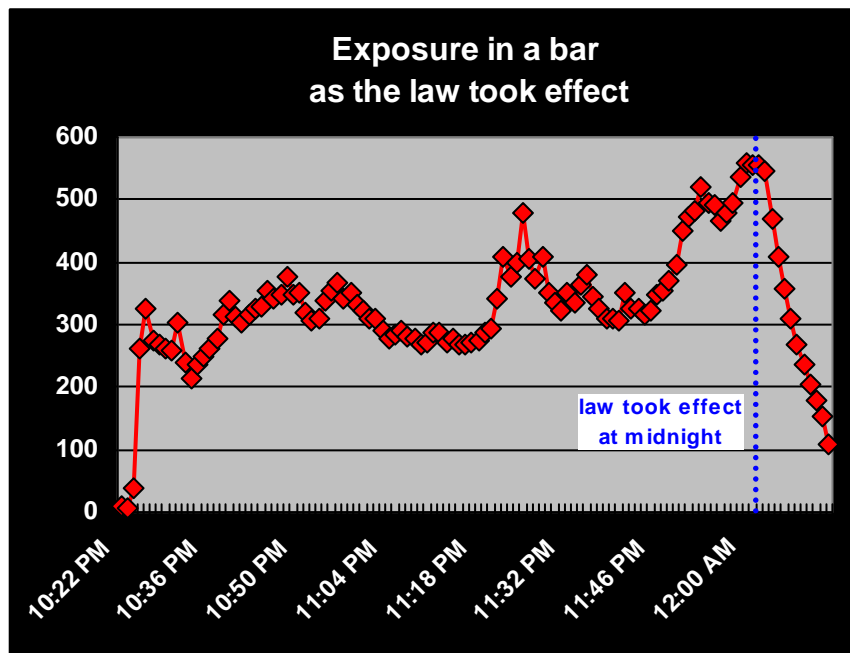
v = very unhealthy

h = hazardous

The chart at the right shows that 21 monitored businesses, representing an estimated 27% of Colorado hospitality venues, had *unhealthy* air quality before the Colorado law was enacted. An estimated 5% of venues had *hazardous* air quality. Air quality had no predictable relationship to the number of cigarettes being smoked at the time. This lack of connection is presumably due to different ventilation systems, presence or absence of open doors or windows and varying levels and types of separation between nonsmoking and smoking areas.



The chart at the right shows air quality in one bar during the evening on which the law took effect. Air quality was *hazardous* during most of an evening. At five minutes to midnight, when the law would take effect, the bartender announced "last call" for smoking, and air quality reached its worst level, more than two times the trigger level for a *hazardous* rating. Ten minutes after the smoke-free law went into effect, air quality had improved by 80%.





## Discussion

The EPA has established a public health rating system for outdoor air quality.<sup>9</sup> Before Colorado's smoke-free law, fine-particle indoor air pollution averaged 131  $\mu\text{g}/\text{m}^3$  in bars, casinos, bingo halls and pool halls – twice the EPA threshold of unhealthy air. Full-time employees were breathing an annual average of 31  $\mu\text{g}/\text{m}^3$  – more than twice the EPA annual limit.\* Their exposure was in addition to any outdoor exposure they might have had. For example, in the week before the clean-air law took effect, Denver's outdoor air contained 10 to 15  $\mu\text{g}/\text{m}^3$  of fine particles.<sup>10</sup>

EPA air quality standards are being revised. Using improved scientific knowledge, air is *unhealthy* to breathe when it reaches 35  $\mu\text{g}/\text{m}^3$ , less than half the previous level.<sup>11</sup>

The health hazards of secondhand cigarette smoke are not in doubt. This year, the U.S. Surgeon General issued an updated, comprehensive report<sup>3</sup> that presented the following conclusions:

1. Secondhand smoke causes premature death and disease in children and in adults who do not smoke.
2. Children exposed to secondhand smoke are at an increased risk for sudden infant death syndrome (SIDS), acute respiratory infections, ear problems, and more severe asthma. Smoking by parents causes respiratory symptoms and slows lung growth in their children.
3. Exposure of adults to secondhand smoke has immediate adverse effects on the cardiovascular system.
4. Exposure of adults to secondhand smoke causes coronary heart disease and lung cancer.
5. The scientific evidence indicates that there is no risk-free level of exposure to secondhand smoke.
6. Many millions of Americans, both children and adults, are still exposed to secondhand smoke in their homes and workplaces despite substantial progress in tobacco control.
7. 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 exposures of nonsmokers to secondhand smoke.

A newly reported study<sup>12</sup> shows how quickly the ill-health effects of secondhand smoke are reversed when cigarette smoke exposure is removed. Among Scottish bar workers, lung function was improved just one month after that nation made public places smoke-free, and white blood cells (immune reactions to inflammation) were significantly reduced within two months. Among workers with asthma or nasal allergies, a biochemical measure of airway inflammation was reduced by one-third within two months of the smoke-free law.

In conclusion, secondhand cigarette smoke contains tiny particles (particulate matter) that carries cancer-causing and heart-irritating chemicals deep into the lungs of smokers. Results of the Colorado indoor air study indicates that, except in casinos, employees and guests of the state's hospitality venues are now working, playing and breathing healthier.

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\* The projected exposure level is based on a 40-hour work week and assumes indoor air quality is consistent during business hours.

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