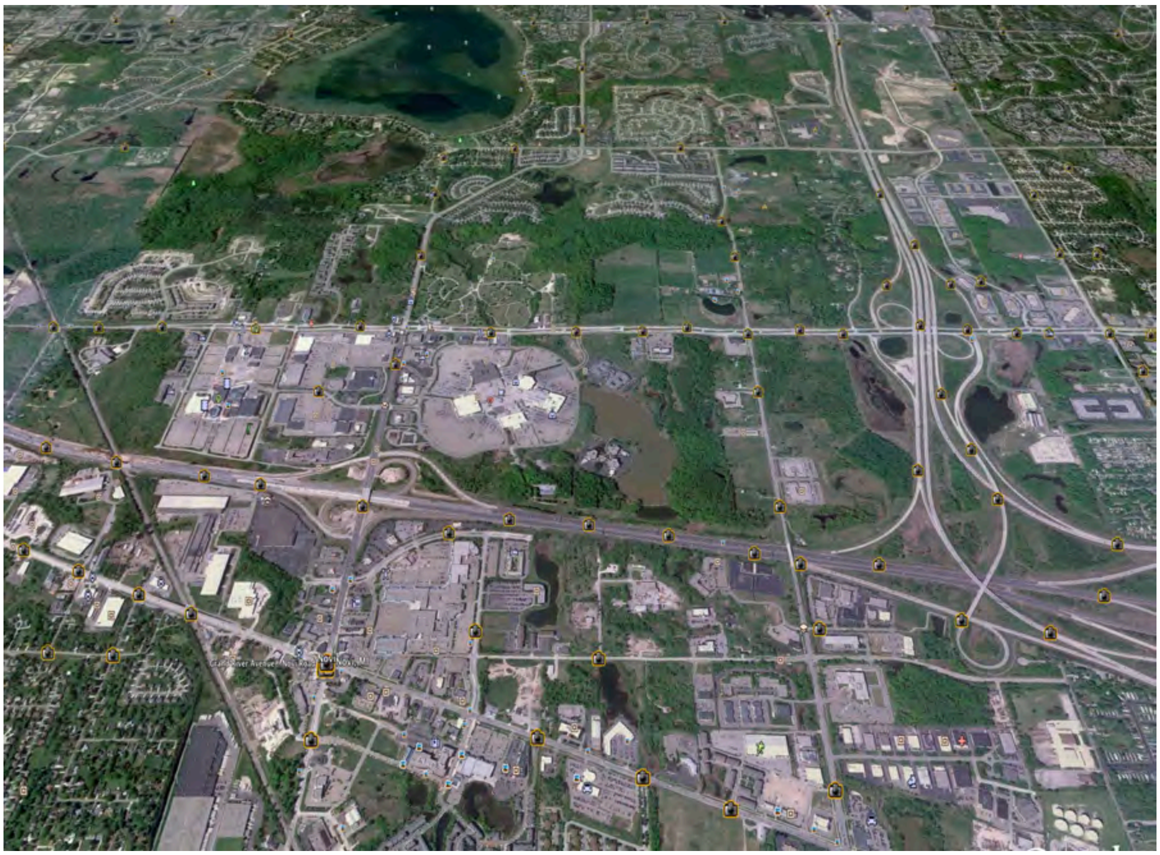
AIR QUALITY IN NOVI RESTAURANTS
Before and After
Michigan's *Dr. Ron Davis* State Smoke-free Law

September 7, 2011



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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 hospitality venues 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 were also 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 Novi. Reducing exposure to secondhand smoke is important because it is a known human carcinogen and has other serious health effects (SG, 2010; SG, 2006; CalEPA, 2005; IARC, 2002; NIEHS, 2000; USEPA, 1992).

One of the two pre-eminent atmospheric markers for secondhand smoke is $PM_{2.5}$, the other being nicotine. However, only $PM_{2.5}$ can be measured in real-time. $PM_{2.5}$ is a harmful combustion source air pollutant that is regulated in the outdoor air, and is widely monitored in all states, including Michigan, which maintains an extensive outdoor air quality monitoring network (MDEQ, 2011a). 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 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 US Environmental Protection Agency (USEPA) standards are 35 $\mu g/m^3$ averaged over 24 h, and the annual average is 15 $\mu g/m^3$ (USEPA, 2006). USEPA is currently considering the merits of reducing the annual standard level to 13 $\mu g/m^3$, and revising the 24-hour $PM_{2.5}$ standard level down to 30 $\mu g/m^3$ (USEPA, 2011). USEPA(2006) stated that "Scientific studies have found an association between exposure to particulate matter and significant health problems, including: aggravated asthma; chronic bronchitis; reduced lung function; irregular heartbeat; heart attack; and premature death in people with heart or lung disease." 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 (Surgeon General, 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 a variety of 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 Novi restaurant venues were monitored for $PM_{2.5}$ in February 2005 and 2006, prior to the enactment of Michigan's state smoke-free air law, and again in August, 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 Novi 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 (Jiang, et al., 2011). 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; 2011), 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.

3.0 Results. Table 1 shows the results of the pre-law monitoring, averaged over both smoking and nonsmoking sections, in 6 restaurant venues in Novi in 2005. Table 1 gives the statistics for fine particle air pollution ($PM_{2.5}$): maximum, minimum, and the measures of central tendency (mean with 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 which ranged from 34-62 minutes in the various venues. These durations 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 of the smoking area. 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 each of the 6 venues is calculated by multiplying the average active smoking count, n_s, by 3, and dividing by the average number of persons, ranges from 0% to 48% (Pritsos et al., 2008; Repace, 2007). For individual restaurants, pre-law means ranged from 27.2 to 457 $\mu g/m^3$, and averaged 178 $\mu g/m^3$, (median 144 $\mu g/m^3$).

Table 1. NOVI RESTAURANT $PM_{2.5}$ PRE-LAW November 4 & 5, 2005.

Statistic	Venue #1	Venue #2	Venue #3	Venue #4	Venue #5	Venue #6
Day	Friday 4th	Friday 4th	Friday 4th	Friday 4th	Saturday 5th	Saturday 5th
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	52.2	34.2	7.2	290	21.6	17.4
Maximum	131	60.3	601	540	689	40.5
Mean	79.6	45.3	252	457	209	27.2
Median	73.5	44.1	251	470	166	26.4
Std. Dev.	21.7	7.91	100	45.5	201	6.29
Duration, Minutes	39	36	62	36	34	37
D_S	1.40	1.22	2.17	0.31	0.47	0
V, m^3	191	246	184	535	285	53.5
n_s	2.67	3	4	1.67	1.33	0
P	48.7	18.7	66.3	38.3	39.3	3.33
Estimated Smoking Prevalence, %	16.4	48	18	13	10	0

D_s = smoker density (average active smokers per hundred cubic meters (m^3)); V= space volume, m^3; n_s = average number of active smokers; P = average number of persons.

Figure 1 shows a plot of the real-time SidePak $PM_{2.5}$ data versus time on a linear scale, over 46-62 minute periods for Venue # 3, and characterizes the nature of the real-time data recorded minute-by-minute for all venues pre-law and post-law. Figure 1 compares indoor air pollution levels when smoking was permitted (upper curve) with the $PM_{2.5}$ levels after the Law eliminated smoking (lower curve). The average $PM_{2.5}$ pre-law is 252 $\mu g/m^3$, compared to 12.0 $\mu g/m^3$ post-law (Table 2). For this restaurant, an estimated 99% of the pre-law $PM_{2.5}$ was due to secondhand smoke pollution.

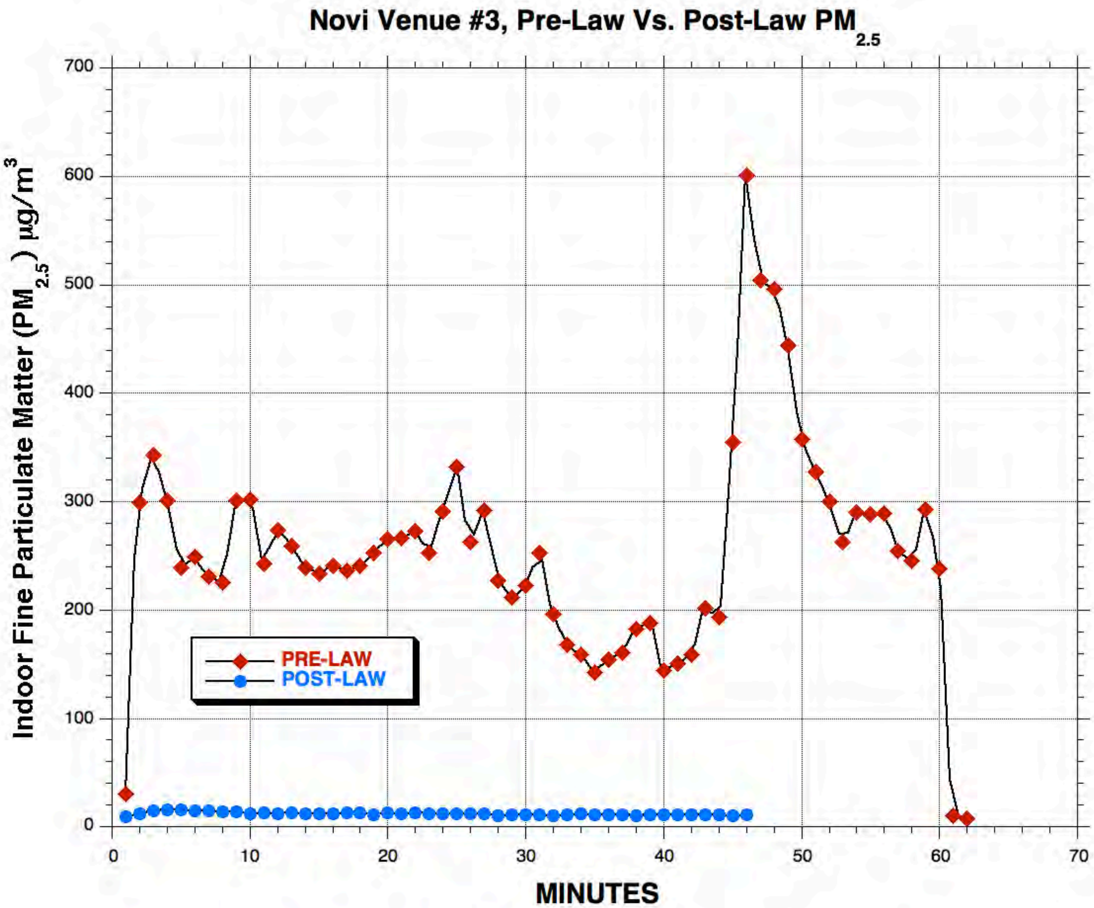

Figure 1. Real-time SidePak measurements in Venue # 3, Pre- and Post-Law. Michigan's state smoke-free air law reduced its indoor air pollution from $PM_{2.5}$ to ~5% of its pre-law value.

Table 2 shows the same parameters measured on Friday and Saturday nights in August 2011, 15 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 about 81% to 96%. Venue #4, which closed down in June 2011, is not included. Post-law restaurant means for all 6 venues ranged from from 5.1 to 12 μg/m^3, and averaged 8.8 μg/m^3 (median 8.4 μg/m^3). Sampling periods ranged from 33 to 62 minutes.

Figure 2 compares the mean pre-law smoking and post-law results for each venue. In every case, but Venue # 4, which was not measured post-law, the reductions in $PM_{2.5}$ are dramatic.

Table 2. NOVI RESTAURANT $PM_{2.5}$ POST LAW August 26th & 27th, 2011.

Statistic	Venue #1	Venue #2	Venue #3	Venue #4*	Venue #5	Venue #6
Day	Friday, 26th	Saturday, 27th	Friday, 26th	Friday, 15th	Friday, 26th	Saturday, 27th
Units	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Minimum	9	4.8	9.3		6.9	4.2
Maximum	12.3	12	15.9		10.2	6.9
Mean	10.5	8.38	12		8.03	5.11
Median	10.5	8.1	11.7		8.1	4.8
Std Dev.	0.804	1.7	1.45		0.692	0.87
D_S	0	0	0		0	0
P	29.5	203	64		70	17
Duration, Minutes	48	62	46		36	33
% Decrease in $PM_{2.5}$	86.8	81.5	95.2		96.2	81.2

*Out Of Business, June 2011.

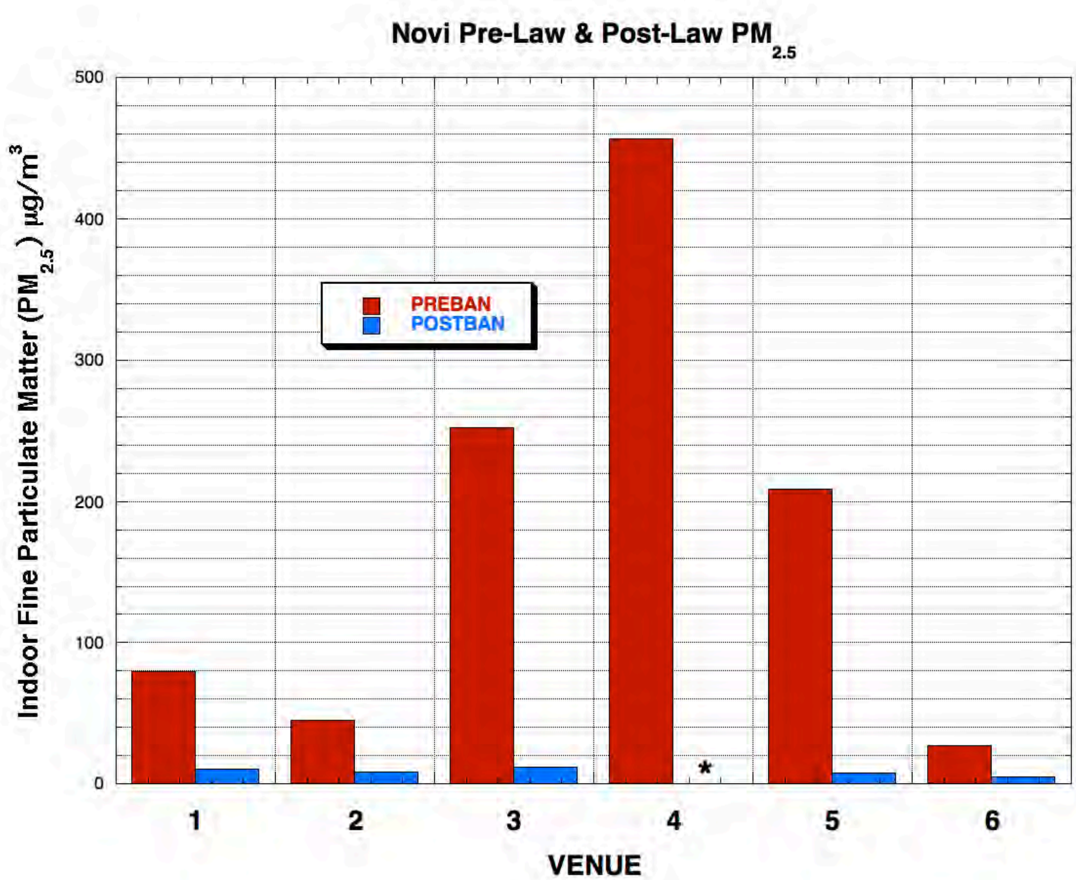

Figure 2. Mean air pollution levels in 6 restaurant venues, pre-law and 5 post-Smokefree Air Law; Venue # 4 closed down in June 2011 and could not be measured post-law.

4.0. Discussion. The combined percent reduction in median $PM_{2.5}$ for the 5 Novi restaurant venues for which both pre- and post-ban measurements were made, was 89% (means declined by an average of 93%), indicating that the vast majority of indoor air pollution in these venues was due to secondhand smoke, as shown in Figure 3. 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%. 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. Similarly, Travers et al. (2004) measured $PM_{2.5}$ in 24 hospitality venues, 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 $\mu g/m^3$ to 25 $\mu g/m^3$; $p<0.001$). 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. Thus, the Novi results are consistent with the Wilmington, Boston, and Western New York pre- and post-law studies.

The reported estimated adult smoking prevalence for Michigan in 2009 was 19.6% compared to 17.9% for the US (CDC-BRFSS, 2009). The total number of persons present pre-law for all 6 venues was $P_{tot} = 211.3$, and the total active number of cigarettes was $Ns_{tot} = 12.67$. The total number of smokers present in these 6 venues, averaged over the sampling time, is estimated as $3Ns_{tot} = 38$, for an estimated overall smoking prevalence for the patrons of these 6 venues of (38/211.3)(100%) = 18%, comparable to the Michigan adult smoking prevalence in 2009.

The SidePak

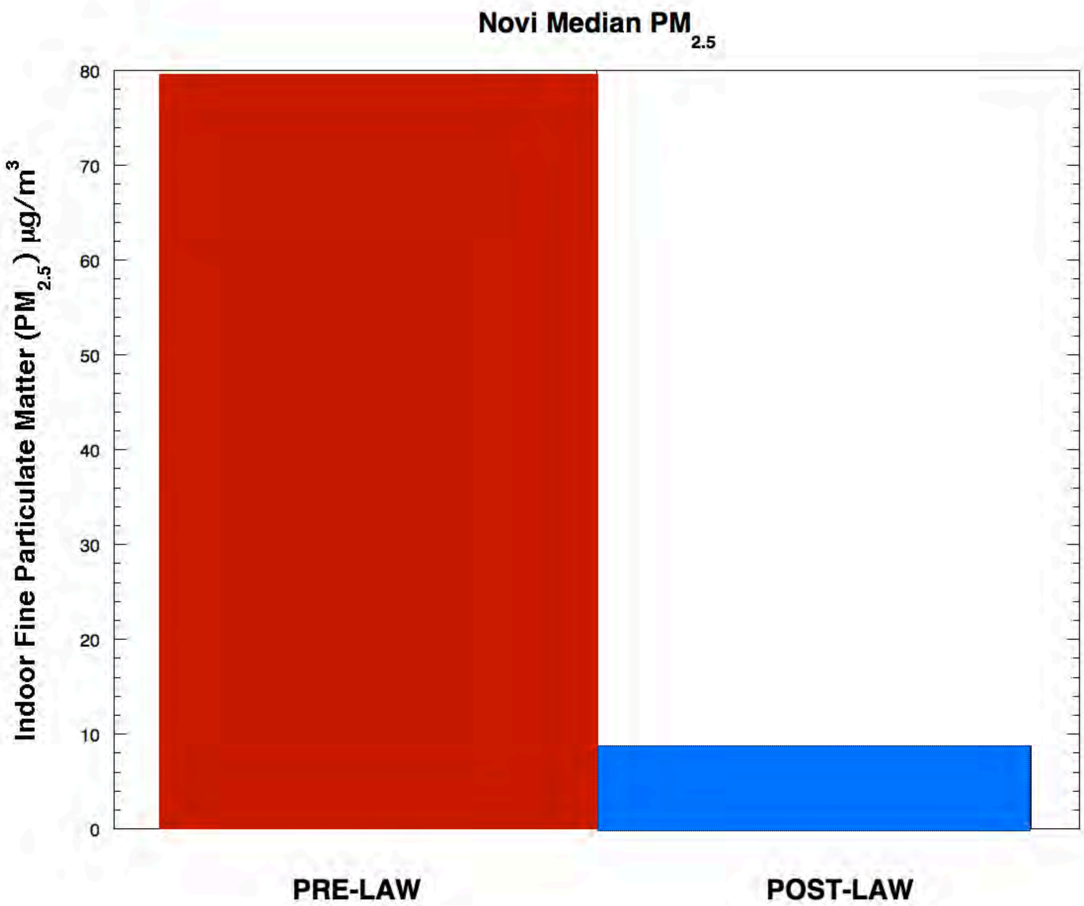

Figure 3. Combined median $PM_{2.5}$ level for 5 Novi restaurants drops an average of 89% due to Michigan's Dr. Ron Davis Indoor Air Law.

6.0. Health Implications. Many jurisdictions around the US have acted to reduce public secondhand smoke exposure in the hospitality industry. 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 2003 comprehensive non-smoking ordinance, which extended its 1994 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). Unsurprisingly, secondhand smoke particulate matter measured in numerous hospitality venues, including bars, restaurants, and casinos, has been found to contain 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 shows the frequency distributions for the 6 restaurant venues with smoking (pre-law) and the 5 venues measured without smoking (post-law). Five of the six restaurants had very polluted indoor air pre-law, ranging from Unhealthy for Sensitive Groups to Hazardous (Geometric mean, Unhealthy, 115 $\mu g/m^3$). The 6^{th} restaurant which had no observed smoking, had Moderate air quality. On this type of plot (log-probability), the best measure of central tendency of the curve-fit to the data is the geometric mean. The Five measured venues had good air quality post-law, Geometric mean, Good, 8.8 $\mu g/m^3$. The pre-law geometric mean (not shown) for the same 5 venues measured post-law was 57 $\mu g/m^3$. Thus for the same 5 venues, geometric mean $PM_{2.5}$ air pollution decreased by 85%.

By comparison, the geometric mean for all 41 air-quality monitoring sites in the State of Michigan in 2008 was 10.52 $\mu g/m^3$ and the 3-year Geometric Mean for 2007-2010 was 13.25 $\mu g/m^3$ (Appendix C, Figures C-1, C-2). 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 massively failed to control $PM_{2.5}$ air pollution, while the state clean indoor air law easily attained this goal.

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 range in air quality that might be expected for the remainder of unsampled Novi restaurants before and after the protection of the Dr. Ron Davis Law. For example, to find the estimated 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, 7%. If the venues selected were to be considered as representative of the distribution to be found for all Novi restaurants pre-law, this suggests that 100% - 7% = 93% of the venues would be at or above 25 $\mu g/m^3$. Similarly, about 25% of the venues would be below 35 $\mu g/m^3$, so 75% 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 Novi 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, and as such, suggests that $PM_{2.5}$ in the outdoor air and $PM_{2.5}$ from secondhand smoke appear to have similar toxicity Pope et al. (2009). However, secondhand smoke contains numerous toxic substances, many of them not normally present in outdoor air, and some tobacco-specific. 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).

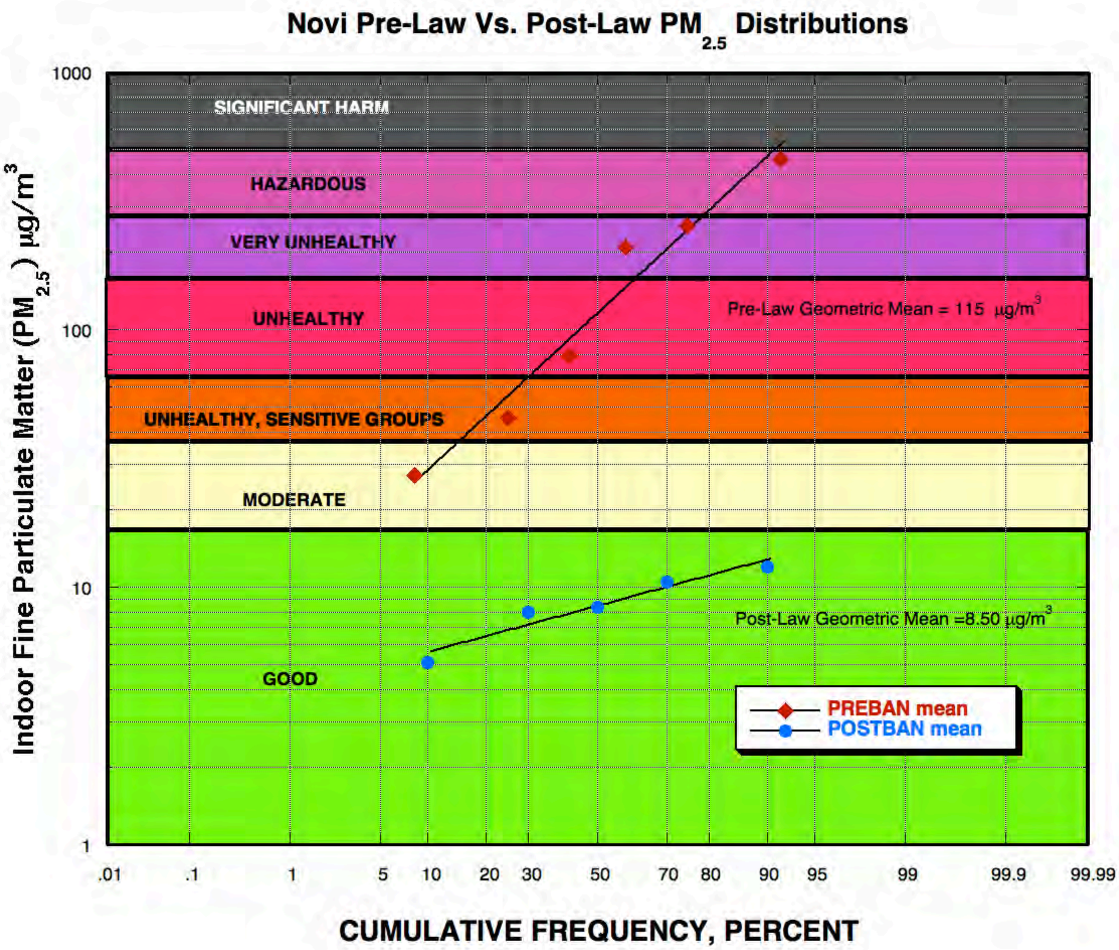

Figure 4. $PM_{2.5}$ frequency distributions for a sampling of Novi restaurants vs. the MI AQI. Pre-law, all 6 venues have Moderate to Hazardous air quality. Post-law, 5 of 6 venues have very good air quality; the remaining one went out of business and was not measured.

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

6. Conclusions.

1. Six Novi 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 ($PM_{2.5}$). Five of these were able to be measured post-law.

2. The Dr. Ron Davis Law succeeded in reducing geometric mean levels of harmful secondhand smoke fine particle air pollution ($PM_{2.5}$) for the five-restaurant sample of Novi Hospitality establishments by 85%.
3. Five of the six restaurants studied had Unhealthy (Sensitive Groups) to Hazardous air quality on average prior to the smoke-free law's enactment, caused by secondhand smoke pollution. The 6th restaurant, which had Moderate air quality, had no observed smoking.
4. The Five restaurants measured post-law had very good $PM_{2.5}$ air quality subsequent to the smoke-free law's enactment, with the remaining one not measured.
5. For Novi, Michigan's Dr. Ron Davis Clean Indoor Air Law, by eliminating secondhand smoke, was highly effective in reducing $PM_{2.5}$ air pollution from secondhand smoke to the low levels found outdoors.

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

<u>Title</u>
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.

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APPENDIX C. MICHIGAN AIR QUALITY INDEX (MDEQ, 2011b), pp 34-35.

AIR QUALITY INDEX:

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) µg/m^3	PM_{10} (24 hr) µg/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.

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.

Health Advisories associated with regulated outdoor air pollutants in Michigan (MDEQ, 2011b). 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.

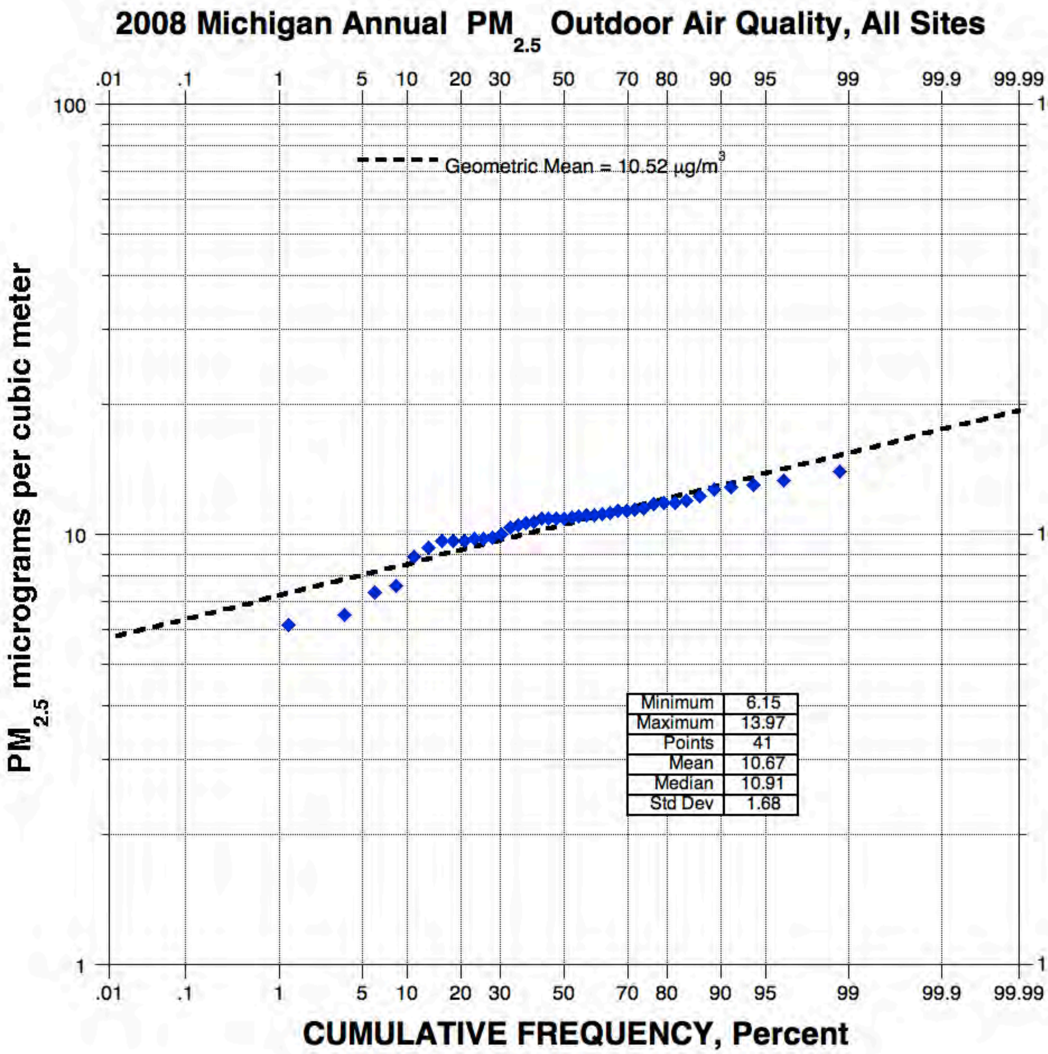

Figure C-1. A log-probability plot of outdoor $PM_{2.5}$ for all 41 sites in the State of Michigan in 2008 (MDEQ, 2011a).

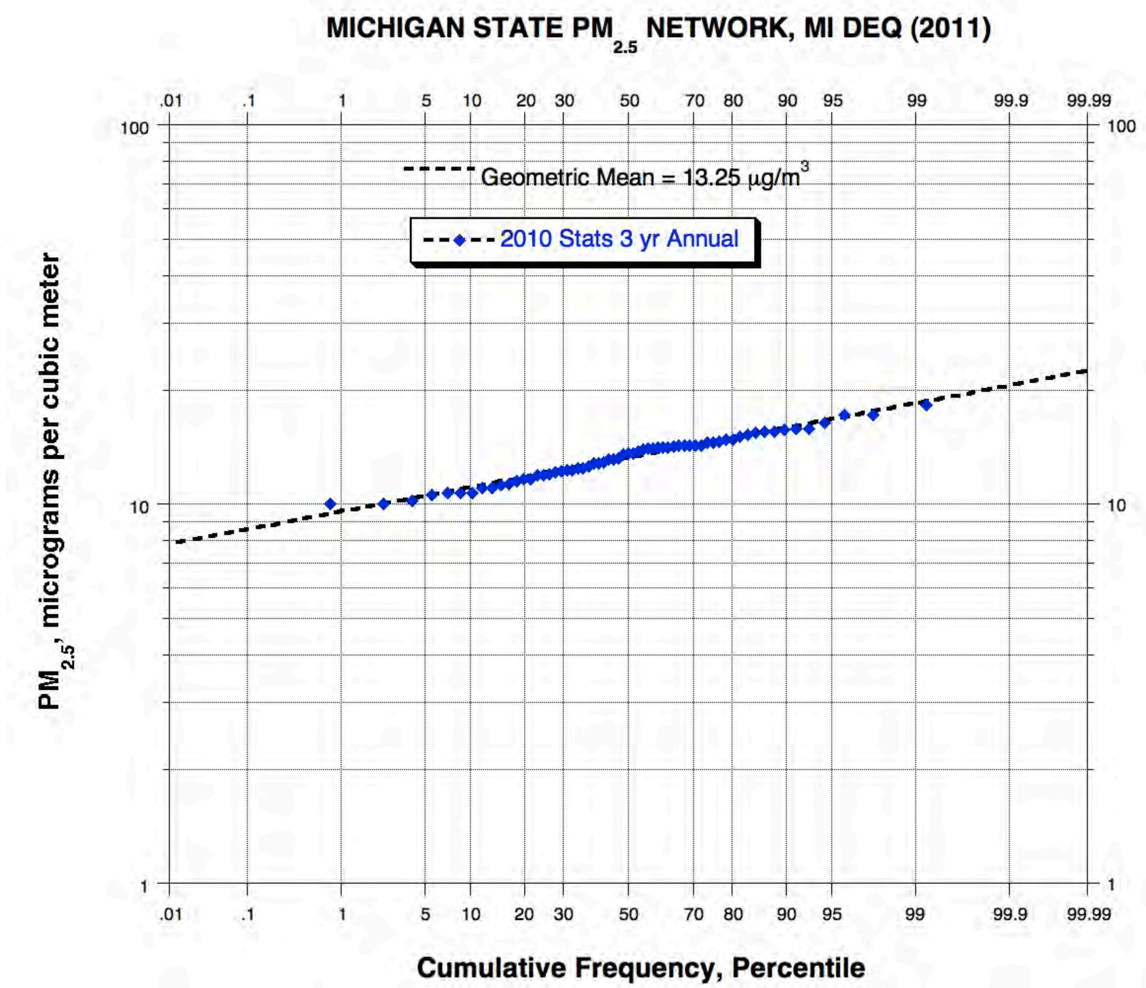

Figure C-2. A log-probability plot of 3-year average outdoor $PM_{2.5}$ for 63 sites in the State of Michigan, 2007-2010 (MDEQ, 2011a).

Statistic	**$\mu g/m^3$**
Minimum	10
Maximum	18.2
Points = 63	
Data Mean	13.37
Data Median	13.60
Model Geometic Mean (curve-fit)	13.25