AIR QUALITY IN SAULT STE. MARIE RESTAURANTS
Before and After
Michigan's Dr. Ron Davis State Smoke-free Law

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1.0 Introduction. The Michigan Department of Community Health, Tobacco Section, with assistance from local health departments and other community agencies, recruited field investigators to measure the air quality in restaurants. The field investigators measured levels of fine particulate matter ($PM_{2.5}$) from secondhand smoke in restaurants before and after the statewide smoke-free air law was passed to determine whether the statewide smoke-free air law was effective in reducing air pollution from secondhand smoke. The study encompassed six major regions of the state: Southeast, West, Upper Peninsula, Northern Lower Peninsula, Thumb, and Central, and the following 14 sites participated in the study: Ann Arbor, Detroit, Flint, Grand Rapids, Kalamazoo, Lansing/E. Lansing, Marquette, Midland, Novi, Saginaw, Sault Ste. Marie, Traverse City, and West Branch. Casinos in the City of Detroit where pre-law data was collected will also be included in the study sample, as well as restaurants. This report analyzes the raw data collected by the field investigators and was prepared by the primary author (Appendix B). Individual result reports were prepared for each study site, and this report includes the results from Sault Ste. Marie.

$PM_{2.5}$ is a harmful combustion source air pollutant that is regulated in the outdoor air, and is widely monitored in all states, including Michigan (Michigan Department of Environmental Quality (MDEQ, 2011a), which maintains an extensive outdoor air quality monitoring network. Exposure to $PM_{2.5}$ affects breathing and the cellular defenses of the lungs, aggravates existing respiratory and cardiovascular ailments, and causes adverse health effects on the respiratory and cardiovascular systems; the entire population is affected, but susceptibility to $PM_{2.5}$ pollution varies with age and health status, and persons with heart or lung disease, the elderly, and children being at highest risk from exposure to $PM_{2.5}$ (MDEQ, 2011b; World Health Organization (WHO), 2005; National Academy of Sciences (NAS), 2010; Pope and Dockery, 2006). The World Health Organization (WHO) 24-hour $PM_{2.5}$ air quality guideline is 25 $\mu g/m^3$, and its annual standard is 10 $\mu g/m^3$, while the less stringent USEPA standards are 35 $\mu g/m^3$ averaged over 24 h, and the annual average is 15 $\mu g/m^3$ (USEPA, 2010). There is little evidence to suggest a threshold below which no adverse health effects are anticipated. Adverse health effects may occur at $PM_{2.5}$ concentrations as low as 3–5 $\mu g/m^3$ and the risk increases as exposure increases (WHO, 2005).

$PM_{2.5}$ is copiously emitted by cigarettes, pipes, and cigars, and is the largest component of secondhand tobacco smoke by mass. Secondhand smoke consists of smoke from the burning end of the tobacco product, plus exhaled smoke from the smoker, both of which contain numerous gaseous carcinogens and toxins (Hoffmann and Hoffmann, 1987; Repace, 2007). The evidence on the mechanisms by which tobacco smoke causes disease indicates that there is no risk-free level of exposure; low levels of exposure, such as those encountered by breathing secondhand smoke, lead to a rapid and sharp increase in endothelial dysfunction and inflammation, which are implicated in acute cardiovascular events and thrombosis (U.S. Department of Health and Human Services, 2010).

When measured before and after a smoke-free policy has been emplaced, $PM_{2.5}$ is a demonstrated atmospheric marker for the presence of secondhand smoke, and numerous compact and portable real-time monitors are available for its measurement (Repace, 2004; Repace, et al., 2006; Travers et al., 2004; Repace and Lowrey, 1980). Six Sault Ste. Marie restaurant venues were monitored for $PM_{2.5}$ on August 29th and 30th, 2008, prior to the enactment of Michigan's state smoke-free air law and again on January 14-15, 2011, subsequent to the enactment of the state smoke-free air law, which was effective on May 1, 2010.

2.0 Methods. This study addressed the following research aims: (1) What are the concentrations of secondhand smoke fine particle air pollution ($PM_{2.5}$) in Sault Ste. Marie hospitality venues before and after Michigan's smoke-free air law? (2) Does secondhand smoke create an air quality hazard for hospitality workers and patrons?

In order to address the research questions, a real-time fine particle monitor was deployed by a team of 2 field investigators who visited a convenience sample of six restaurants, before and after the enactment of the state smoke-free air law. Real-time monitors measure particle mass concentration and time. The SidePak™ AM510 Personal Aerosol Monitors were deployed. The SidePak is a rugged, battery-powered lightweight laser photometer, weighing about 16 oz. It is compact and quiet, minimizing interference with normal activities in the area to be measured, and has been widely used in secondhand smoke studies (Travers et al., 2004; Repace, 2009; Jiang et al., 2010. The built-in sampling pump has a size-selective inlet for area measurements with a $PM_{2.5}$ impactor. SidePak AM 510 (TSI, Inc., MN) flow rates were set to 1.7 L/min, fitted with 2.5 μm impactors, and set for 1 minute log intervals.

The calibration factor was set to 1 during the measurements, based on the factory calibration using Arizona Road Dust. In the data analysis, a custom calibration factor of 300 (Jiang et al., 2010) was used to convert the logged nominal instrument readings from uncorrected milligrams per cubic meter to actual micrograms per cubic meter ($\mu g/m^3$) of $PM_{2.5}$ from secondhand smoke or background using a gravimetrically-derived calibration factor derived from controlled experiments. The basic calibration and monitoring protocols are described in detail in Jiang et al. (2010), Repace (2009) and in Repace (2004). The investigators carried the monitors around as they counted patrons and smokers, so that the measurements represent a composite average of the entire area. The field investigators completed total person and active smoker counts 3 to 5 times per visit. The field investigators measured ceiling heights using a laser ruler, recorded times of arrival and departure from venues in a diary. The detailed study protocol is described in Appendix A.

3. Results. Table 1 shows the results of the pre-law monitoring for 6 hospitality venues in Sault Ste. Marie on September 22 and 23, 2008 on Friday and Saturday nights. Table 1 gives the statistics for fine particle air pollution ($PM_{2.5}$): maximum, minimum, and the measures of central tendency (mean, standard deviation, and median). The units of concentration are expressed in micrograms per cubic meter ($\mu g/m^3$). The number of active smokers (burning cigarettes), n_s, counted during the duration of the sampling intervals ranged from 31 to 54 minutes in the various venues. These also represent the number of 1-minute $PM_{2.5}$ data points for each venue. The active smoker density, D_s, is defined as the average number of burning cigarettes being smoked per unit volume, and is given in units of active smokers per hundred cubic meters of space volume. The average number of patrons present in the venues during the monitoring period is given by P, and the volume of the premises is given by V, expressed in metric units of cubic meters (m^3), where a cubic meter is equivalent to 35.315 cubic feet. The estimated smoking prevalence in the venues is calculated by multiplying the average active smoking count, n_s, by 3 and dividing by the number of persons, and expressed as a percentage, ranges from about 6% to 16% (Pritsos et al., 2008; Repace, 2007). For individual restaurants, pre-law means ranged from 16.1 to 244 $\mu g/m^3$, and averaged 117 $\mu g/m^3$, (median 112 $\mu g/m^3$).

Table 1. SAULT STE. MARIE RESTAURANT $PM_{2.5}$ PRE-LAW September 22-23, 2008.

Statistic	Venue #1	Venue #2	Venue #3	Venue #4	Venue #5*	Venue #6
Day	Friday	Friday	Saturday	Saturday	Saturday	Saturday
Units	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Minimum	173	29.1	114	33.9	77.4	11.4
Maximum	317	90.6	254	91.2	242	31.8
Mean	244	53.2	167	56	168	16.1
Median	234	45.3	159	49.5	160	12.9
Std. Dev.	42.7	19.1	30.5	15.3	32	6.32
Duration, Minutes	35	33	32	31	54	37
D_S	0.22	0.26	2.67	0.23	0*	0
V, m^3	1053	504	368	421	367	351
n_s	2.33	0.26	2.67	1.00	0*	0
P	44	42.7	20.3	47.3	20.5	14
Estimated Smoking Prevalence	15.9%	9.34%	13.4%	6.34%	0%*	0%

D_s = smoker density (average active smokers per hundred cubic meters); V= space volume, m^3; n_s = average number of active smokers; P = average number of persons. ***[smoke infiltration from adjacent bar area]**

Figure 1 illustrates the real-time data recorded for all venues, and shows a plot of the real-time $PM_{2.5}$ data (on a logarithmic scale) versus time on a linear scale, over a 30-35 minute period for Venue #1. Figure 1 compares indoor air pollution levels when smoking was permitted (upper curve) with the $PM_{2.5}$ levels after the Law eliminated smoking. The average $PM_{2.5}$ pre-law is 244 $\mu g/m^3$, compared to about 9.3 $\mu g/m^3$ post-law (Table 2). For this restaurant, an estimated 96% of the pre-law $PM_{2.5}$ was due to secondhand smoke pollution. In other words, for this venue, the effect of Michigan's state smoke-free air law was to reduce its indoor air pollution from $PM_{2.5}$ to 4% of its pre-law value.

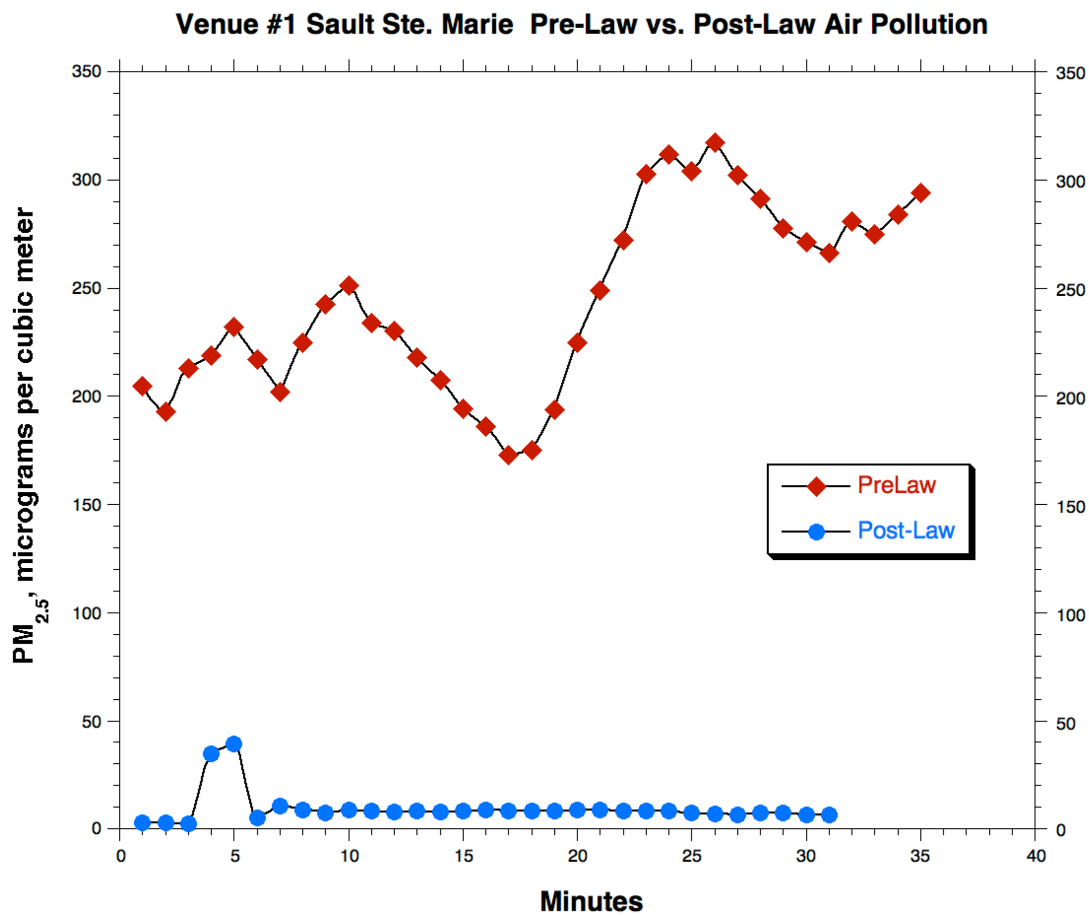

Figure 1. Real-time SidePak measurements in Venue #1, Pre- and Post-Law

Table 2 shows the same parameters measured on Friday and Saturday nights in January 2011, 7 months subsequent to enactment of the Dr. Ron Davis smoke-free law. Table 2 shows that the reductions in $PM_{2.5}$ due to secondhand smoke afforded by the Law ranged from 62% to 98%, with the exception of Venue #4.

Post-law restaurant means for all 6 venues ranged from 3 to 182 $\mu g/m^3$, but with Venue #4 removed, the means for the 5 remaining venues ranged from 3 to 16.8 $\mu g/m^3$, and averaged 9.5 $\mu g/m^3$ (median 9.3 $\mu g/m^3$). Venue #4, averaging 182 $\mu g/m^3$, had oil candles and a smoky grill which created new sources of indoor air pollution.

Figure 2 compares the mean pre-law smoking and post-law results for smoke-free case (lower curve). In every case except Venue #4, the reductions in $PM_{2.5}$ are dramatic, with pollution levels declining in the restaurants by 62% to 98%.

Table 2. SAULT STE. MARIE RESTAURANT $PM_{2.5}$ POST LAW January 14-15, 2011

Statistic	Venue #1	Venue #2	Venue #3	Venue #4*	Venue #5	Venue #6
Day	Friday	Friday	Friday	Saturday	Saturday	Saturday
Units	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Minimum	2.4	6.9	1.8	2.7	2.4	3.3
Maximum	39.3	25.2	6	603	42.6	6.6
Mean	9.25	14.3	3	182	16.8	4.05
Median	8.1	12.3	3	162	17.5	3.9
Std Dev.	7.67	4.91	0.702	123	8.27	0.73
D_S	0	0	0	0	0	0
P	34.5	37.3	31	62.8	5.4	4.5
Duration, Minutes	31	31	51	46	40	31
% Reduction in $PM_{2.5}$	-96%	-62%	-98%	+190%*	-90%	-75%

***[smoke from oil candles on each table and infiltration from the barbeque grill permeated the restaurant].**

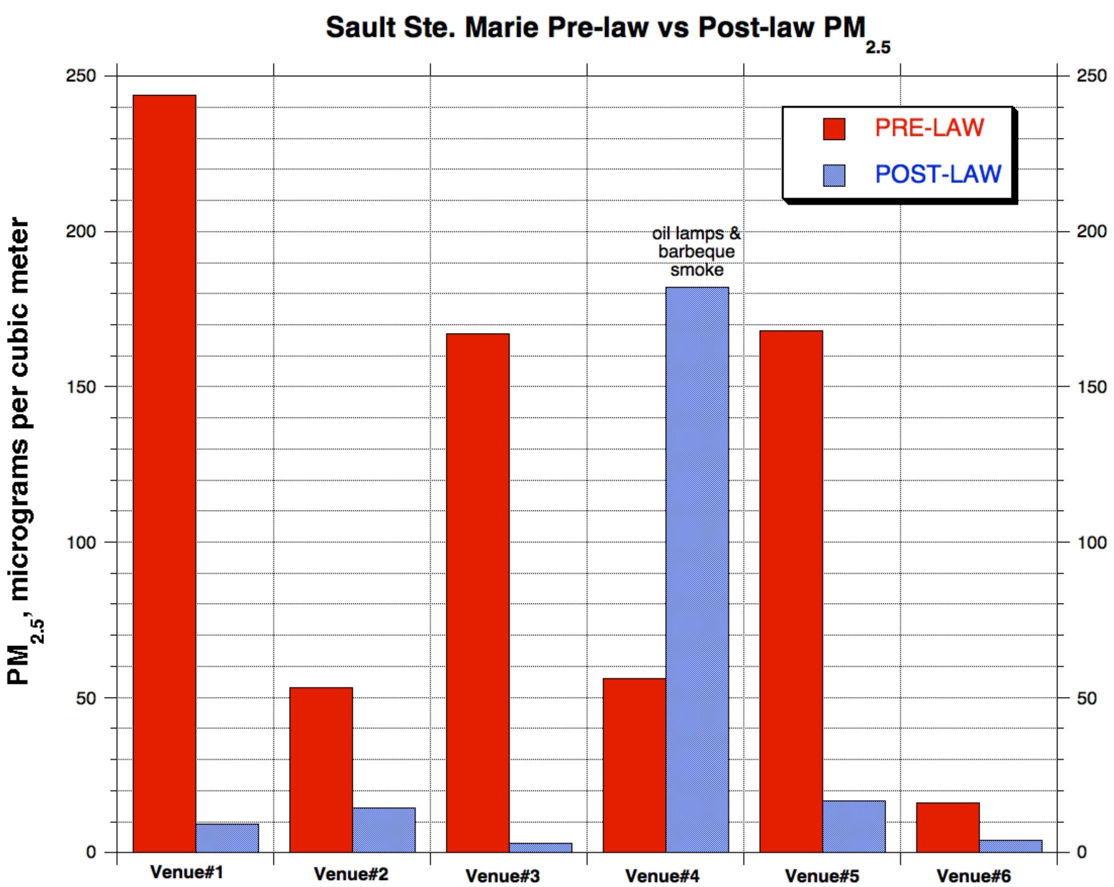

Figure 2. Mean air pollution levels in 6 hospitality venues, pre-and-post Smoke-free Air Law.

4. Discussion. The average percent reduction in median $PM_{2.5}$ for the 5 Sault Ste. Marie venues that had no residual air quality problems was 94%, indicating that the vast majority of indoor air pollution in these venues was due to secondhand smoke, as shown in Figure 3. By comparison, Repace (2004) performed real-time measurements of respirable particle (RSP) air pollution and particulate polycyclic aromatic hydrocarbons (PPAH), in a casino, six bars, and a pool hall in Wilmington, DE before and after Delaware's smoke-free workplace law. In this study, secondhand smoke contributed 90% to 95% of the $PM_{2.5}$ air pollution during smoking, and 85% to 95% of the carcinogenic particulate polycyclic aromatic hydrocarbons (PPAH), greatly exceeding levels of these contaminants encountered on major truck highways and polluted city streets.

Repace, Hyde, and Brugge (2006) found similar results in 6 pubs in Boston, MA before and after Boston's smoke-free law: levels of $PM_{2.5}$ declined by 96%, while PPAH declined by 90%. Similarly, Travers et al. (2004) measured before and after New York State's clean indoor air law. The average $PM_{2.5}$ concentration was substantially lower after the law went into effect in every venue where smoking or indirect SHS exposure had been observed at baseline, with a grand mean reduction in $PM_{2.5}$ concentration of 84% (324 μg/m3 to 25 μg/m3; $p<0.001$) (Table). When stratified by the type of venue sampled, the average $PM_{2.5}$ concentration decreased 90% ($p<0.001$) in the 14 bars and restaurants in which smoking was occurring at baseline. The Sault Ste. Marie results (Figure 3) are consistent with the Wilmington, Boston, and Western New York studies.

The reported estimated adult smoking prevalence for Michigan in 2009 was 19.6% compared to 17.9% for the US (CDC-BRFSS, 2009). By comparison, the total number of persons present in the 5 of the 6 venues (except for Venue # 5, where smoke drifted in from the bar) pre-law was $P_{tot} = 168$, and the total active number of cigarettes was $Ns_{tot} = 7.33$. The total number of smokers present in the 5 venues is estimated as 3Ns = 22, for an estimated overall smoking prevalence for the patrons of these 5 venues of (22/168)(100%) = 13%, lower by 34% than the Michigan adult smoking prevalence. Figure 3 shows that the median levels for the 5 restaurants with no oil-lamp-related indoor air quality problem declined by 94%, (means declined by an average of 93%). Two studies found indoor air quality problems related to infiltration from restaurant kitchens (Repace, Hyde, and Brugge, 2006) or from oil lamps (Repace and Johnson, 2006).

The SidePak

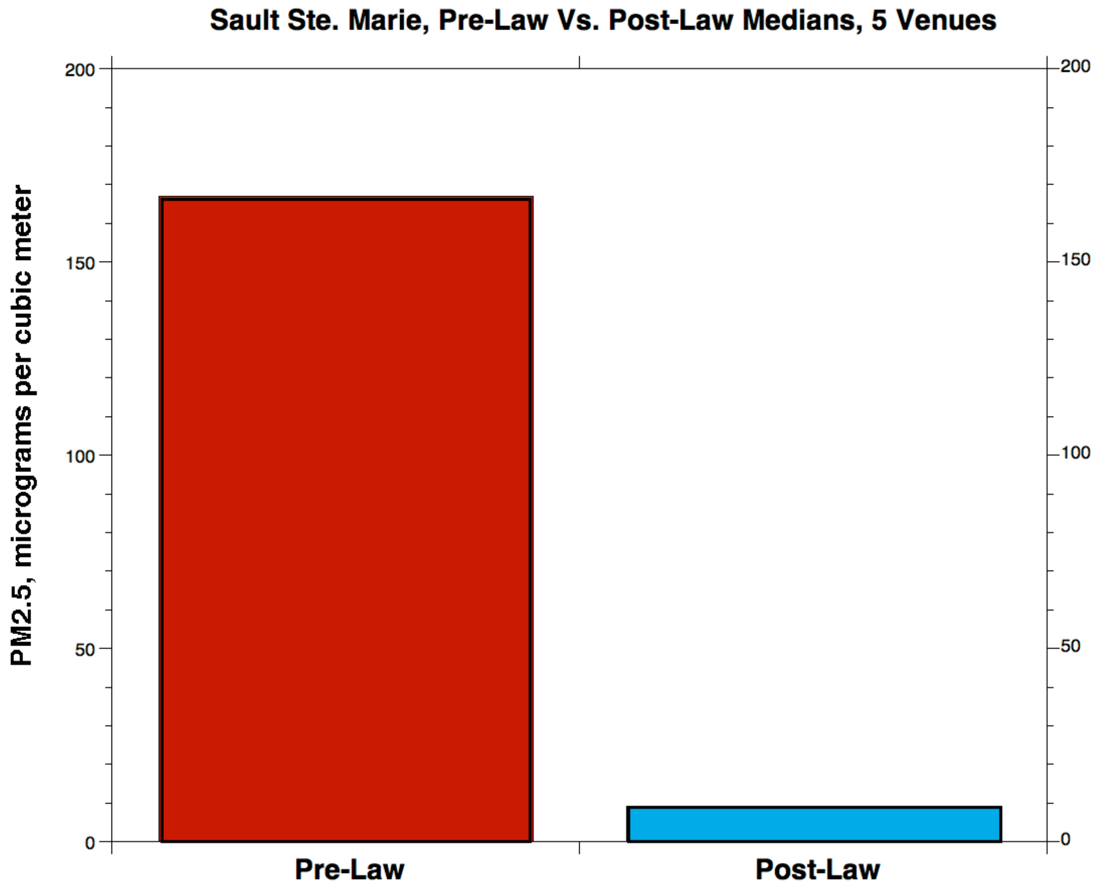

Figure 3. Combined median $PM_{2.5}$ level for 5 of 6 Sault Ste. Marie restaurants drops an average of 93% due to Michigan's Clean Indoor Air Law.

5. Health Implications. Many jurisdictions around the US have recognized that secondhand smoke is harmful to human health. Smoke-free laws now cover almost 74% of US restaurants and 63% of US bars (ANR, 2010). These laws afford significant protection from the adverse health effects due to secondhand smoke. For example, Moraros et al. (2010) reported that Delaware's comprehensive non-smoking ordinance, which extended a decade-long workplace smoking ban to restaurants, bars, and casinos, was associated with statistically significant decreases in both acute myocardial infarction and asthma incidence in Delaware residents when compared with non-Delaware residents. The National Toxicology Program has identified secondhand smoke as a known human carcinogen (NIEHS, 2000). Secondhand smoke has been identified as a cause of cancer of the lung, breast, and nasal sinus (Johnson et al., 2011; CalEPA, 2006). Secondhand smoke particulate matter measured in numerous hospitality venues, including bars, restaurants, casinos, contains a substantial fraction of carcinogenic polycyclic aromatic hydrocarbons (Repace, et al., 2011). Secondhand smoke is a prolific source of $PM_{2.5}$ in indoor air, with each cigarette emitting about 14 milligrams of $PM_{2.5}$, and cigars emitting 3 to 5 times as much (Repace, et al., 1998).

Appendix C describes the Air Quality Index used by Michigan's Department of Environmental Quality, *"developed and federally mandated to quickly communicate* *short-term, current air information to the public. Simply put, the AQI is a health indicator for people who want to know whether the air they are breathing 'right now' is healthy. ... It is calculated in near real-time using hourly data [primarily ozone and $PM_{2.5}$] from continuous air monitors. The AQI identifies air pollutant concentrations as one of six color-code category levels ranging from good to hazardous. This simple tool allows people to make health decisions about daily activities... "* (MDEQ, 2011b).

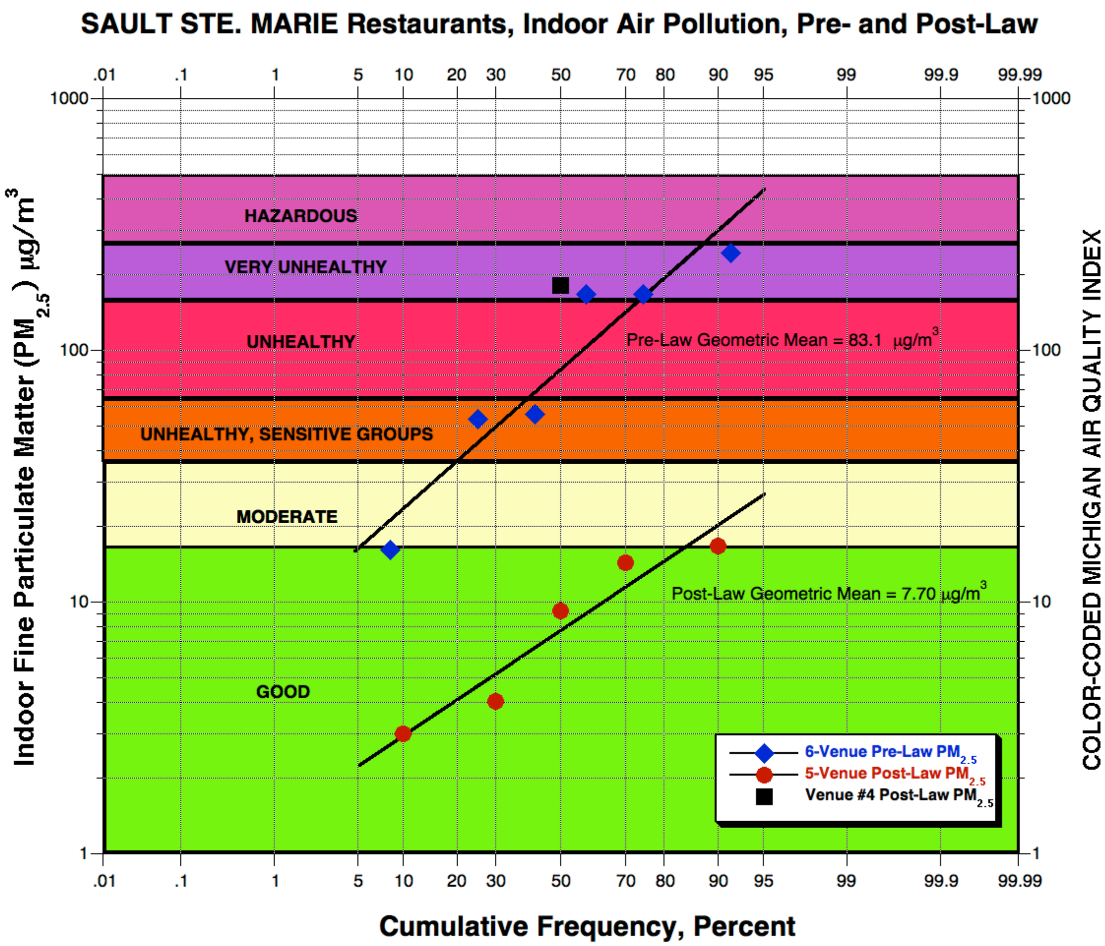

Figure 4. $PM_{2.5}$ frequency distributions for 5 of 6 restaurants vs. the MI AQI. Pre-law, 5 of 6 venues have bad air quality air quality; the 6th venue had no smoking observed, and had good air quality. Post-law, 5 of 6 venues have good-moderate air quality. Post-Law, Venue #4, although nonsmoking, developed a new indoor air quality problem.

Figure 4 shows the frequency distributions in the 6 venues with smoking (pre-law) and the same 6 venues without smoking (post-law). Five of the 6 restaurants had polluted indoor air pre-law, ranging from Good (no smoking observed) to Hazardous (Geometric mean, Unhealthy, at 83.1 μg/m^3), while 5 of 6 venues had good to moderate air quality post-law (Geometric mean, Good, at 7.70 μg/m^3). However, post-law, one venue, restaurant #4, developed a new indoor air problem due to emissions from oil lamps and infiltrating barbeque smoke, resulting in very unhealthy air. Repace, Hyde, and

Brugge (2006) noted a similar problem in a Boston restaurant, due to a defective gas-fired deep fat fryer. These authors reported the high carbon monoxide readings in this restaurant to the Boston Health Department, which investigated the problem, and notified the owners, who corrected the problem. Further, Repace and Johnson (2006) observed high $PM_{2.5}$ and carcinogen emissions from oil lamps in an air quality investigation of smoke-free Ottawa pubs.

By comparison, the geometric mean for all 41 air-quality monitoring sites in the State of Michigan in 2008 was 10.52 $\mu g/m^3$ (Appendix C, Figure C-1). Thus the post-law $PM_{2.5}$ concentrations are comparable to the low average levels found in the outdoor air. Figures 1-4 demonstrate clearly that the ventilation and air cleaning practices followed by these venues did not control $PM_{2.5}$ air pollution, but the state clean indoor air law did.

The frequency distributions plotted in Figure 4 are interpreted as follows: any point on the line gives the percentage of the restaurants below a particular concentration on the horizontal axis. The solid lines for the curve-fits in Figure 4 can be generalized or modeled to estimate the air quality expected for the remainder of unsampled Sault Ste. Marie restaurants before and after the protection of the Dr. Ron Davis Law. For example, to find the percentage of venues with indoor concentrations above the level of WHO's 25 $\mu g/m^3$ 24-h guideline, we find "25" on the vertical axis in $\mu g/m^3$, and then we read corresponding horizontal axis value, 11%. If the venues selected were to be considered as representative of the distribution to be found for all Sault Ste. Marie restaurants pre-law, this suggests that 100% - 11% = 89% of the venues were at or above 25 $\mu g/m^3$. Similarly, 20% of the venues would be below 35 $\mu g/m^3$, so 80% would be at or above 35 $\mu g/m^3$, the numerical value of EPA's 24-h standard. In this way, the estimated frequency distribution of Sault Ste. Marie restaurants can be displayed, and the percent of the venues at or above any concentration can be read directly from the graph by simple subtraction.

The AQI refers only to $PM_{2.5}$ as a criteria air pollutant, while secondhand smoke contains many toxic substances: Secondhand smoke contains at least 172 toxic substances in both its gas and particulate phases, of which 33 are classified as hazardous air pollutants, 47 as hazardous wastes, 3 as criteria air pollutants, and 67 as known carcinogens (Repace, 2007). Of the latter, 20 are involved in lung carcinogenesis, and of these, PPAH (10 compounds) are among the most significant (Hecht, 1999). However, Pope et al. (2009) suggest that $PM_{2.5}$ in the outdoor air and $PM_{2.5}$ from secondhand smoke appear to have similar toxicity.

This study demonstrates that secondhand smoke causes major indoor air quality problems, but that indoor air quality improves dramatically after smoke-free laws are enforced.

6. Conclusions.

1. **Six Sault Ste. Marie restaurants were monitored for fine particulate air**

pollution before and after Michigan's Dr. Ron Davis Smoke-free Air Law, using real-time air quality monitors for fine particulate air pollution ($PM_{2.5}$).

2. **The Dr. Ron Davis Law succeeded in reducing geometric mean levels of harmful secondhand smoke fine particle air pollution ($PM_{2.5}$) for a six-restaurant sample of Traverse City Hospitality establishments by approximately 91% for 5 of the 6 venues. The 6th venue developed a new indoor air quality problem unrelated to smoking.**
3. **Five of six restaurants studied had bad air quality prior to the law's enactment (excepting one venue where no smoking was observed), despite an estimated smoking prevalences ranging from about 6% to 16%, and averaging two third of the State average.**
4. **Five of the six restaurants had good to moderate air quality subsequent to the law's enactment.**
5. **For Sault Ste. Marie, Michigan's Dr. Ron Davis Clean Indoor Air Law was highly effective in reducing secondhand smoke $PM_{2.5}$ air pollution to the low levels found outdoors.**

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APPENDIX A. **Study Protocol for Evaluating Changes in Air Quality Before and After the Implementation of a Smoke-free Air Worksite Law**
[MDCH, Tobacco Control, 2010]

Title
Michigan Smoke-free Air Law Air Monitoring Study

Introduction:
The MDCH, Tobacco Section, with assistance from the local health departments and other community agencies, will be recruiting adult volunteers to measure the air quality in restaurants before (conducted between 2005 and 2008) and after the statewide smoke-free air law is passed.

Purpose:
To measure changes in the level of particulate matter from secondhand smoke in restaurants before and after the statewide smoke-free air law has passed to determine whether the statewide smoke-free air law is effective in reducing air pollution from secondhand smoke.

Method & Sample:
The State of Michigan will be represented by the following six major regions of the state: Southeast, West, Upper Peninsula, Northern Lower Peninsula, Thumb, and Central, and the following 14 sites will participate in the study: Ann Arbor, Detroit, Flint, Grand Rapids, Kalamazoo, Lansing/E. Lansing, Marquette, Midland, Novi, Saginaw, Sault Ste. Marie, Traverse City, and West Branch. Casinos in the City of Detroit where pre-law data was collected will also be included in the study sample, as well as restaurants. Data using the TSI SidePak AM 510 Personal Aerosol Air Monitor was collected in a convenience sample of restaurants, between 2005 and 2008, for the pre-law data collection. Six of the same restaurants where pre-law data was collected will be re-visited for the post-law data collection. In the case where six of the same restaurants cannot be re-visited, additional smoke-free restaurants will be added to obtain the difference in the average measurement of particulate matter before and after the law was passed. Local agency coordinators from each of the 14 sites will be asked to recruit at least two volunteers to visit these restaurants using the air monitor. Two air monitors will be used in succession in the 14 cities.

In addition to particulate matter data that is collected by the air monitor, the date, entry and exit time, number of people in the venue, and dimensions of the venue (i.e., length, width, and height), will be collected via a measurement laser and noted by the volunteers on a data sheet provided by MDCH, Tobacco Section. Local coordinators and volunteers will be trained by MDCH Tobacco Sections staff on how to use the air monitor and collect other data approximately 2 weeks before their scheduled data collection. MDCH Tobacco Section staff will develop a training schedule with local coordinators for their particular site.

Risk/incentive:

No risk is expected to volunteers in collecting the data or to anyone in the restaurants during data collection via the air monitor. The name of the restaurant will be documented for reference to compare the pre- and post-law data; however, the name of the restaurant will not be used for any other purposes and the data that is shared with local coordinators via report form will not include restaurant names, as the data will be de-identified and reported in a summary format. Each volunteer will be provided a total stipend of $30 per evening to cover the cost of food and drinks while they are collecting data at the restaurants. The volunteers will need to purchase drinks or food while they visiting the restaurants so that they can be customers while they are collecting air quality data via the air monitor.

Period of the study:

Data collection will occur over a six-month period, between October 1, 2010 and April 30, 2011, and data analysis and a study report will be completed by July 2011.

Data Management:

Data will be stored in the air monitor and then transferred into a secured, electronic file in the air monitoring software, TrakPro, and transferred into a secure file in SPSS 15 for data analysis. Local raw data for each site will be provided up on request. A study report with aggregated statewide and local level results will be provided to all local contractors.

Study Team:

The study team will provide the technical assistance throughout the duration of the study to all participating agencies, collect the air monitoring data from each local site, conduct the data analysis, and provide a study report to all local contractors. The study team will involve staff members from the MDCH, Tobacco Section.

APPENDIX B. **Qualifications of the Primary Author:**

James Repace, MSc., is a biophysicist and an international secondhand smoke consultant who has published 86 scientific papers, 79 of which concern the hazard, exposure, dose, risk, and control of secondhand smoke. His work was cited 19 times in the 2006 Surgeon General's Report.* He has received numerous national honors for his pioneering work on secondhand smoke exposure, dose, risk, and control, including the Flight Attendant Medical Research Institute Distinguished Professor Award, the Robert Wood Johnson Foundation Innovator Award, the Surgeon General's Medallion, and a Lifetime Achievement Award from the American Public Health Association. He holds an appointment as a Visiting Assistant Clinical Professor at the Tufts University School of Medicine, Dept. of Public Health. Website: www.repace.com.

**The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General. June 27, 2006* <http://www.surgeongeneral.gov/library/secondhandsmoke/>.

15 Selected Publications:

Repace JL, and Lowrey AH. Indoor Air Pollution, Tobacco Smoke, and Public Health. *SCIENCE* 208: 464-474 (l980).

Repace JL, and Lowrey AH. Tobacco Smoke, Ventilation, and Indoor Air Quality. *ASHRAE TRANSACTIONS* 88: Part I, 895-914 (l982).

Photo

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AIR QUALITY INDEX:

The Air Quality Index (AQI) was developed and federally mandated to quickly communicate short-term, current air information to the public. Simply put, the AQI is a health indicator for people who want to know whether the air they are breathing 'right now' is healthy. **MIair** AQI values are displayed in a forecast table and shown as color-coded dots plotted on a Michigan map. It is calculated in near real-time using hourly data [primarily ozone and $PM_{2.5}$] from continuous air monitors. The AQI identifies air pollutant concentrations as one of six, color-coded category levels ranging from good to hazardous.[13] This simple tool allows people to make health decisions about daily activities, such as whether to adjust physical exertion levels. Staff meteorologists include a Forecast Discussion to provide upcoming conditions.

A relative scale of 0 to 500 (shown below in **Table 4-1**) is used to display AQI values; the higher the AQI number, the greater the pollution concentration and potential for short-term health concerns. The index is not intended to provide an indication of long-term chronic air pollution exposure (months or years), nor does it reflect additive or synergistic health effects that may result from exposure to multiple air pollutants. Note that during 2008, the AQI values for $PM_{2.5}$ and O_3 concentrations were adjusted to align closely with National Ambient Air Quality Standard changes.

Table 4.1: BREAKPOINTS FOR AQI POLLUTANT CONCENTRATIONS

AQI VALUE	$PM_{2.5}$ (24 hr) $\mu g/m^3$	PM_{10} (24 hr) $\mu g/m^3$	SO_2 (24 hr) ppm	O_3 (8 hr) ppm	O_3 (1 hr) ppm	CO (8 hr) ppm	NO_2 (1 hr) ppm
301-500 **Hazardous**	250.5 – 500.4	425 – 604	0.605 – 1.004	→	0.405 – 0.604	30.5 – 50.4	1.25 – 2.04
201-300 **Very Unhealthy**	150.5 – 250.4	355 – 424	0.305 – 0.604	0.116 – 0.374	0.205 – 0.404	15.5 – 30.4	0.65 – 1.24
151-200 **Unhealthy**	65.5 – 150.4	255 – 354	0.225 – 0.304	0.096 – 0.115	0.165 – 0.204	12.5 – 15.4	-
101-150 **USG**	35-5 – 65.4	155 – 254	0.145 – 0.224	0.076 – 0.095	0.125 – 0.164	9.5 – 12.4	-
51-100 **Moderate**	15.5 – 35.4	55 – 154	0.035 – 0.144	0.060 – 0.075	-	4.5 – 9..4	-
0-50 **Good**	0.0 – 15.4	0 – 54	0.00 – 0.03	0.000 – 0.059	-	0.0 – 4.4	-

[13] The AQI must not be confused with NAAQS, which determine an area's compliance with provisions set forth in the federal CAA.

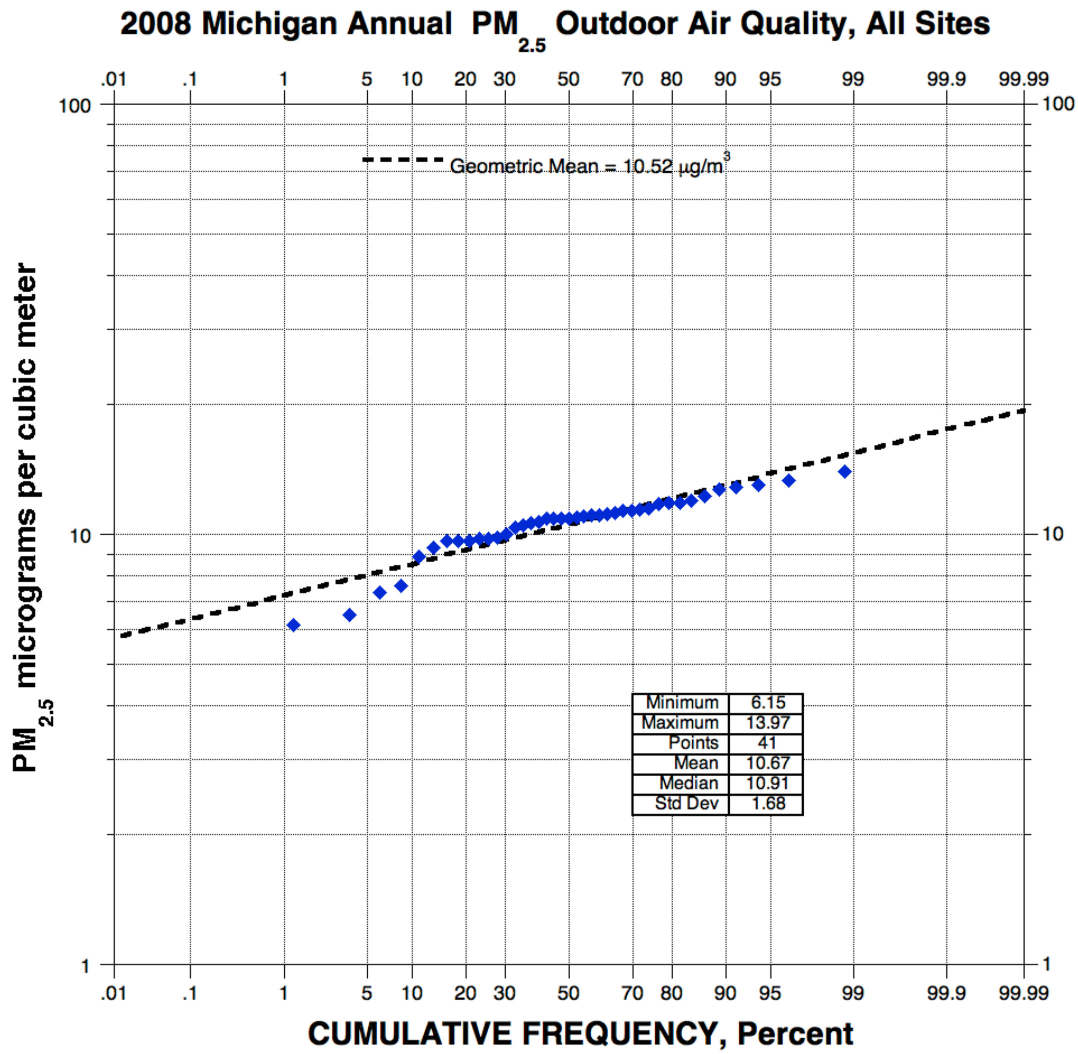

Figure C-1. A log-probability plot of outdoor $PM_{2.5}$ for all 41 sites in the State of Michigan (MDEQ, 2011a).

Air quality in Michigan generally falls in the good or moderate range. An area will occasionally fall into the "unhealthy for sensitive groups" range, but rarely reaches unhealthy levels.

Table 4.2 identifies the AQI colors and the associated health statements by individual air pollutant.

Table 4.2: The AQI Colors and Health Statements

AQI COLOR, CATEGORY & VALUE	PARTICULATE MATTER (µg/m^3) 24-Hour	OZONE (ppm) 8-Hour / 1-Hour	CARBON MONOXIDE (ppm) 8-hour	SULFUR DIOXIDE (ppm) 24-hour	NITROGEN DIOXIDE (ppm) 1-hour
GREEN: Good 1-50	None	None	None	None	None
YELLOW: Moderate 51-100	Unusually sensitive people should consider reducing prolonged or heavy exertion.	Unusually sensitive people should consider reducing prolonged or heavy exertion.	*None*	None	None
ORANGE: Unhealthy for Sensitive Groups 101-150	People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.	Active children and adults, and people with lung disease such as asthma, should reduce prolonged or heavy outdoor exertion.	People with cardiovascular disease, such as angina, should limit heavy exertion and avoid sources of CO, such as heavy traffic.	People with asthma should consider limiting outdoor exertion.	None
RED: Unhealthy 151-200	People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion. Everyone else should limit prolonged exertion.	Active children and adults, and people with lung disease such as asthma, should avoid pro-longed or heavy exertion. Everyone else, especially children, should reduce prolonged outdoor exertion.	People with cardiovascular disease, such as angina, should limit moderate exertion and avoid sources of CO, such as heavy traffic.	Children, asthmatics, and people with heart or lung disease should limit outdoor exertion.	None
PURPLE: Very Unhealthy 201-300	People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.	Active children and adults, and people with respiratory disease such as asthma, should avoid all outdoor exertion. Everyone else, especially children should limit outdoor exertion.	People with cardiovascular disease, such as angina, should avoid exertion and sources of CO, such as heavy traffic.	Children, asthmatics, and people with heart or lung disease should avoid outdoor exertion. Everyone else should limit outdoor exertion.	Children and people with respiratory disease, such as asthma, should limit heavy outdoor exertion.
MAROON: Hazardous 301-500	Everyone should avoid any outdoor exertion; people with heart or lung disease, older adults, and children should remain indoors.	Everyone should avoid all outdoor exertion.	People with cardiovascular disease, such as angina, should avoid exertion and sources of CO, such as heavy traffic. Everyone else should limit heavy exertion.	Children, asthmatics, and people with heart or lung disease should remain indoors. Every-one else should avoid outdoor exertion.	Children and people with respiratory disease, such as asthma, should limit moderate or heavy outdoor exertion.

Figure C-2. Health Advisories associated with regulated outdoor air pollutants in Michigan (MDEQ, 2011a). Although the pollutants are not regulated in the indoor environment, the health effects associated with a given pollutant at a given level of air quality are apt descriptors.