

AIR QUALITY IN MARQUETTE 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 Marquette.

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 µg/m³, and its annual standard is 10 µg/m³, while the less stringent USEPA standards are 35 µg/m³ averaged over 24 h, and the annual average is 15 µg/m³ (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 µg/m³ 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 enacted, 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 Marquette restaurant venues were monitored for PM_{2.5} on August 1-2, 2008, prior to the enactment of Michigan's state smoke-free air law, and again on February 25-26, 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 Marquette 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 (µg/m³) 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 Marquette in 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 (µg/m³). The number of active smokers (burning cigarettes), n_s , counted during the duration of the sampling intervals, that ranged from 31-61 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. 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 (m³), 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 9.9% to 53% (Pritsos et al., 2008; Repace, 2007). For individual restaurants, pre-law means ranged from 50.9 to 250 $\mu\text{g}/\text{m}^3$, and averaged 160 $\mu\text{g}/\text{m}^3$, (median 183 $\mu\text{g}/\text{m}^3$).

Table 1. MARQUETTE RESTAURANT PM_{2.5} PRE-LAW August 1-2, 2008.

Statistic	Venue #1	Venue #2	Venue #3	Venue #4	Venue #5	Venue #6
Day	Friday	Friday	Friday	Friday	Saturday	Saturday
Units	$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$
Minimum	87.9	92.7	110	51.3	4.8	12.6
Maximum	893	484	711	425	169	176
Mean	250	217	194	172	77	50.9
Median	220	164	165	164	72	36.9
Std. Dev.	140	113	110	66.3	38.1	38.3
Duration, Minutes	41	55	34	40	50	37
D _s	7.3	3.97	2.10	1.52	0.20	1.05
V, m ³	105	151	254	263	334	190
n _s	7.67	6	5.33	4	0.67	2
P	43.33	40.33	40.67	36	20.33	13.33
Estimated Smoking Prevalence	53%	45%	39%	33%	9.9%	45%

D_s = smoker density (average active smokers per hundred cubic meters); V= space volume, m³; n_s = average number of active smokers; P = average number of persons.

Figure 1 illustrates the real-time data recorded for all venues, and shows a plot of the real-time PM_{2.5} data versus time on a linear scale, over a 29-41 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 250 $\mu\text{g}/\text{m}^3$, compared to 14.8 $\mu\text{g}/\text{m}^3$ post-law (Table 2). For this restaurant, an estimated 94% of the pre-law PM_{2.5} was due to secondhand smoke pollution. In other words, for venue #1, the effect of Michigan's state smoke-free air law was to reduce its indoor air pollution from PM_{2.5} to 6% of its pre-law value.

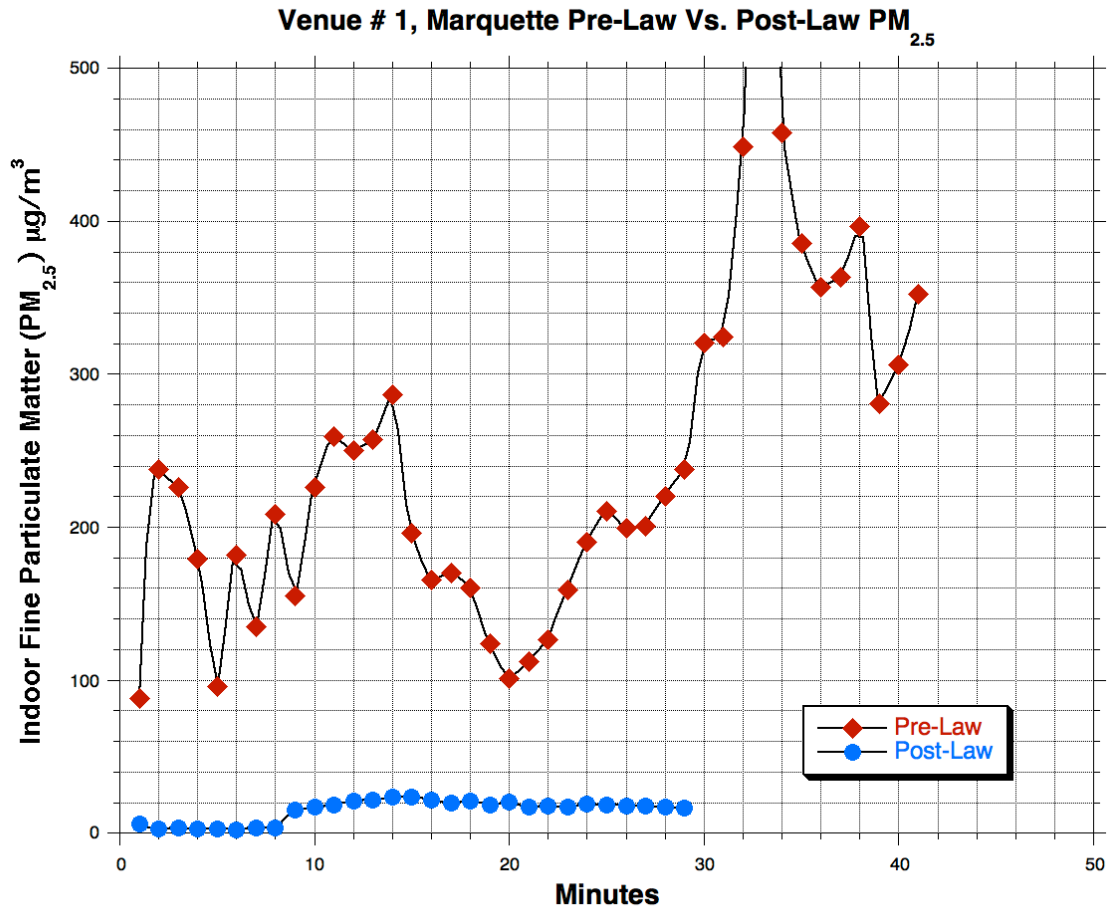


Figure 1. Real-time SidePak measurements in Venue # 1, Pre- and Post-Law

Table 2 shows the same parameters measured on Friday and Sunday nights in March 2011, 8 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 82% to 99%. Post-law restaurant means for all 6 venues ranged from from 2.92 to 14.8 µg/m³, and averaged 6.80 µg/m³ (median 5.59 µg/m³).

Figure 2 compares the mean pre-law smoking and post-law results for each venue. In every case, the reductions in PM_{2.5} are dramatic.

Table 2. MARQUETTE RESTAURANT PM_{2.5} POST LAW February 25-26, 2011.

Statistic	Venue #1	Venue #2	Venue #3	Venue #4	Venue #5	Venue #6
Day	Saturday	Saturday	Friday	Saturday	Friday	Friday
Units	µg/m ³	µg/m ³	µg/m ³	µg/m ³	µg/m ³	µg/m ³
Minimum	2.4	1.2	2.1	1.5	2.1	2.1
Maximum	23.7	31.2	6	6.3	5.4	15.3
Mean	14.8	7.63	2.92	2.6	3.54	9.32
Median	17.1	7.5	2.7	2.4	3.3	8.55
Std Dev.	7.16	6.03	0.735	0.845	0.935	2.82
D _s	0	0	0	0	0	0
P	25.33	14	25.67	53.8	72	113.25
Duration, Minutes	31	46	31	61	32	40
% Reduction in PM _{2.5}	94.1	96.5	98.5	98.5	95.4	81.7

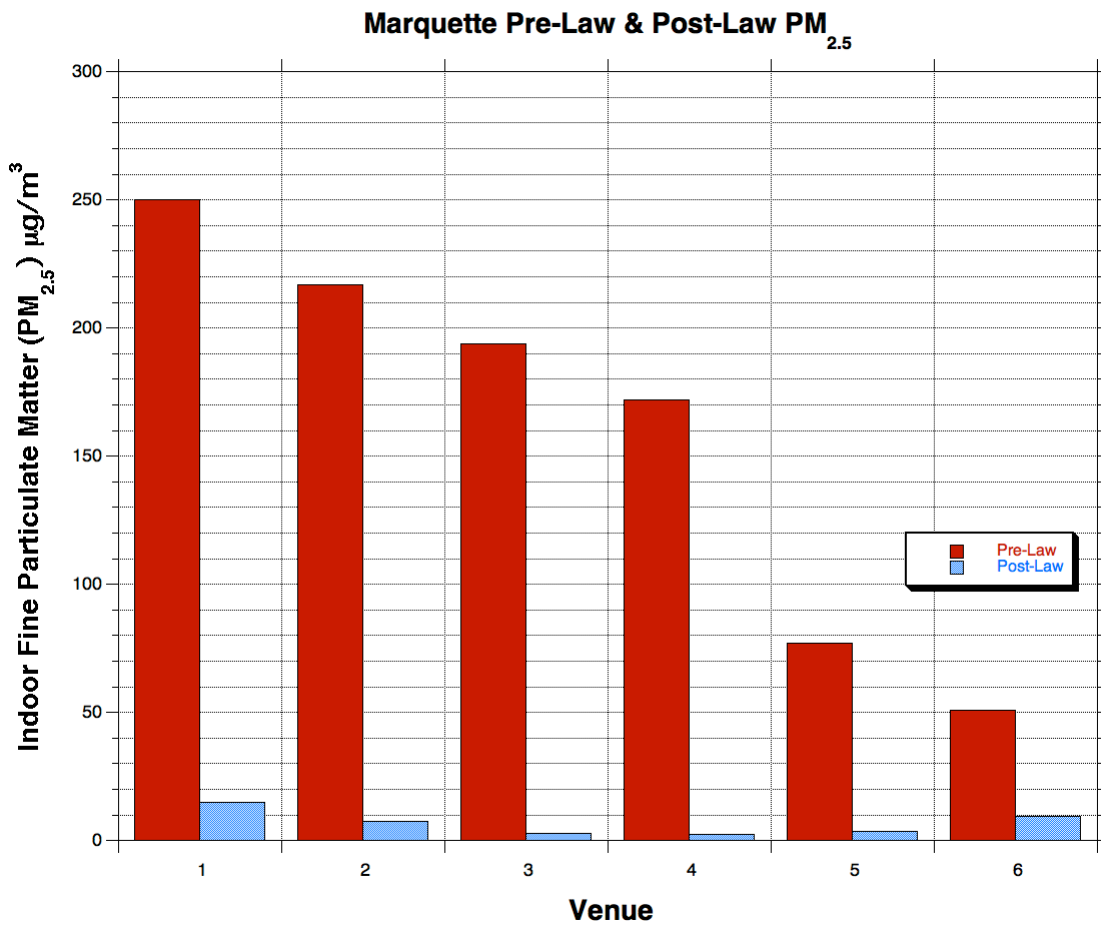


Figure 2. Mean air pollution levels in 6 hospitality venues, pre-and-post Smoke-free Air Law.

4. Discussion. The percent reduction in median $PM_{2.5}$ for all 6 Marquette venues combined was 96%, 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 $PM_{2.5}$ 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% ($324 \mu\text{g}/\text{m}^3$ to $25 \mu\text{g}/\text{m}^3$; $p < 0.001$). 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.

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 in the 6 venues was $P_{\text{tot}} = 194$, and the total active number of cigarettes was $N_{\text{stot}} = 25.67$. The total number of smokers present in these 6 venues, averaged over the sampling time, is estimated as $3N_{\text{stot}} = 77$, for an estimated overall smoking prevalence for the patrons of these 6 venues of $(77/194)(100\%) = 39.7\%$, double ($39.7\%/19.6\% = 2$) the Michigan adult smoking prevalence in 2009. Figure 3 illustrates the 96% decline in the median $PM_{2.5}$ levels for the 6 restaurants (means declined by an average of 94%). Thus, the Marquette results are consistent with the Wilmington, Boston, and Western New York studies.



The SidePak

6 Marquette Venues: Pre-Law Vs. Post-Law Median

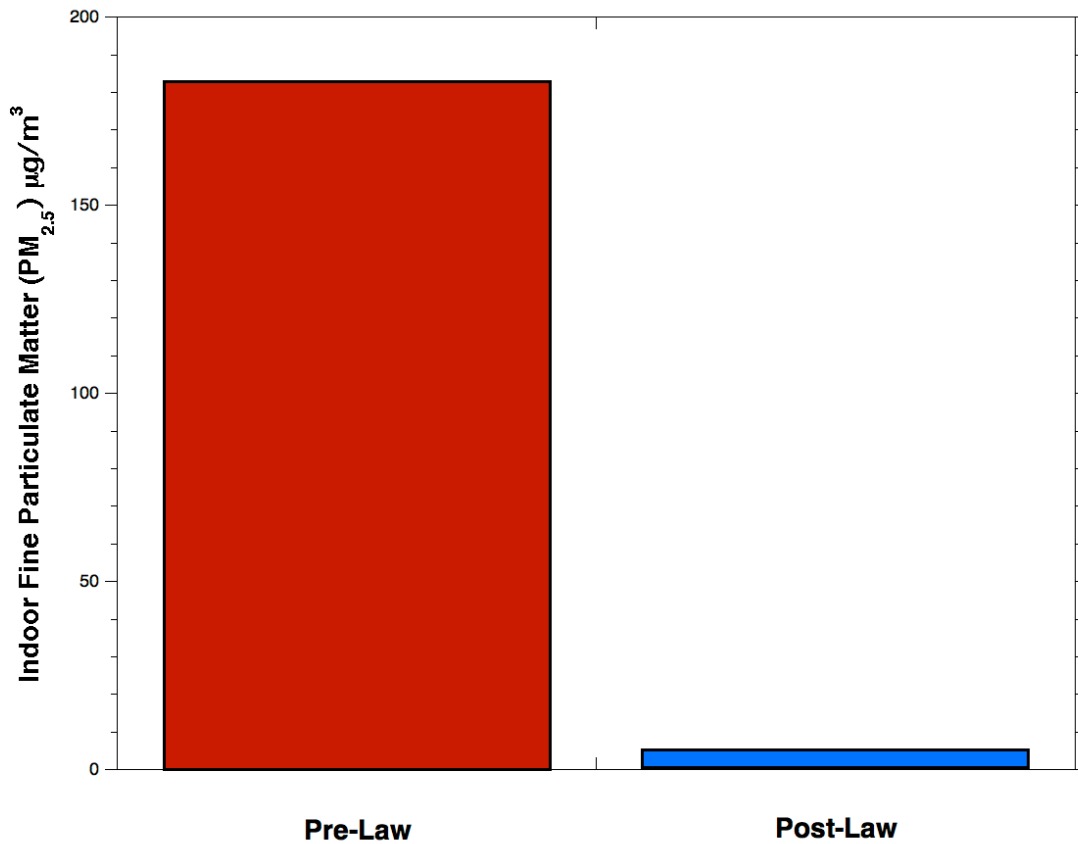


Figure 3. Combined median PM_{2.5} level for 6 Marquette restaurants drops an average of 96% due to Michigan’s Dr. Ron Davis Indoor Air Law.

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 shows the frequency distributions in the 6 venues with smoking (pre-law) and the same 6 venues without smoking (post-law). All six restaurants had polluted indoor air pre-law, ranging from Unhealthy for Sensitive Groups to Very Unhealthy (Geometric mean, Unhealthy, 139 µg/m³). All 6 venues had good air quality post-law (Geometric mean, Good, 5.52 µg/m³).

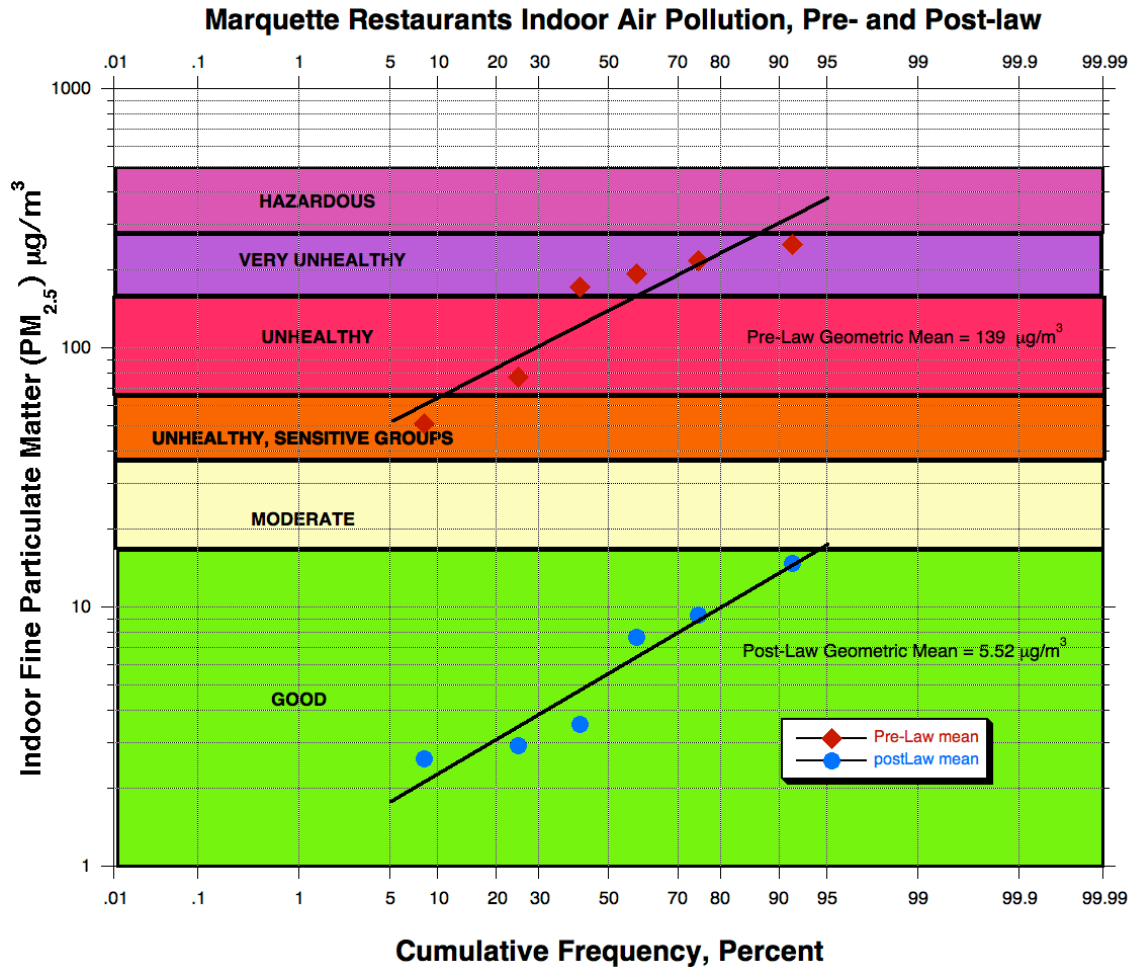


Figure 4. PM_{2.5} frequency distributions for 6 restaurants vs. the MI AQI. Pre-law, all 6 venues have bad air quality air quality. Post-law, all 6 venues have good air quality.

By comparison, the geometric mean for all 41 air-quality monitoring sites in the State of Michigan in 2008 was $10.52 \mu\text{g}/\text{m}^3$ and the 2007-2010 3-year Geometric Mean was $13.25 \mu\text{g}/\text{m}^3$ (Appendix C, Figures C-1, C-2). Thus the post-law $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$ 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 Marquette 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 $25 \mu\text{g}/\text{m}^3$ 24-h guideline, we find "25" on the vertical axis in $\mu\text{g}/\text{m}^3$, and then we read corresponding horizontal axis value, 20%. If the venues selected were to be considered as representative of the distribution to be found for all Marquette restaurants pre-law, this suggests that $100\% - 20\% = 80\%$ of the venues were at or above $25 \mu\text{g}/\text{m}^3$. Similarly, about 38% of the venues would be below $35 \mu\text{g}/\text{m}^3$, so 62% would be at or above $35 \mu\text{g}/\text{m}^3$, the numerical value of EPA's 24-h standard. In this way, the estimated frequency distribution of Marquette 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 $\text{PM}_{2.5}$ as a criteria air pollutant, while secondhand smoke contains numerous 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 $\text{PM}_{2.5}$ in the outdoor air and $\text{PM}_{2.5}$ 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 Marquette 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 ($\text{PM}_{2.5}$).
2. The Dr. Ron Davis Law succeeded in reducing geometric mean levels of harmful secondhand smoke fine particle air pollution ($\text{PM}_{2.5}$) for a six-restaurant sample of Marquette Hospitality establishments by 96%.
3. All six restaurants studied had bad air quality on average prior to the smoke-free law's enactment, caused by secondhand smoke pollution.

4. All six restaurants had good PM_{2.5} air quality subsequent to the smoke-free law's enactment.
5. For Marquette, Michigan's Dr. Ron Davis Clean Indoor Air Law, by eliminating secondhand smoke, was highly effective in reducing 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/>>.

17 Selected Publications:

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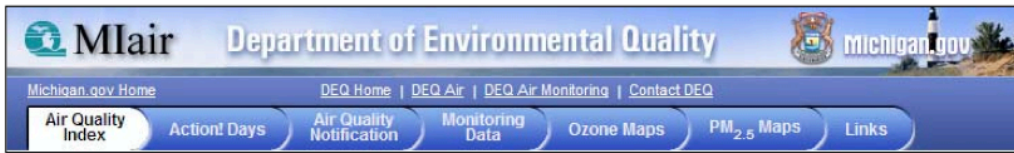
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AIR QUALITY INDEX:

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 O₃ 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 ($\mu\text{g}/\text{m}^3$) 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 prolonged 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. Everyone 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.

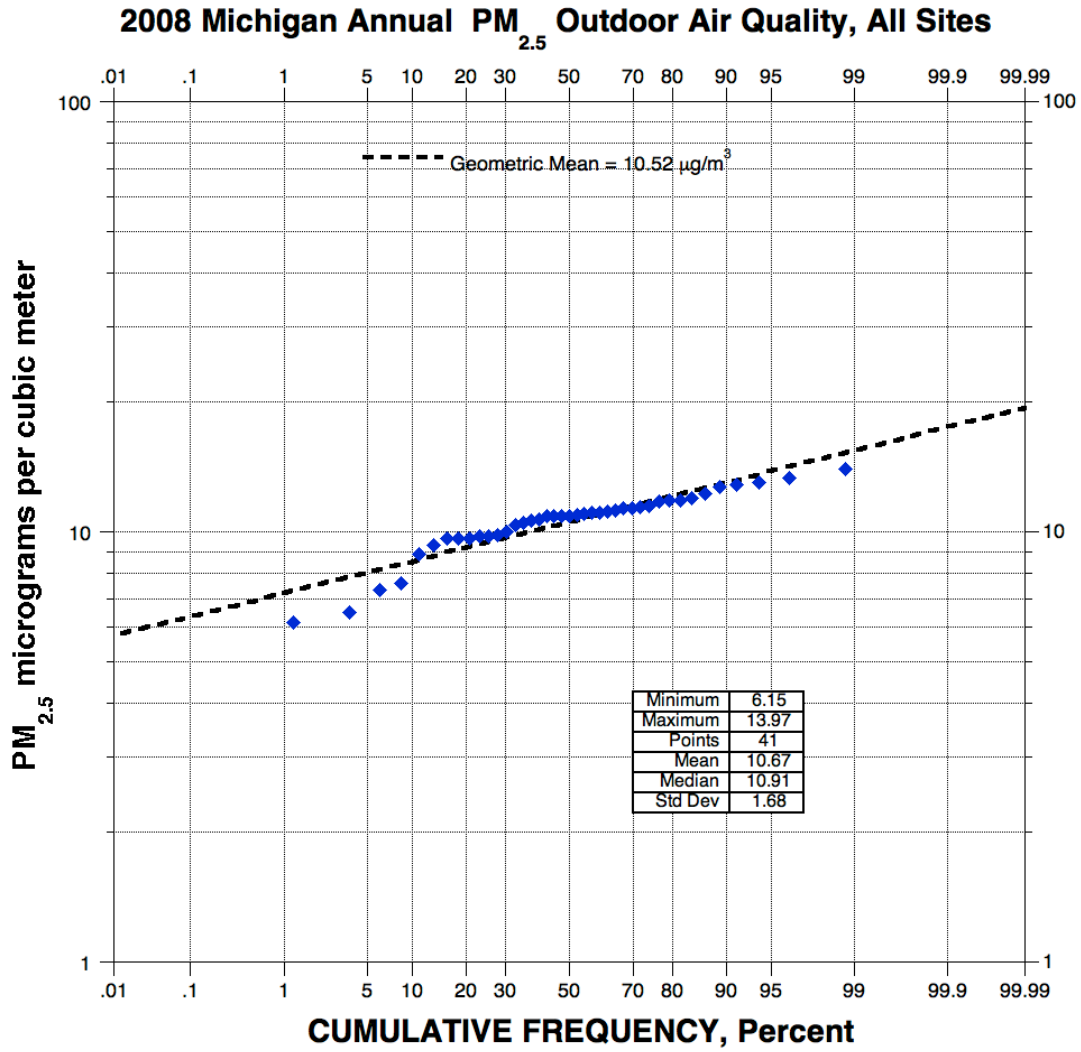


Figure C-1. A log-probability plot of outdoor PM_{2.5} for all 41 sites in the State of Michigan in 2008 (MDEQ, 2011a).

MICHIGAN STATE PM_{2.5} NETWORK, MI DEQ (2011)

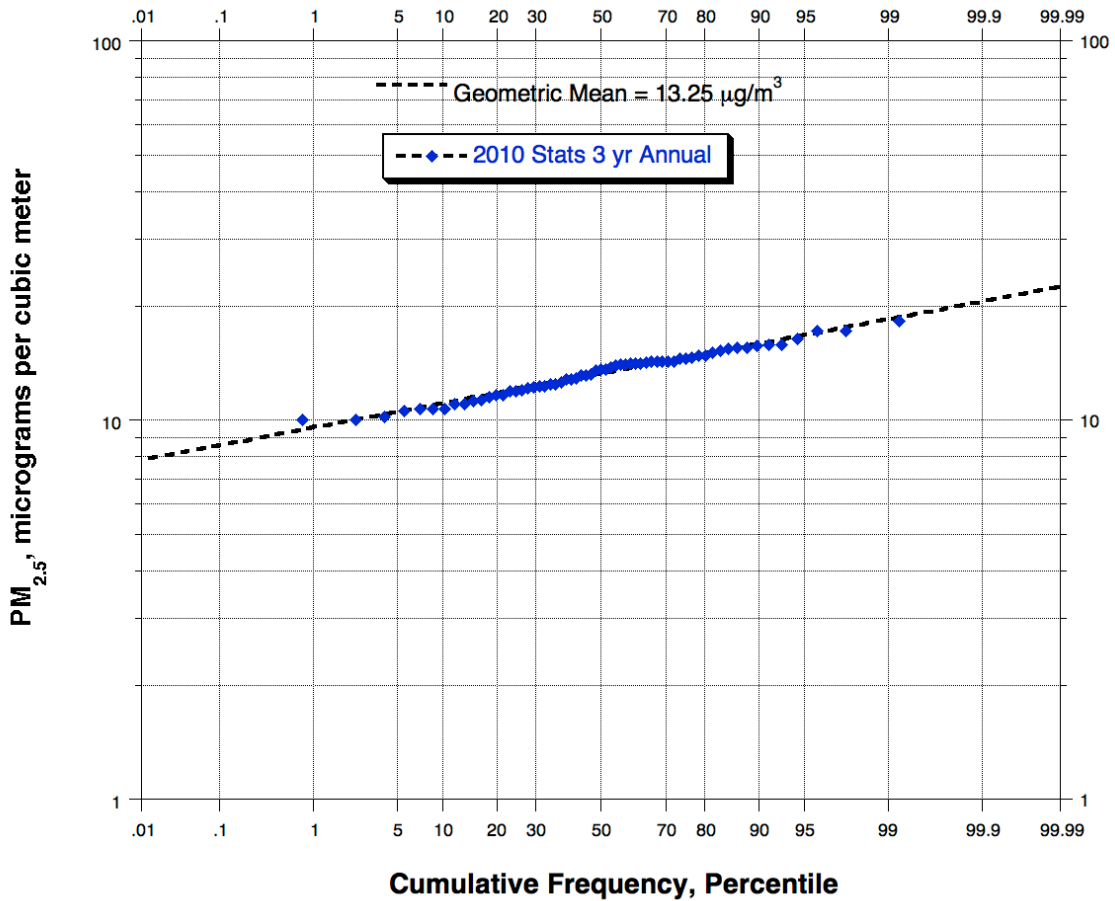


Figure C-2. A log-probability plot of 3-year average outdoor PM_{2.5} for 63 sites in the State of Michigan, 2007-2010 (MDEQ, 2011a).

Statistic	µg/m ³
Minimum	10
Maximum	18.2
Points = 63	
Data Mean	13.37
Data Median	13.60
Model Geometric Mean (curve-fit)	13.25