AIR QUALITY IN DETROIT CASINOS
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 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 Detroit casinos. Reducing exposure to secondhand smoke is important because it is a known human carcinogen and has other serious health effects (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 (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 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). Three Detroit casinos were monitored for $PM_{2.5}$ in April 2009, prior to the enactment of Michigan's state smoke-free air law, and again in May 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 Detroit casinos before and after their exemption from Michigan's smoke-free air law? (2) Does secondhand smoke create an air quality hazard for casino workers and patrons?

In order to address the research questions, real-time fine particle monitor were deployed by 2 teams of field investigators who visited the same 3 Detroit casinos, 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.

For the 2011 survey, the monitor 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 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. In the 2009 study (Travers, 2009), the 3 casinos were visited sequentially on Saturday, April 18, for an average of 40 minutes each, beginning at 4:30 PM; continuous measurements were taken both outside and inside the casinos. In the second set of measurements, taken Post-Law, the same 3 casinos were visited sequentially, on Saturday, May 14, 2011, beginning at 1:30 PM.

3.0. Results. Table 1 gives the Pre-Law April 2009 data and Post-Law May 2011 results for 3 Detroit Casinos. The smoker density, space volume, average number of active smokers and average number of persons were not recorded. Sampling times ranged from 31 to 39 minutes. The median for all 3 casinos Pre-Law is 92.1 $\mu g/m^3$; Post-Law it is 82.9 $\mu g/m^3$; the means are 94.9 $\mu g/m^3$ Pre-Law and 85.7 $\mu g/m^3$ post-law.

Table 1. DETROIT CASINOS $PM_{2.5}$ PRE-LAW April 18, 2009 & POST-LAW May 14, 2011.

Statistic	Casino #A	Casino #B	Casino #C	Casino #A	Casino #B	Casino #C
Day	Saturday 18th	Saturday 18th	Saturday 18th	Saturday 14th	Saturday 14th	Saturday 14th
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	6.6	21.6	59.7	48.3	23.1	21.3
Maximum	173	139	193	152	138	281
Mean	70.7	92.1	122	82.9	81.4	92.8
Median	68.1	96.6	118	80.7	85.2	91.2
Std. Dev.	35.5	28.7	30.1	23.1	20.6	49.9
Duration, Minutes	31	34	37	39	39	38

Figure 1 shows a plot of the real-time SidePak $PM_{2.5}$ data versus time on a linear scale, over a 37-minute period for Casino C in 2011, 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 in 2011 during smoking (upper curve) with the average $PM_{2.5}$ levels outdoors during the period 2007 to 2010. The average $PM_{2.5}$ is 92.8 $\mu g/m^3$, compared to the 2007-2010 geometric mean of 13.3 $\mu g/m^3$. Casino C in 2009 measured a mean of 122 $\mu g/m^3$.

The SidePak

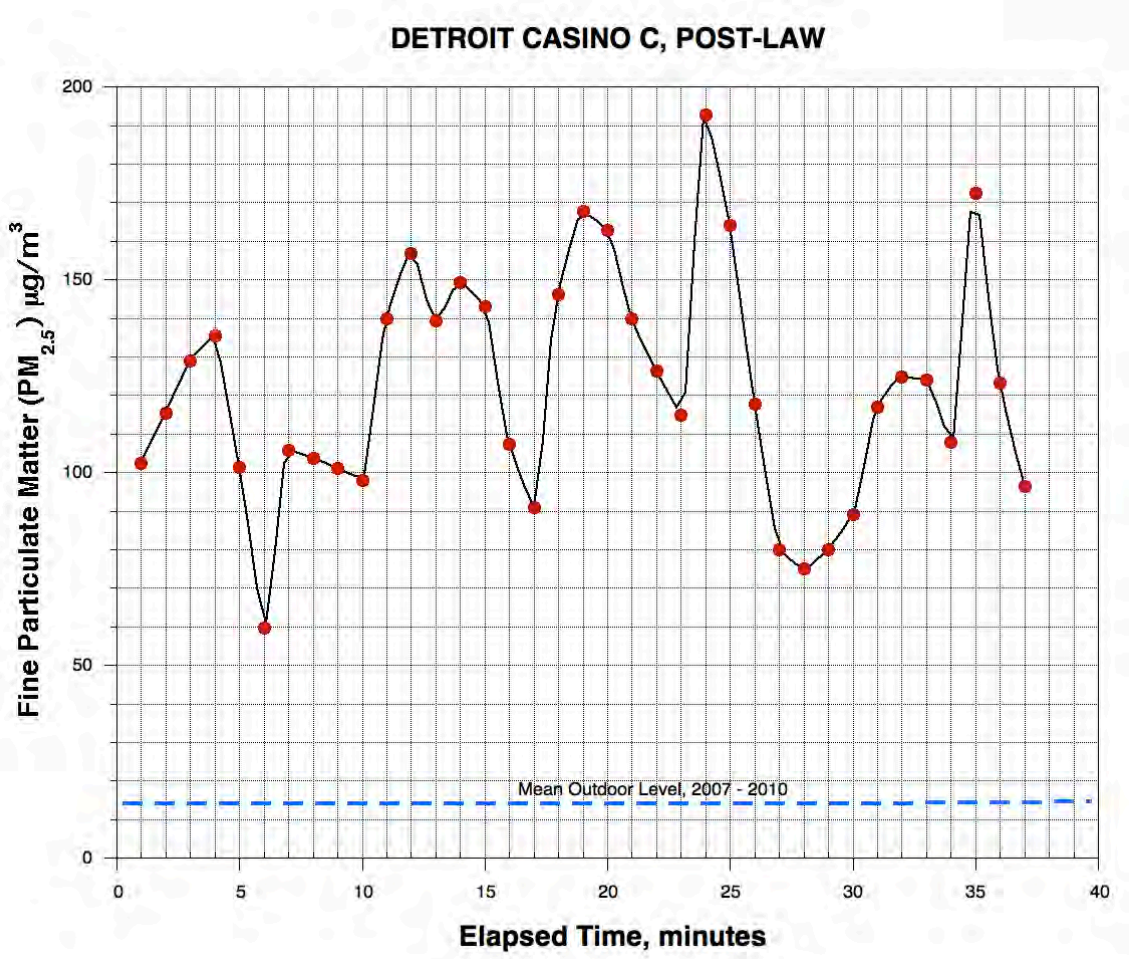

Figure 1. Real-time SidePak measurements in Casino C Post-Law, versus Mean Outdoor level, illustrating the nature of real-time data. The mean indoor level is 9 times outdoors.

Figure 2 compares the mean pre-law smoking and post-law results for each Detroit casino and to the 3 smoke-free casinos in California, Delaware, and Nevada (Repace et al., 2011). The Detroit casinos, exempt from the Dr. Ron Davis smoke-free law, had high levels pre-law, and post-law they remained high. By marked contrast, the 3 smoke-free casinos studied had very low levels of $PM_{2.5}$ pollution.

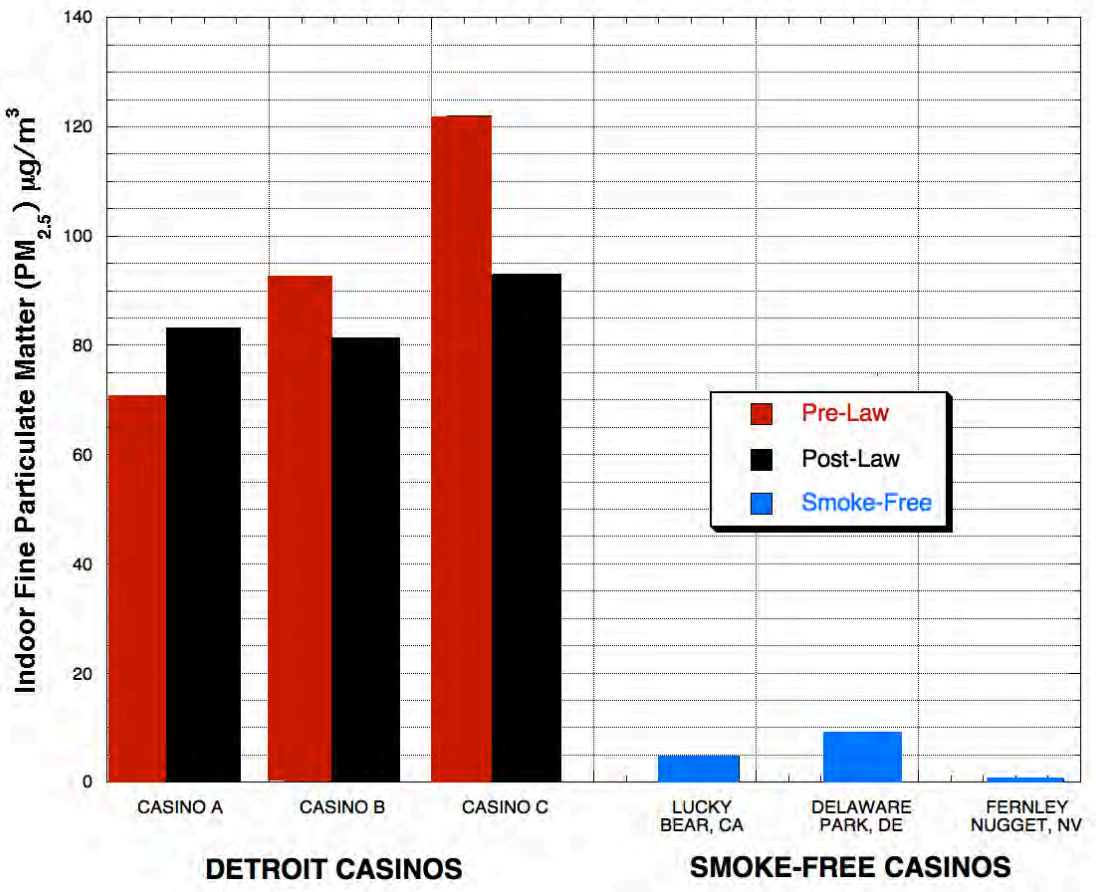

Figure 2. Mean air pollution levels in 3 smoky Detroit venues exempted from Michigan's Dr. Ron Davis Smoke-free Air Law, versus 3 smoke-free casinos in California, Delaware, and Nevada.

4.0. Discussion.

Smoking bans often exempt casinos, exposing occupants to fine particles ($PM_{2.5}$) from secondhand smoke. Repace et al. (2011a) quantified the relative contributions to $PM_{2.5}$ from both secondhand smoke and infiltrating outdoor sources. They measured real-time $PM_{2.5}$, particulate polycyclic aromatic hydrocarbons (PPAH), and carbon dioxide (CO_2) (as an index of ventilation rate) inside and outside of 8 casinos in Reno, Nevada. They combined these data with that from previous published studies, yielding a total of 66 US casinos with smoking in California, Delaware, Nevada, New Jersey, and Pennsylvania, developing $PM_{2.5}$ frequency distributions, with 3 nonsmoking casinos for comparison. Geometric means for $PM_{2.5}$ were 53.8 µg/m^3 inside smoking casinos, 4.3 µg/m^3 outside those casinos, and 3.1 µg/m^3 inside 3 nonsmoking casinos. In a subset of 21 Reno and Las Vegas smoking casinos, $PM_{2.5}$ in gaming areas averaged 45.2 µg/m^3; adjacent nonsmoking casino restaurants averaged 27.2 µg/m^3, while $PM_{2.5}$ outside the casinos averaged 3.9 µg/m^3. For a subset of 10 Nevada and Pennsylvania smoking casinos, incremental (indoor–outdoor) $PM_{2.5}$ was correlated with incremental PPAH (R^2 = 0.79), with ventilation rate-adjusted smoker density (R^2 = 0.73), and with smoker density (R^2 = 0.60), but not with ventilation rates (R^2 = 0.15). PPAH levels in 8 smoking casinos in 3 states averaged 4 times outdoors. The nonsmoking casinos' $PM_{2.5}$ (n = 3) did not differ from outdoor levels, nor did their PPAH (n = 2). Incremental $PM_{2.5}$ from

secondhand smoke in approximately half the smoking casinos exceeded a level known to produce cardiovascular morbidity in nonsmokers after less than 2 hours of exposure, posing acute health risks to patrons and workers. Casino ventilation and air cleaning practices failed to control secondhand smoke $PM_{2.5}$. Drifting $PM_{2.5}$ from secondhand smoke contaminated unseparated nonsmoking areas. Smoke-free casinos reduced $PM_{2.5}$ to the same low levels found outdoors**.**

Repace et al. (2011b) extended this study by including unpublished reports of $PM_{2.5}$ performed in several states for state health departments to amass data for a total of 94 casinos, 91 of which were smoking, and 3 smoke-free. Repace et al. (2011b) found that gaming floor geometric means were 60.8 $\mu g/m^3$ for the 91 casinos with smoking, 3.1 $\mu g/m^3$ for 3 control casinos without smoking, and 4.96 $\mu g/m^3$ outdoors. They estimated that, overall, 92% of the $PM_{2.5}$ in smoking casinos is from secondhand smoke. For 32 Nevada, Illinois, and Pennsylvania casinos, geometric mean $PM_{2.5}$ levels were 44.6 $\mu g/m^3$ in smoking areas and 21.6 $\mu g/m^3$ in nonsmoking restaurants or areas, compared with 3.44 $\mu g/m^3$ outdoors. For 10 Nevada and Pennsylvania casinos, indoor minus outdoor (incremental) $PM_{2.5}$ was correlated with incremental PAH (R^2 = 0.79) and with smoker density (R^2 = 0.57), but not with ventilation rate (R^2 = 0.14), indicating that smoker density, not ventilation or air cleaning, was the most important determinant of secondhand smoke pollution.

5.0. 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 3 shows the frequency distributions for the 3 Detroit casinos with smoking (pre-law) and the same 3 casinos with smoking (post-law), indicating little change. The average of the pre-law and post-law geometric mean $PM_{2.5}$ is 89.1 $\mu g/m^3$, well into the the "Unhealthy" band of the AQI. Detroit's casinos are exempt from the Dr. Ron Davis Law, and thus all 3 remain Unhealthy despite the law's passage.

Figure 4 shows these three Detroit casinos are more polluted than 73% of all 91 US casinos with smoking that have been measured to date, which have a geometric mean of 61 $\mu g/m^3$, (Repace, 2011b). By comparison, the 3 smoke-free casinos, with a geometric mean 3.1 $\mu g/m^3$, had cleaner air than 70% of the air outside all smoking casinos, with a geometric mean of 5.5 $\mu g/m^3$ (Repace et al., 2011a,b). $PM_{2.5}$ air quality in the 3 Detroit casinos averaged nearly 29 times that of the 3 smoke-free casinos studied, and 13.5 times that of the average level of $PM_{2.5}$ in the air outside those casinos.

The frequency distributions plotted in Figure 4 can be interpreted as follows: any point on the line gives the percentage of the casinos below a particular concentration on the horizontal axis. For example, to find the percentage of casinos 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%. This result means that 100% - 7% = 93% of the US casinos were at or above 25 $\mu g/m^3$. Similarly, 20% of the casinos were below 35 $\mu g/m^3$, so 80% were at or above 35 $\mu g/m^3$, the numerical value of EPA's 24-h standard. In this way, the entire frequency distribution of US indoor casino concentrations is available, with each datum displayed, and the percent of the casinos at or above any concentration can be read directly from the graph by simple subtraction.

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). The 3 nonsmoking casinos shown in Figure 2 have $PM_{2.5}$ concentrations comparable to the low average levels found in the outdoor air. Figures 1-3 demonstrate clearly that the ventilation and air cleaning practices followed by Detroit casinos massively failed to control $PM_{2.5}$ air pollution, while smoke-free casinos easily attained this goal.

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).

Repace et al. (2011a), analyzed data from a federal (NIOSH) study of cotinine, a biomarker for secondhand smoke, in 114 nonsmoking dealers employed in 3 Las Vegas casinos, and exposed to secondhand smoke at work only (Achutan et al., 2011). Repace et al. (2011a) found that the workers' doses of secondhand smoke exceeded that of 95% of a national sample of US nonsmoking adults. Further, Repace et al. (2011a) also found that the Las Vegas casino workers' mean dose of NNAL, a potent tobacco-specific lung carcinogen, exceeded that of 80% of the US nonsmoking adult population. The $PM_{2.5}$ levels to which these Las Vegas casino workers were exposed averaged 42 $\mu g/m^3$, less than half of the 89.1 $\mu g/m^3$ measured in the 3 Detroit casinos studied in this report, suggesting that Detroit casino workers are at very high exposure, and therefore at very high risk of the diseases caused by breathing secondhand smoke on the job.

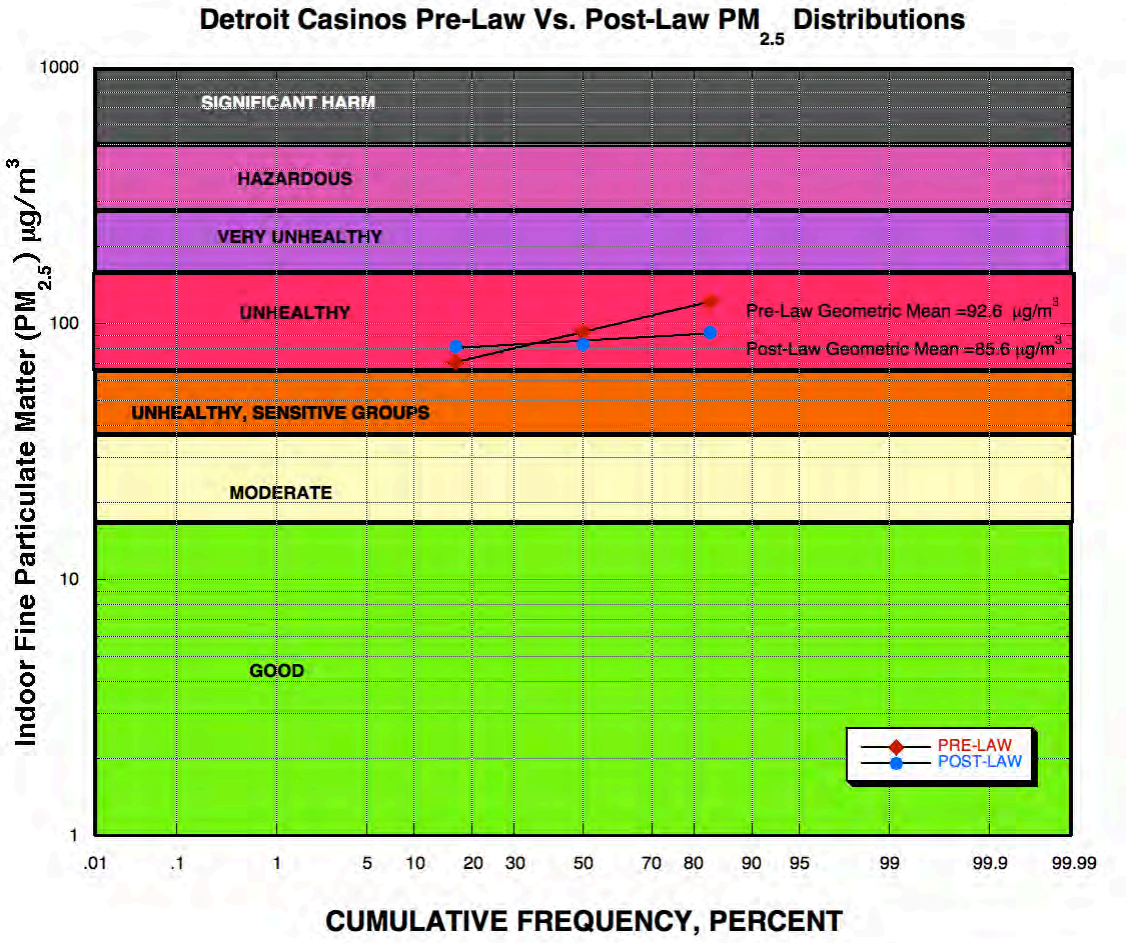

Figure 3. $PM_{2.5}$ air quality in 3 Detroit Casinos remained Unhealthy -- both pre- and post-law, due to secondhand smoke.

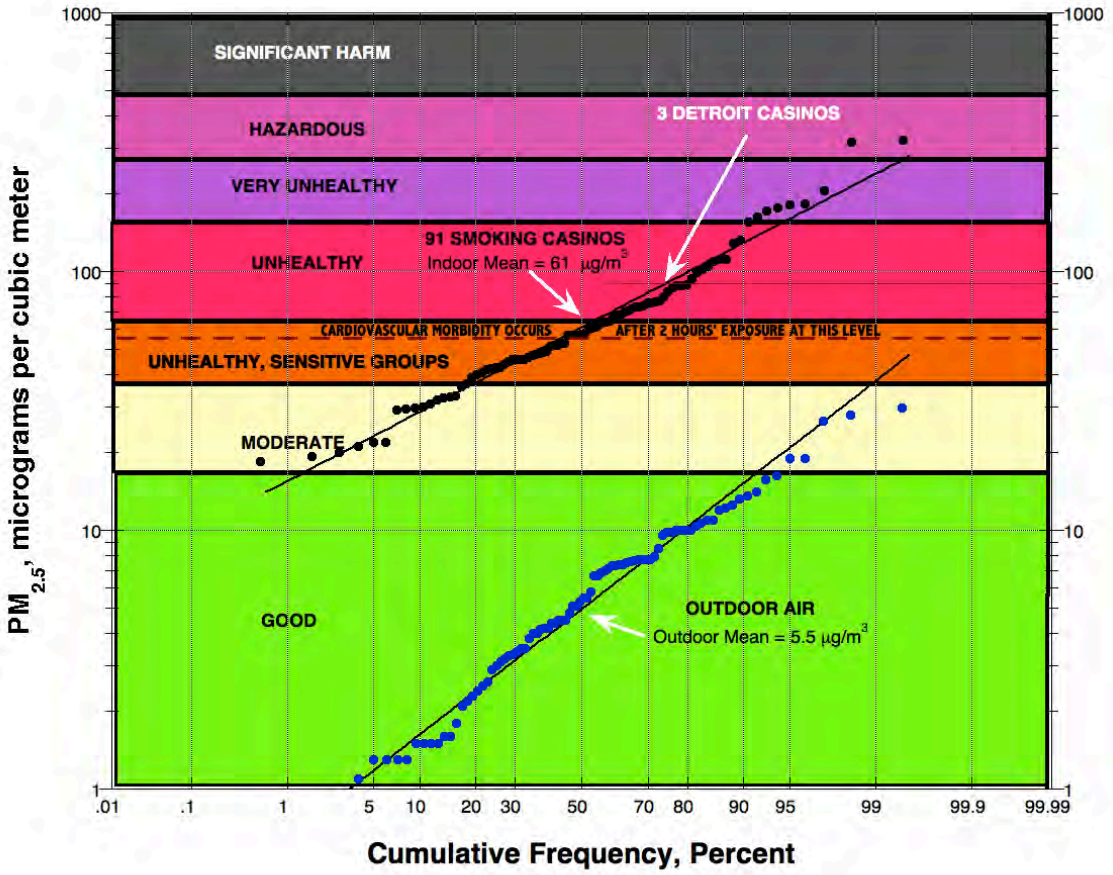

Figure 4. Air Quality in 3 Detroit Casinos versus 91 other US Casinos. The Detroit casinos are more polluted than 73% of the 91 smoking casinos studied.

6. Conclusions.

1. Three casinos 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. Secondhand smoke in the three Detroit casinos rose to Unhealthy levels both pre- and post Michigan's Dr. Ron Davis Smoke-free Air Law, since Michigan casinos are exempt from this law.
3. $PM_{2.5}$ air quality in Detroit casinos remains more polluted than 73% of the 91 smoking casinos measured in the US.
4. Air quality in Detroit casinos was 29 times as polluted with $PM_{2.5}$ as 3 smoke-free casinos in California, Nevada, and Delaware.
5. Detroit casino workers have far higher exposures to secondhand smoke than most of the US adult population.

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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:**

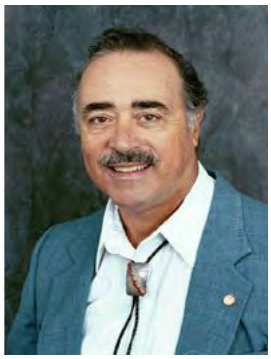
James Repace, MSc., is a biophysicist and an international secondhand smoke consultant who has published 86 scientific papers, 79 of which concern the hazard, exposure, dose, risk, and control of secondhand smoke. His work was cited 19 times in the 2006 Surgeon General's Report.* He has received numerous 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:

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

Repace JL. Indoor concentrations of environmental tobacco smoke: field surveys". J.L.Repace, *Ch. 10, IARC Scientific Publications no. 81, Environmental Carcinogens--Selected Methods of Analysis--Volume 9 Passive Smoking;* I.K. O'Neill, K.D. Brunnemann, B. Dodet & D. Hoffman, International Agency for Research on Cancer, World Health Organization, United Nations Environment Programme, Lyon, France, (1987).

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Lee, K., Hahn, E.J., Okoli, C.T.C., Repace, J., Troutman, A. Differential impact of smoke-free laws on indoor air quality. *JOURNAL OF ENVIRONMENTAL HEALTH* 70:24-70 (2008).

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Jiang RT, Cheng K-C, Acevedo-Bolton V, Klepeis NE, Repace JL, Ott WR, and Hildemann LM. Measurement of Fine Particles and Smoking Activity in a Statewide Survey of 36 California Indian Casinos. *JOURNAL OF EXPOSURE SCIENCE & ENVIRONMENTAL EPIDEMIOLOGY* (2010). 1-11 (online access: < http://www.nature.com/jes/journal/vaop/ncurrent/abs/jes200975a.html>).

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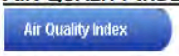
Hedley AJ, Lai HK, Repace JL, So C, Lu QY, McGhee SM, Fielding R. Lung function and exposure to workplace secondhand smoke during exemptions from smoking ban legislation - an exposure response relationship based on indoor $PM_{2.5}$ and urinary cotinine levels. Thorax (2011, *in press*)

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

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/m³	PM_{10} (24 hr) µg/m³	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 ($\mu g/m^3$) 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.

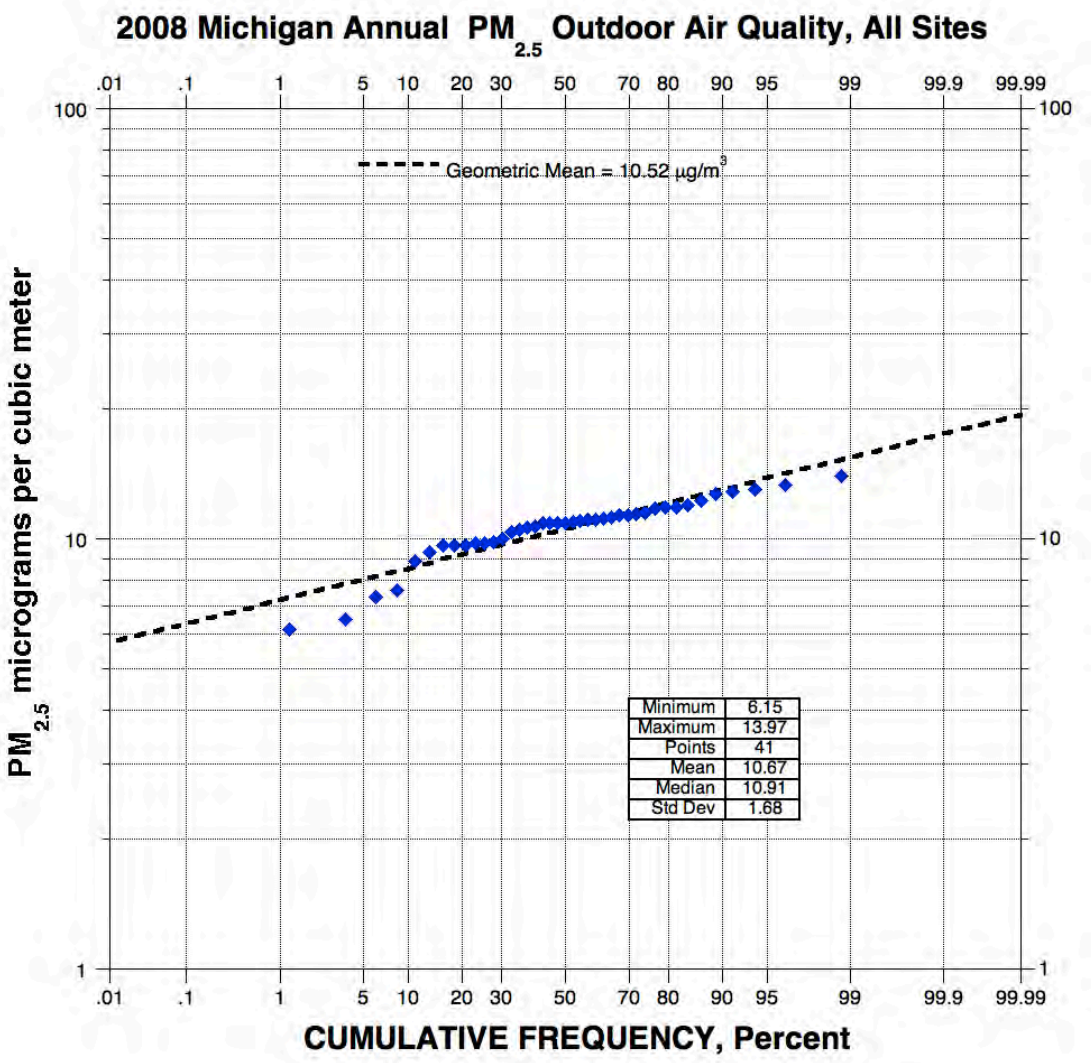


Figure C-1. A log-probability plot of outdoor $PM_{2.5}$ for all 41 sites in the State of Michigan in 2008 (MDEQ, 2011a).

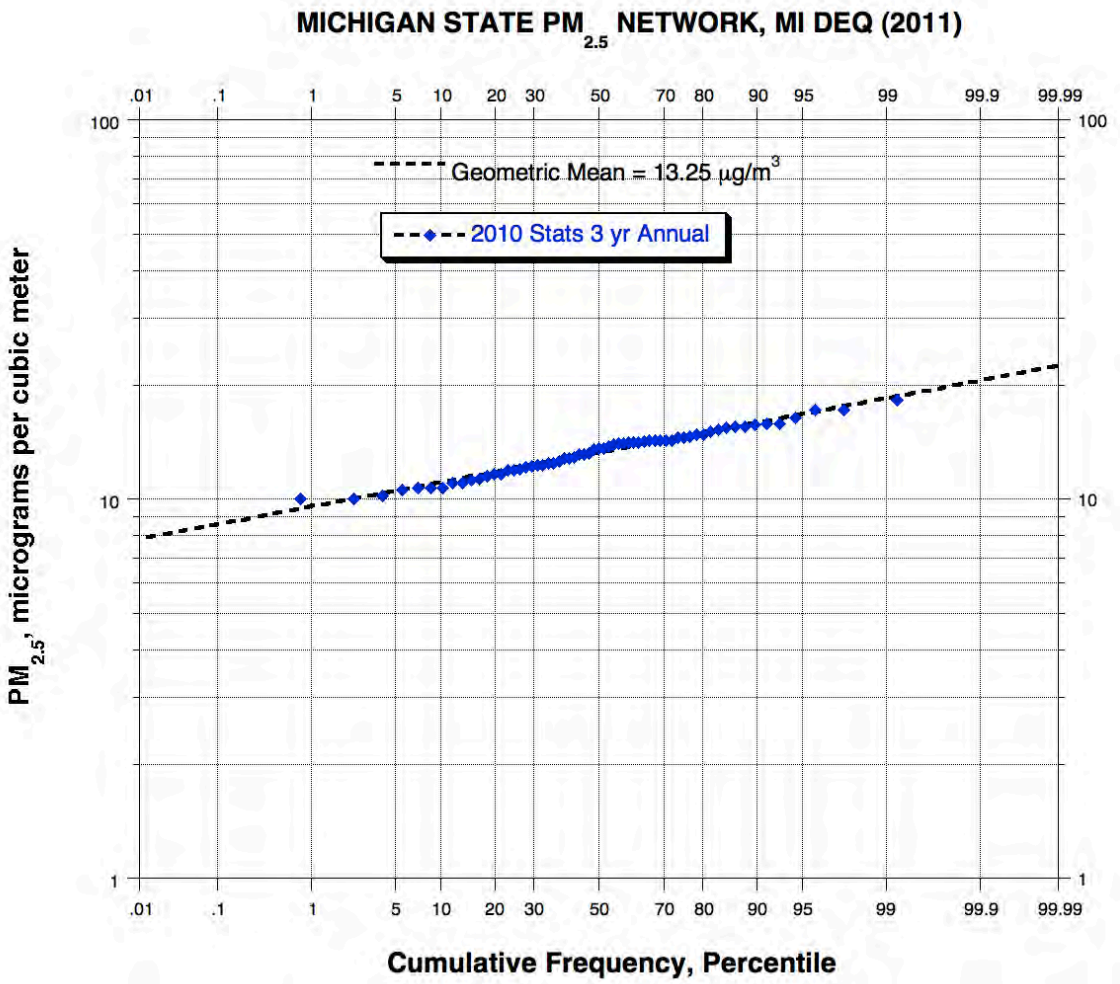


Figure C-2. A log-probability plot of 3-year average outdoor $PM_{2.5}$ for 63 sites in the State of Michigan, 2007-2010 (MDEQ, 2011a).

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