Rolla
Air Quality Monitoring Study

School of Medicine
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CASE
Campus-Community Alliances for Smoke-Free Environments

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Executive Summary

Secondhand smoke (SHS) was classified in 1992 by the U.S. Environmental Protection Agency (EPA) as a cause of cancer in humans. It contains more than 7,000 chemicals of which more than 250 are known to be poisonous. For such a substance, there is no minimum safe level of exposure. The 2006 U.S. Surgeon General's Report, reviewing thousands of research studies, finds SHS is a cause for stroke, emphysema, bronchitis, asthma, respiratory infections, Sudden Infant Death Syndrome and other illnesses. SHS is responsible for almost 50,000 deaths per year from heart disease and lung cancer in nonsmokers. The 2006 Surgeon General's Report concluded that policies for smokefree environments are the most effective method of reducing SHS exposure in public places and workplaces.

The purpose of this study was to sample the air quality in public places in Rolla and compare results to the EPA Air Quality Index. Indoor air quality for fine particulate matter pollution ($PM_{2.5}$ particles) was sampled in seven various locations in Rolla on the evenings of January 22, 2010 before the city's smokefree ordinance went into effect and February 17, 2012 after the ordinance was in effect for several weeks. One location did not allow smoking, while six locations allowed smoking indoors.

Key findings of this study include:

- Before the ordinance was in effect:
  - Particulate matter air pollution for –
    - The six smoking-allowed locations averaged 245 $\mu g/m^3$ (EPA rating of "very unhealthy").
    - One no smoking-allowed location used as a control averaged 6 $\mu g/m^3$ (EPA rating of "good").
  - The level of particulate matter air pollution was more than 42 times higher in places that allowed smoking compared to that where smoking was not allowed.
  - Due solely to their occupational exposure, a full-time employee in one of those Rolla public places that allowed smoking was exposed to 374% the EPA's average annual limit for particulate matter air pollution.
  - On average, only 6% of people were actively smoking in the locations where smoking was permitted. This is less than one-third the adult smoking prevalence of 22% for Phelps County and refutes the commonly held misperception that a higher percent of employees or customers in restaurants, bars or recreational venues smoke.
- After the ordinance was in effect:
  - Particulate matter air pollution for the public places that previously allowed smoking averaged 12 $\mu g/m^3$ (EPA rating of "good") and represents a 95% reduction for this pollutant.
  - A full-time employee in one of these Rolla public places that previously allowed smoking would be exposed to only half the EPA's average annual limit for particulate matter air pollution.
  - No smoking was observed in any of the public places, indicating high compliance with the ordinance.

The findings of this study are consistent with those of similar previous studies that found that approximately 90% or more of the fine particle pollution could be attributed to SHS.

Introduction

Secondhand smoke (SHS) contains more than 7,000 chemicals, of which more than 250 are known to be either toxic and/or carcinogenic, and by itself was classified in 1992 by the U.S. Environmental Protection Agency as a human carcinogen.[1] Exposure to SHS is responsible for an estimated 35,000 deaths per year from heart disease and lung cancer in nonsmokers.[2] The U.S. Surgeon General issued reports in 1984 and 2006 concluding SHS was also a cause for stroke, emphysema, bronchitis, asthma, respiratory infections, Sudden Infant Death Syndrome and other illnesses. The Surgeon General also concluded there is no safe level of exposure to SHS.[1,3,4]

With specified exemptions, Missouri state law requires all public places to prohibit smoking unless designated smoking areas are provided. Such designated areas are not to exceed 30% of its entire space. The specified exemptions are for bars, restaurants that seat less than 50 people, billiard parlors, and bowling alleys.

The Rolla City Council passed a smokefree ordinance by a vote of 8 to 4 on July 5, 2011 which covered all workplaces and public places and went into effect on January 1, 2012.

On December 21, 2011, about a week prior to the effective date of the ordinance, the city council deliberated on an amendment to the ordinance that would allow smoking at a private club during public events if using unpaid volunteers. Initially the council voted down the amendment 6 to 5, went into closed session for other business, then re-convened the open session to an empty gallery and passed the amendment on a 9 to 2 vote.

Policies prohibiting smoking are the most effective method for eliminating SHS exposure in public places and workplace environments. While many businesses voluntarily establish smokefree policies, the hospitality industry (including restaurants, bars, bowling alleys, casinos, etc.), representing approximately 10-14% of workplaces, has been slow to enact smokefree policies. Consequently, workers and patrons are exposed to SHS. An increase in state- and city-wide smokefree ordinances across the United States has resulted in declining SHS exposure among the overall U.S. population,[5] but a majority of Missouri municipalities remain without comprehensive smokefree laws.

To protect public health, the U.S. Environmental Protection Agency (EPA) issued National Ambient Air Quality Standards which include fine particulate matter as one of the criteria pollutants. The EPA first issued standards for daily exposure to pollution consisting of particulate matter of 2.5 microns in size ($PM_{2.5}$) in 1971 with periodic revisions, the latest in 2006 and currently in a public comment period. Current EPA standards based on review of thousands of peer-reviewed scientific studies recommend exposure during a 24-hour period to be not greater than 35 $\mu g/m^3$. Further, over the period of a year a person's exposure should not have a daily average of more than 15 micrograms per cubic meter ($\mu g/m^3$). EPA assigned levels for $PM_{2.5}$ ranging from "good" to "hazardous" with accompanying health advisories as presented in Table 1.[6] Because the impact on health is the same regardless of whether the air is in an outdoor or indoor environment, the EPA index is a valuable measure of health risk.

Table 1. U.S. Environmental Protection Agency – Air Quality Index

Air Quality	$PM_{2.5}$ ($\mu g/m^3$)	Health Advisory
Good	≤ 15	None
Moderate	16-35	Unusually sensitive people should consider reducing prolonged or heavy exertion
Unhealthy for Sensitive Groups	36-55	People with heart or lung disease, older adults and children should reduce prolonged or heavy exertion
Unhealthy	56-150	People with heart or lung disease, older adults and children should avoid prolonged or heavy exertion. Everyone else should reduce prolonged or heavy exertion

Very Unhealthy	151-250	People with heart or lung disease should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.
Hazardous	≥ 251	People with heart or lung disease, older adults, and children should remain indoors and keep activity levels low. Everyone else should avoid all physical activity outdoors.

Methods

Overview

Indoor air quality for fine particulate matter pollution was sampled for eight locations in Rolla before and after the smokefree workplace ordinance went into effect. Seven of the locations allowed smoking indoors while one did not allow smoking. Particulate matter smaller than 2.5 micrograms ($PM_{2.5}$) was measured. The $PM_{2.5}$ particles are easily inhaled deep into the lungs, are associated with causing or exacerbating pulmonary and cardiovascular disease and mortality.

Measurement Protocol

A minimum average of 45 minutes was spent in each public place to monitor air for data collection. The number of people inside the venue and the observed number of burning cigarettes were recorded every 10 minutes during the air quality sampling period.

A sonic measuring device was used to measure room dimensions, enabling unobtrusive calculation of the volume of each location. Active smoker density was calculated by dividing the average number of burning cigarettes by the volume of the room in meters. The number of burning cigarettes was divided by the number of people at the location to determine the percent of people smoking.

A TSI Sidepak AM510 Personal Aerosol Monitor (TSI, Inc., St. Paul, MN) was used to sample and record the levels of particulate matter pollution 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 to assess the real-time concentration of particulate matter smaller than 2.5 micrograms to be recorded as $PM_{2.5}$. The concentrations of particulate matter were recorded as micrograms per cubic meter ($\mu g/m^3$). The Sidepak was zero-calibrated prior to each use by attaching a HEPA filter according to the manufacturer's specifications. The Sidepak was set to a one-minute log interval, which averages the previous 60 one-second measurements.

Air quality sampling was conducted discreetly in order to not disturb the normal behavior of workers or patrons. For each location, the first and last minute of logged data were removed because they were averaged with outdoor and/or entryway air. The remaining data points were averaged to provide an average $PM_{2.5}$ concentration within the location.

Descriptive data including the location volume in cubic meters (m^3), number of people, number of burning cigarettes, and smoker density (number of burning cigarettes per 100 m^3) were recorded for each location and averaged for all locations. Additionally, the results are compared to the EPA Air Quality Index.

Results

The locations were visited on Friday evenings before and after the ordinance went into effect (January 22, 2010 and February 17, 2012) between 6 p.m. to 10:30 p.m. The six sampled public places that allowed smoking had $PM_{2.5}$ levels averaging 245.4 $\mu g/m^3$ (range: 68.6 – 522.6 $\mu g/m^3$).

The one smokefree venue sampled had an average $PM_{2.5}$ level of 5.8 μg/m^3. The level of particulate matter air pollution was 42.3 times higher in those public places that allowed smoking compared to the smokefree venue. On average, 3.7 cigarettes (range: 2.3 – 6.6 cigarettes) were burning during the monitoring timeframe at smoking venues. This represents an overall average of 5.7% of patrons. Table 2 provides additional details of the monitored venues.

After the implementation of the smokefree ordinance, the same six public places that previously allowed smoking then had an average $PM_{2.5}$ level of 11.9 μg/m^3 (range: 6.0 – 21.5 μg/m^3). This represents a 95.2% reduction for this pollutant. No incidents of smoking were observed at any of these places.

Additional details of the monitored venues are provided in Tables 2 and 3.

Table 2. Smokefree and Smoking Establishments in Rolla

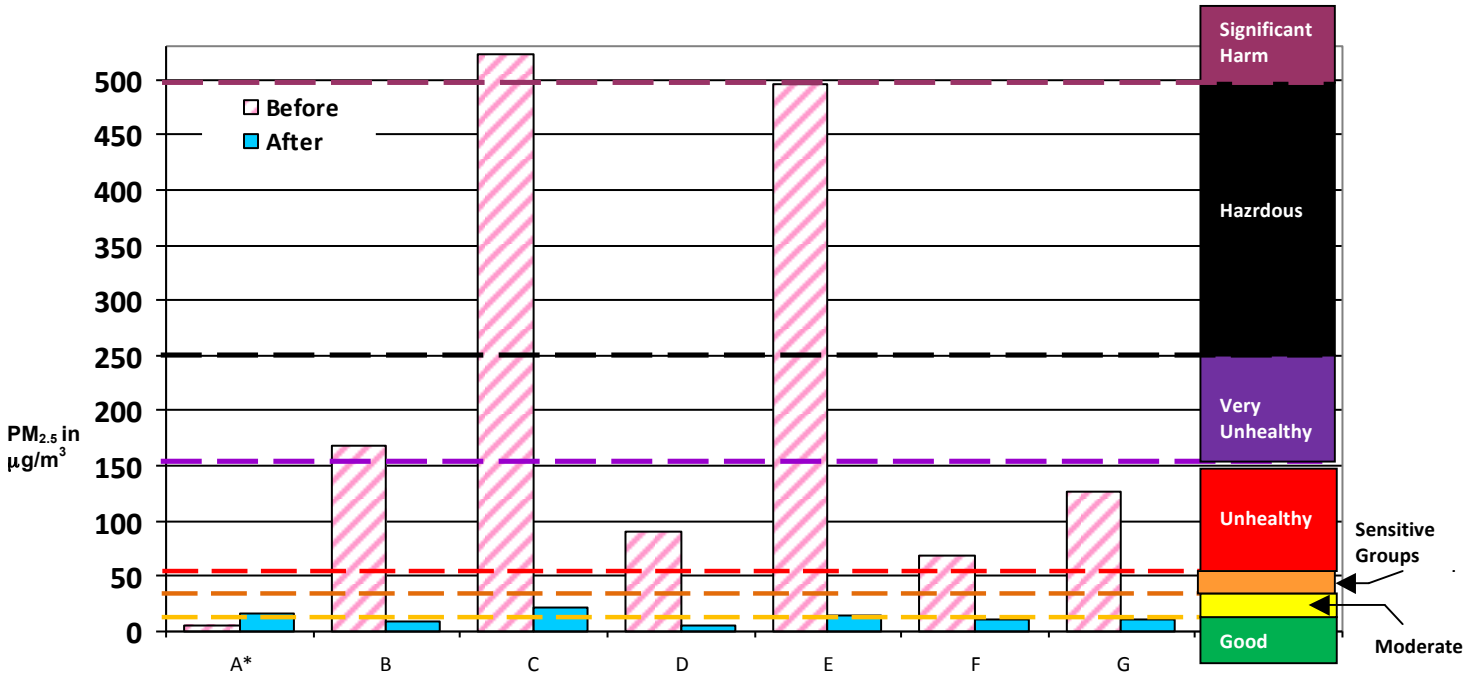
Public Place	Average # people	Average # burning cigarettes	Active smoker density	% burning cigarettes to # people	Average $PM_{2.5}$ level (μg/m^3)	EPA Air Quality Index category
SMOKEFREE ESTABLISHMENT						
A	48.0	0	0	0	5.8	Good
SMOKING ESTABLISHMENTS						
B	64.3	3.2	0.23	5.0	168.1	Very Unhealthy
C	56.2	6.6	0.94	10.7	522.6	Significant Harm
D	112.3	2.3	0.61	1.5	89.6	Unhealthy
E	34.4	3.0	0.37	6.8	496.2	Hazardous
F	24.3	2.7	0.80	10.0	68.6	Unhealthy
G	105.6	4.4	0.10	4.3	127.1	Unhealthy
Average	63.6	3.7	0.51	5.7	245.4	Very Unhealthy

Table 3. $PM_{2.5}$ Levels in Rolla Public Places that previously allowed smoking

	Before Ordinance		After Ordinance		
Public Place	Average $PM_{2.5}$ level (μg/m^3)	EPA Air Quality Index category	Average $PM_{2.5}$ level (μg/m^3)	EPA Air Quality Index category	% $PM_{2.5}$ change
B	168.1	Very Unhealthy	8.7	Good	-94.9%
C	522.6	Significant Harm	21.4	Moderate	-95.9%
D	89.6	Unhealthy	6.0	Good	-93.3%
E	496.2	Very Unhealthy	14.0	Good	-97.2%
F	68.6	Unhealthy	10.9	Good	-84.2%
G	127.1	Unhealthy	10.1	Good	-92.0%
Average	245.4	Very Unhealthy	11.9	Good	-95.2%

Figure 1 presents air quality data of the one non-smoking and the six smoking areas with comparison to the EPA Air Quality Index standards.

Figure 1 – Air Quality Measures for Rolla Public Places – Jan 2010 & Feb 2012



NOTE: *Venue A smokefree before ordinance

Discussion

Particulate matter pollution is a complex mixture of extremely small particles that when breathed in can reach the deepest regions of the lungs. Exposure to $PM_{2.5}$ is linked to a variety of significant health problems, ranging from aggravated asthma to premature death in people with heart and lung disease.

Pre-Ordinance

Before the Rolla smokefree ordinance was in effect $PM_{2.5}$ pollution was 42 times higher in public places that permitted smoking compared to a smokefree public place (245.4 $\mu g/m^3$ vs. 5.8 $\mu g/m^3$).

Of the six smoking-allowed venues:

- 3 had air quality classified as “unhealthy”
- 1 as “very unhealthy”
- 1 as “hazardous”
- 1 as “significant harm”

The average air quality in the sampled smoking-allowed public places was classified as “very unhealthy” by the EPA Air Quality Index, almost in the range of “hazardous”; while the average air quality for the smokefree public place was classified as “good”.

Due solely to their occupational exposure, a full-time employee in one of these smoking-allowed public places was 374% the EPA’s average annual daily limit for particulate matter air pollution.

Counts of the number of people and of the number of burning cigarettes conducted every 10 minutes revealed that on average 5.7% of the people in these public places were actively smoking at any given time, about 1/4th the 21.8% adult smoking prevalence in Phelps County.[7] Despite commonly held misperceptions that a high percent of employees or customers in bars or other public hospitality venues smoke, this study finds only an average of 3.7 cigarettes were actually smoked at any given time; and yet, these few cigarettes created levels of pollution to the degree to be rated as "unhealthy" by the EPA standards.

The findings of this study are consistent with those of similar previous studies. A study of eight hospitality venues in Delaware before and after a statewide smokefree law was implemented found about 90% of the fine particle pollution could be attributed to tobacco smoke.[8] Similarly, a study of 22 hospitality venues in western New York found a 90% reduction in $PM_{2.5}$ levels in bars and restaurants and an 84% reduction in large recreation venues (e.g., bingo halls, bowling alleys).[9] Similar findings of reductions of more than 90% of $PM_{2.5}$ levels in public places were reported after several communities in Kentucky implemented smokefree workplace ordinances.[10] The current study in Rolla finds 98% lower particulate matter pollution in the smokefree public venue compared to public venues that allowed smoking.

Post-Ordinance

Average particulate matter air pollution for the six public places that previously allowed smoking was 11.9 $\mu g/m^3$, a decrease of 95.2% compared to the 245.4 $\mu g/m^3$ average seen before the ordinance was in effect.

Of these six previously smoking-allowed venues that became smokefree under the city ordinance:
- 4 had air quality classified as "good"
- 2 as "moderate"

Occupational exposure to this type of air pollution was found to be only about half (54%) of the EPA average annual daily limit rather than the 374% noted prior to the implementation of the smokefree ordinance.

Most of the findings of this study are consistent with those of similar previous studies regarding numbers of smokers among customers and employees, and levels of particulate matter air pollution.

A study of eight hospitality venues in Delaware before and after a statewide smokefree law was implemented found about 90% of the fine particle pollution could be attributed to tobacco smoke.[11] Similarly, a study of 22 hospitality venues in western New York found a 90% reduction in $PM_{2.5}$ levels in bars and restaurants and an 84% reduction in large recreation venues.[12] Similar findings of reductions of more than 90% of $PM_{2.5}$ levels in public places were reported after several communities in Kentucky implemented smokefree workplace ordinances.[13]

Health Considerations

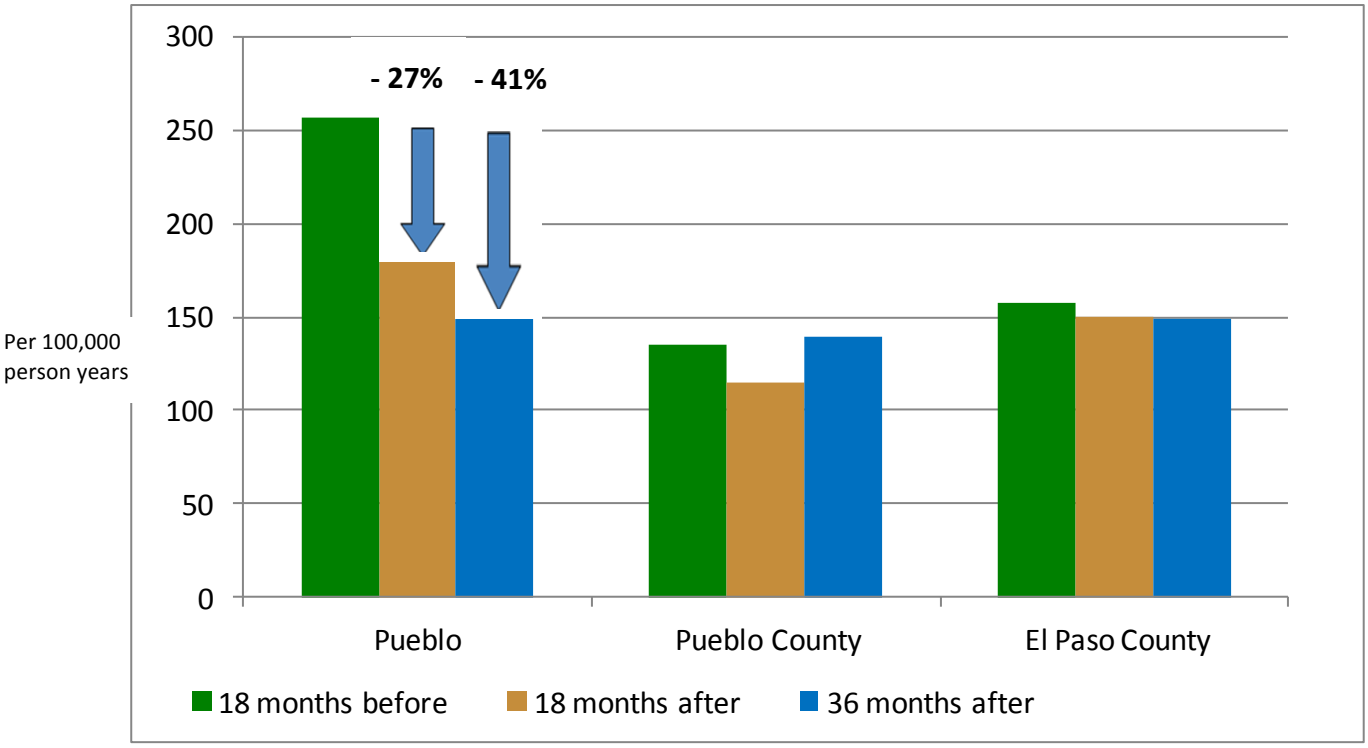
Studies have directly assessed the effects of SHS exposure on human health. One study found that respiratory health improved rapidly in a sample of bartenders after a state smokefree workplace law was implemented in California, as well as after national smokefree laws were implemented in Ireland and Scotland.[14,15,16] Additional studies found a significant reduction in cotinine (a metabolic byproduct of nicotine) and of polycyclic aromatic hydrocarbons (a known human carcinogen found in SHS) in the bodies of hospitality industry workers or customers.[17,18] Experimental studies examining blood chemistries of smokers and nonsmokers find negative effects of even brief (minutes to hours) exposures to SHS on the cardiovascular system.[19,20]

A "66 casino" study by Repace found that incremental $PM_{2.5}$ pollution from secondhand smoke in approximately half of the smoking-allowed casinos exceeded a level known to impact cardiovascular health in nonsmokers after less than 2 hours of exposure, posing acute health risks to patrons and workers.[13] This is of particular importance in that the EPA previously determined in a 2003 publication that even short term exposure to $PM_{2.5}$ air pollution can aggravate irregular heartbeat, set the stage for heart attacks, and for those with heart disease can cause a heart attack with no warning symptoms. Older adults, who comprise a significant proportion of casino customers, are at greater risk as they may have undiagnosed heart or lung disease.[21]

Still additional studies found a significant reduction in cotinine (a metabolic byproduct of nicotine) and of polycyclic aromatic hydrocarbons (a known human carcinogen found in SHS) in the bodies of bar and/or casino employees or customers.[22,23] A study of air quality in Pennsylvania casinos found that despite low smoking prevalence and with ventilation rates 50% higher than those previously recommended by engineers for smoking-permissible casinos, levels of polycyclic aromatic hydrocarbons and particulate matter were 4 and 6 times respectively that of outdoor air and cotinine levels increased among customers. This study estimated 6 Pennsylvania casino workers' deaths annually per 10,000 at risk; a risk 5 times greater than that of Pennsylvania mining disasters.[24]

Additional studies report an average of a 17% reduction in hospital admissions for acute myocardial infarctions (heart attacks) within the first year after implementation of a smokefree ordinance or law in the communities.[25,26,27,28,29,30,31,32,33,34,35] Of note are reports in which hospitalizations for heart attacks were reduced by 28% in Pueblo, Colorado, within the first 18 months after their smokefree ordinance was implemented; and that the decline continued to a 41% reduction within the first 36 months after the time the ordinance was implemented. However, rates in surrounding Pueblo County and adjacent El Paso County, which had no smokefree ordinances, remained virtually flat for the same periods.[36,37]

Figure 2 – Hospitalizations for Heart Attacks; Pueblo, Colorado 2002-2006



A recurring theme is demonstrated by a growing body of evidence showing that smokefree policies are proven to provide health benefits for both smokers and nonsmokers. Health benefits are especially greater among non-smokers as seen in studies that found reductions of 30% - 60% among non-smokers for hospitalization for heart attack within the first year of law for smokefree workplaces and public places.[19,38] Further, a recent Swiss study found a 50% reduction for such hospitalizations among people previously diagnosed with coronary heart disease.[30] Such evidence reinforces the Centers for Disease Control & Prevention recommendation that physicians advise their patients at risk of or with known coronary heart disease to avoid places where they may be exposed to secondhand smoke.[39]

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Conclusions

Before the Rolla smokefree ordinance went into effect, public places that allowed smoking had over 42 times the fine particulate matter air pollution of smokefree public places. Average air quality in smokefree places was rated "good" by EPA standards, while the average air quality in places where smoking was allowed was rated "very unhealthy" bordering on the "hazardous" classification. After the ordinance, average air quality for places that previously allowed smoking improved to a rating of "good".

Before the ordinance, employees in public places that allowed smoking were exposed to 374% the established annual EPA exposure standard to protect human health from fine particle air pollution; after the ordinance these same places that became smokefree saw a decline to 54% the EPA exposure standard.

After implementation of the smokefree ordinance, particulate matter air pollutants for the six places that previously allowed smoking dropped an average 95% to come into the EPA rating of "good."

Hospitality workers and customers in Rolla smoking-allowed public places and workplaces had been exposed to very unhealthy levels of an air pollutant known to cause heart disease, respiratory diseases, cancer and other diseases. Peer-reviewed studies have demonstrated that policies prohibiting smoking in public places and workplaces dramatically reduce SHS exposure and improve employee and public health.

Unfortunately, a subsequent city council approved exemption in the ordinance for private clubs to allow smoking during public events will continue to expose some workers and patrons to this significant and preventable source of disease.

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