
BISMARCK, NORTH DAKOTA
EFFECT OF SMOKE-FREE AIR LAW ON INDOOR AIR QUALITY

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EXECUTIVE SUMMARY

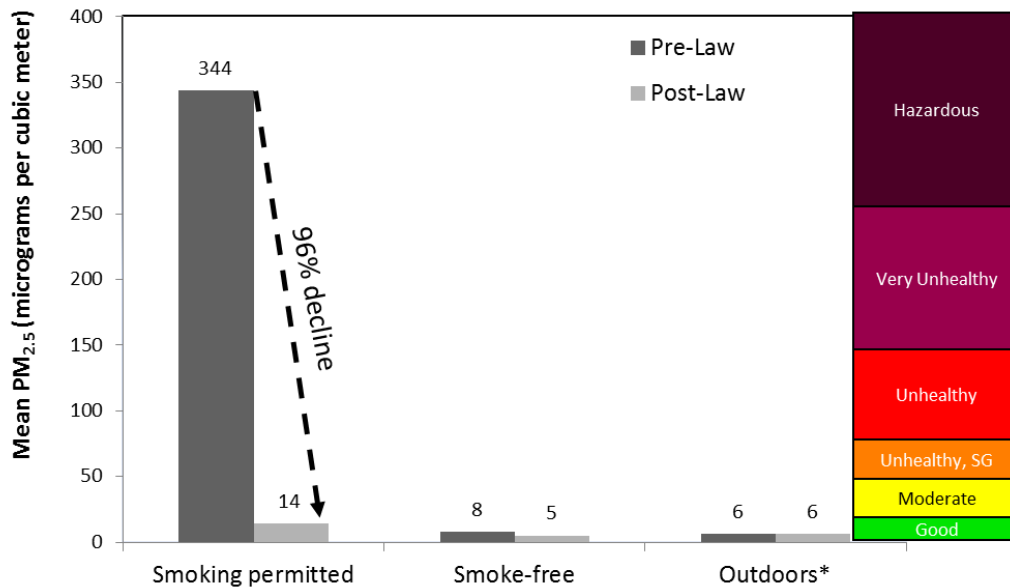
In January and February, 2010 & 2012, indoor air quality was assessed in 10 restaurants and bars in Bismarck, North Dakota. Effective April 27th, 2011, an updated ordinance eliminated exclusions that appeared in the original ordinance (#5463), which prohibited smoking in public places and places of employment. Changes included prohibiting smoking in bars, truck stops, fraternal orders and private clubs, nightclubs, tobacco stores, rented meeting rooms and within 10 feet of any entrance or exit to a public place. Prior to the city of Bismarck passing the updated smoke-free law, 7 of the 10 locations permitted indoor smoking, while 3 had smoke-free policies, one of which was attached to a permitted smoking bar. After the smoke-free law took effect, all 10 restaurants and bars were reassessed to observe the effect of the updated 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 the 7 locations with observed indoor smoking before the law, the level of fine particle air pollution was “hazardous” (PM_{2.5} = 344 µg/m³). This level of particle air pollution was 57 times higher than outdoor air in Bismarck.
- Employees in these locations with indoor smoking were exposed to levels of air pollution 6 times higher than safe annual levels established by the U.S. Environmental Protection Agency due to their occupational exposure to tobacco smoke pollution.
- In these locations that permitted smoking, indoor particle pollution levels declined 96% as a result of the smoke-free air law to low levels, similar to those found in outdoor air.
- In the locations that were smoke-free at baseline, particle pollution levels were low and remained unchanged after the smoke-free air law took effect.

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



*Used for comparison purposes. Based on the 2009 and 2011 PM_{2.5} averages from the EPA monitoring sites in Bismarck, Burleigh County, North Dakota (http://www.epa.gov/airdata/ad_rep_mon.html). The color-coded EPA Air Quality Index is also shown to demonstrate the magnitude of the measured particle levels.

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., and Puerto Rico 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 smoke-free air law on the level of fine particle air pollution in 10 bars and restaurants in Bismarck, North Dakota. Bismarck's smoke-free law prohibits smoking in all restaurants, including attached bars, and all freestanding bars as of April 27th, 2011. Cigarette smoke was also prohibited from other public spaces and buildings that still allowed smoking under exemptions to the original ordinance (#5463).

It is hypothesized that: 1) before the law, levels of indoor fine particle air pollution will be significantly higher in places with indoor smoking compared to those with no observed smoking; 2) 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; 3) there will be no significant change in particle pollution levels in a cohort of establishments that smoke-free at baseline that are sampled before and after the law; and 4) the degree of indoor particle air pollution will be correlated with the amount smoking.

METHODS

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.

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 January and February 2010, indoor air quality was assessed in 10 restaurants and bars in Bismarck, North Dakota. After changes to the original ordinance took effect on April 27th, 2011, all 10 restaurants and bars were reassessed to observe the effect of the updated smoke-free law.

Measurement Protocol

A minimum of 30 minutes were 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 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

TSI SIDEPAK AM510 PERSONAL AEROSOL MONITOR



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 $\text{PM}_{2.5}$. 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 $\text{PM}_{2.5}$ concentration within the venue.

Statistical Analyses

To evaluate the first hypothesis, statistical significance is assessed using the Mann-Whitney test on the $\text{PM}_{2.5}$ concentrations in the smoke-free versus smoking permitted locations. The second and third hypotheses are assessed using the Wilcoxon signed-rank test to compare the difference in the mean levels of $\text{PM}_{2.5}$ between establishments with observed smoking and those with no observed smoking before and after the updated Bismarck smoke-free air law came into effect. The fourth hypothesis is tested by using all 20 sample visits and correlating the average smoker densities to the $\text{PM}_{2.5}$ 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. Before the statewide smokefree law, the average $\text{PM}_{2.5}$ level in the 7 locations permitting indoor smoking was $344 \mu\text{g}/\text{m}^3$ (Figure 1). Before the law, the $\text{PM}_{2.5}$ concentrations in places with observed smoking were significantly higher than locations with no observed smoking where the mean $\text{PM}_{2.5}$ concentration was $8 \mu\text{g}/\text{m}^3$ ($U=0.00$, $p=0.017$). After Bismarck's new smoke-free air law, the mean $\text{PM}_{2.5}$ level in the 7 locations where smoking was previously observed was $14 \mu\text{g}/\text{m}^3$. This is a significant 96% reduction in $\text{PM}_{2.5}$ levels compared to the pre-law levels ($p=0.018$). There was no significant change in $\text{PM}_{2.5}$ levels in the 2 locations that were smoke-free at baseline ($p=0.317$).

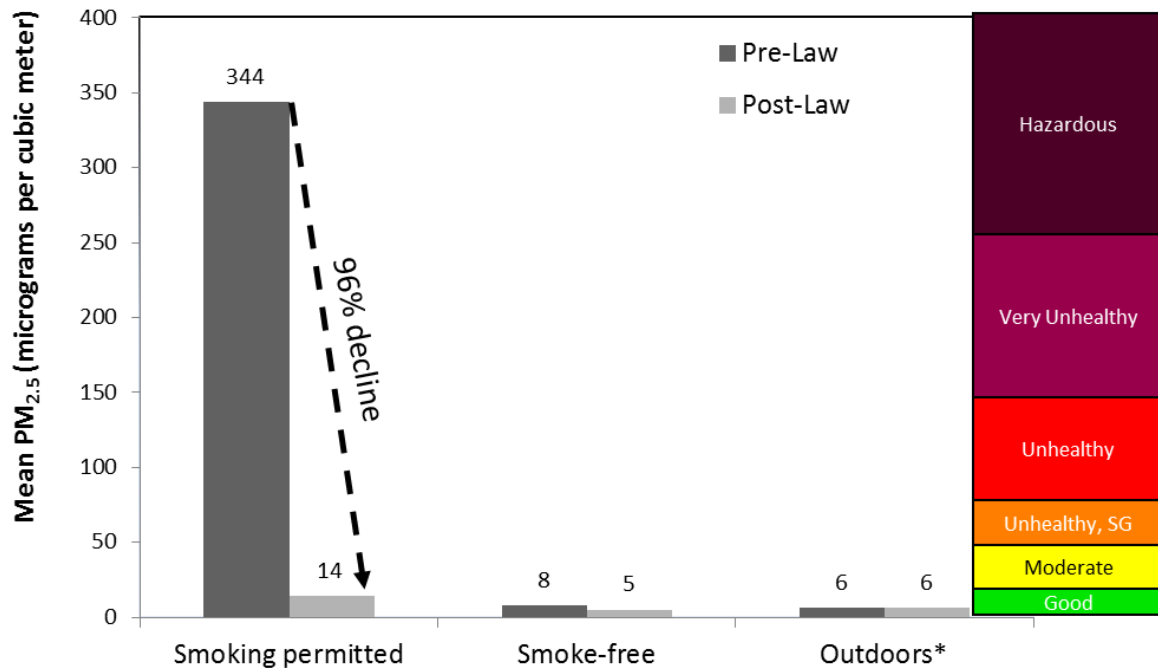
In the 7 locations with observed smoking, before the smoke-free law was passed, the average number of burning cigarettes was 7.6 which corresponds to an average smoker density (ASD) of 0.72 burning cigarettes per 100m^3 . Looking at all 20 sample visits, $\text{PM}_{2.5}$ levels are positively associated with the active smoker density indicating that the amount of indoor smoking is likely the primary driver of the indoor particle pollution levels. This association was statistically significant ($r_s=0.712$, $p<0.01$).

Table 1. Fine Particle Air Pollution in Bismarck, North Dakota Bars

Venue Number	Size (m ³)	Pre-Law				Post-Law			
		Average # people	Average # burning cigs	Active smoker density*	Average PM _{2.5} level (µg/m ³)	Average # people	Average # burning cigs	Active smoker density*	Average PM _{2.5} level (µg/m ³)
No Observed Smoking									
1	917	163	0.0	0.00	4	138	0.0	0.00	4
2	1019	46	0.0	0.00	11	28	0.0	0.00	5
Average (n=2)	968	105	0.0	0.00	8	28	0.0	0.00	5
No Observed Smoking, Attached to Smoking Bar									
3	1189	126	0.0	0.00	75	105	0.0	0.00	7
Smoking Observed									
4	1083	34	6.5	0.60	366	49	0.0	0.00	16
5	421	19	3.0	0.71	106	34	0.0	0.00	24
6	1274	85	7.7	0.60	325	38	0.0	0.00	6
7	1657	148	13.0	0.78	880	71	0.0	0.00	7
8	278	21	3.3	1.19	255	41	0.0	0.00	43
9	1189	78	10.7	0.90	282	76	0.0	0.00	4
10	3053	104	8.7	0.28	194	115	0.0	0.00	7
Average (n=7)	1279	70	7.6	0.72	344	63	0.0	0.00	14

*Average number of burning cigarettes per 100 cubic meters.

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*Used for comparison purposes. Based on the 2009 and 2011 PM_{2.5} averages from the EPA monitoring sites in Bismarck, Burleigh County, North Dakota (http://www.epa.gov/airdata/ad_rep_mon.html). The color-coded EPA Air Quality Index is also shown to demonstrate the magnitude of the measured particle levels.

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 $15 \mu\text{g}/\text{m}^3$ as the average annual level of $\text{PM}_{2.5}$ exposure and $35 \mu\text{g}/\text{m}^3$ for 24-hour exposure.[12] In order to compare the findings in this study with the annual EPA $\text{PM}_{2.5}$ 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 $344 \mu\text{g}/\text{m}^3$ (the average level in the sites with smoking) on the job, and is exposed only to background particle levels of $8 \mu\text{g}/\text{m}^3$ during non-work times. For a full-time employee their average annual $\text{PM}_{2.5}$ exposure is $85 \mu\text{g}/\text{m}^3$. The EPA average annual $\text{PM}_{2.5}$ limit is exceeded by 6 times due to their occupational exposure to tobacco smoke. Based on the latest scientific evidence, the EPA staff currently proposes even lower $\text{PM}_{2.5}$ standards to adequately protect the public health,[13] making the high $\text{PM}_{2.5}$ 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 smokefree 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 smokefree 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 smokefree workplace law was implemented in California[18]. Smokefree 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 smokefree law prohibited smoking in their worksites.[20] A meta-analysis of the 8 published studies looking at the effects of smokefree 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 second-hand 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 second-hand smoke 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 second-hand smoke exposure is also causally associated with stroke, low birthweight, spontaneous abortion, negative effects on the development of cognition and behavior, exacerbation of cystic fibrosis, cervical cancer and breast cancer. The health effects of secondhand smoke 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 Bismarck bars and restaurants with observed indoor smoking, prior to the updated smoke-free air law, were exposed to hazardous levels of indoor air pollution resulting from indoor smoking. The smoke-free air law implemented on April 27th, 2011, that currently prohibits indoor smoking in all restaurants, including attached bars, and all freestanding bars has been shown to decrease exposure to toxic tobacco smoke pollution by 96%. This reduction in exposure to toxic tobacco smoke will result in improved health outcomes for Bismarck workers and residents.

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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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