AIR QUALITY IN GRAND RAPIDS RESTAURANT BARS
Before and After
Michigan's *Dr. Ron Davis* State Smoke-free Law

June 16, 2011

James L. Repace, MSc.
Repace Associates, Inc.
Secondhand smoke Consultants

The Michigan Department
Of Community Health,
Tobacco Section

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 Grand Rapids. 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; NAS, 2010; NIEHS, 2000; WHO, 2005; 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). WHO (2010) concluded that the air quality guidelines for particulate matter recommended by WHO (2005) are also applicable to indoor spaces.

$PM_{2.5}$ 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 Grand Rapids 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 April, 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 Grand Rapids 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? The organizing principle underlying the data collection was the mass balance model, which posits that the concentration of secondhand smoke is proportional to the ratio of the average smoker density (active smokers per unit volume) to the effective air exchange rate (due to ventilation, air cleaning, and sorption on surfaces) (Repace, 2007).

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 gravimetric 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. Ventilation rates were not measured. 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. The individual venue $PM_{2.5}$ data are expressed in terms of arithmetic means and medians, and the curve-fits to the $PM_{2.5}$ data are expressed as geometric means.

The SidePak

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 Grand Rapids in 2005-2006. 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 29-36 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.

Table 1. GRAND RAPIDS RESTAURANT BARS $PM_{2.5}$ PRE-LAW Nov. 19, 2005; Jan 22, 2006.

Statistic	Venue #1	Venue #2	Venue #3**	Venue #4	Venue #5	Venue #6
Day	Saturday 19th	Saturday 19th	Saturday 19th	Saturday 19th	Saturday 19th	Sunday 22nd
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	38.1	86.7	129	11.7	5.7	14.7
Maximum	305	182	232	37.5	13.8	18.9
Mean	251	138	184	20.2	9.07	16.4
Median	259	140	179	19.5	8.85	16.4
Std. Dev.	52.3	21.1	28.3	7.12	2.18	1.11
Duration, Minutes	31	29	30	29	36	20
D_S	0.86	1.42	0.56	1.62	0	*
V, m^3	387	446	120	82	535	*
n_s	3.33	6.33	0.67	1.33	0	*
P	19	23	28.3	19.3	14.7	*
Estimated Smoking Prevalence, %	52	83	7.1	20.6	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. *Not Recorded; **Smoke-eater observed.

The estimated smoking prevalence in each of the 6 Grand Rapids 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 83% (Pritsos et al., 2008; Repace, 2007). For individual restaurant bars, pre-law means ranged from 9.07 to 251 $\mu g/m^3$, and averaged 103 $\mu g/m^3$, (median 79.1 $\mu g/m^3$). Figure 1 shows a plot of the real-time SidePak $PM_{2.5}$ data versus time on a linear scale, over 31-34 minute periods for Venue # 1, 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 251 $\mu g/m^3$, compared to 6.78 $\mu g/m^3$ post-law (Table 2). For this restaurant, an estimated 97% of the pre-law $PM_{2.5}$ pollution was due to secondhand smoke.

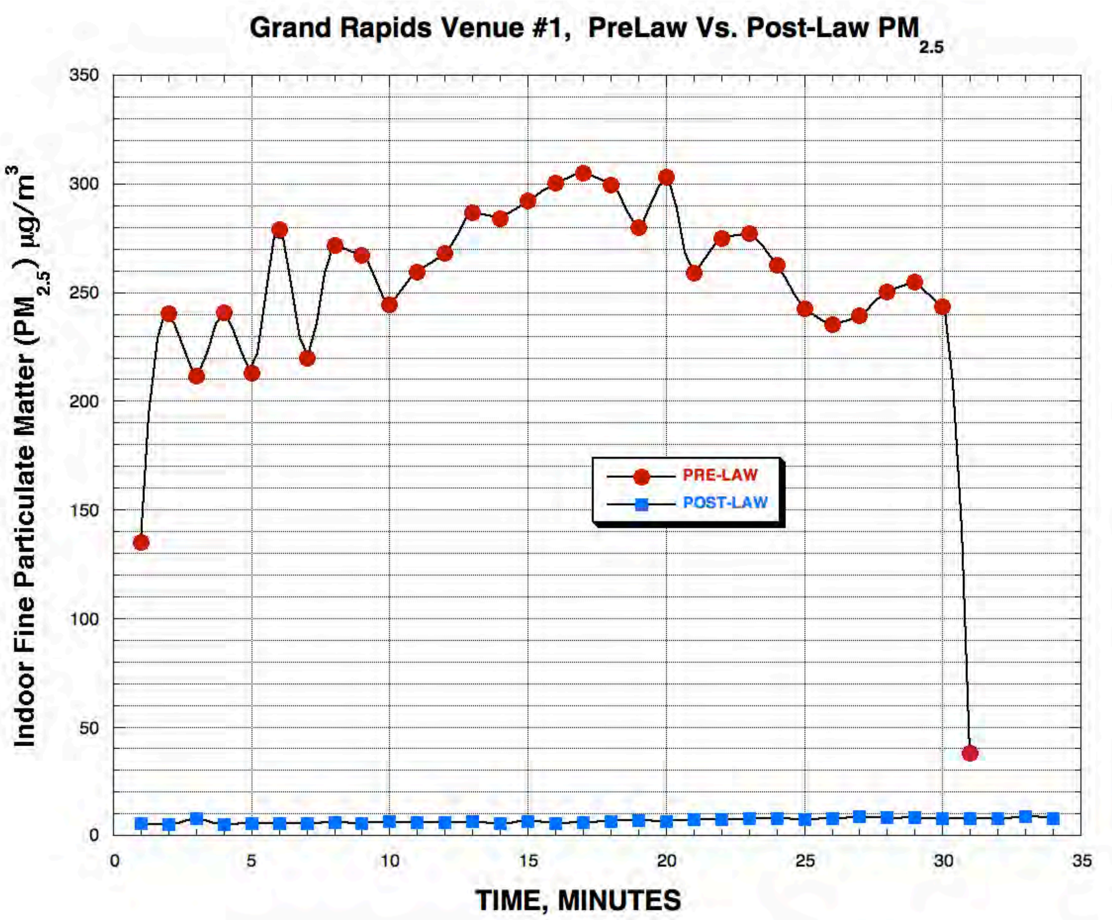

Figure 1. Real-time SidePak measurements in Venue # 1, Pre- and Post-Law. Michigan's state smoke-free air law reduced its indoor air pollution from $PM_{2.5}$ to 3% of its pre-law value.

Table 2 shows the same parameters measured on Friday night in May 2011, 10 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 28% (for Venue # 5, with no observed smoking), to 97% (for Venue # 1, with more than 3 active smokers puffing away constantly). Data on smoking was not reported for Venue #6. Post-law restaurant means for all 6 venues ranged from from 6.02 to 11.9 $\mu g/m^3$, and averaged 7.57 $\mu g/m^3$ (median 6.71 $\mu g/m^3$). Sampling periods ranged from 31 to 35 minutes.

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. GRAND RAPIDS RESTAURANT $PM_{2.5}$ POST LAW May 20, 2011.

Statistic	Venue #1	Venue #2	Venue #3	Venue #4	Venue #5	Venue #6
Day	Friday	Friday	Friday	Friday	Friday	Friday
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	5.1	8.7	6.9	5.7	6	5.4
Maximum	8.7	17.1	8.7	7.8	7.2	6.9
Mean	6.78	11.9	7.56	6.63	6.53	6.02
Median	6.6	11.7	7.5	6.3	6.6	6
Std Dev.	1.09	2.29	0.412	0.546	0.322	0.309
D_S	0	0	0	0	0	0
P						
Duration, Minutes	34	31	30	35	34	31
% Reduction in $PM_{2.5}$	97.3	91.4	95.9	67.2	28.0	63.3

4.0. Discussion. The percent reduction in median $PM_{2.5}$ for all 6 Grand Rapids restaurant venues combined was 92% (means declined by an average of 93%), indicating that the vast majority of indoor air pollution in all 6 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. 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 Grand Rapids results are consistent with the Wilmington, Boston, and Western New York pre- and post-law studies.

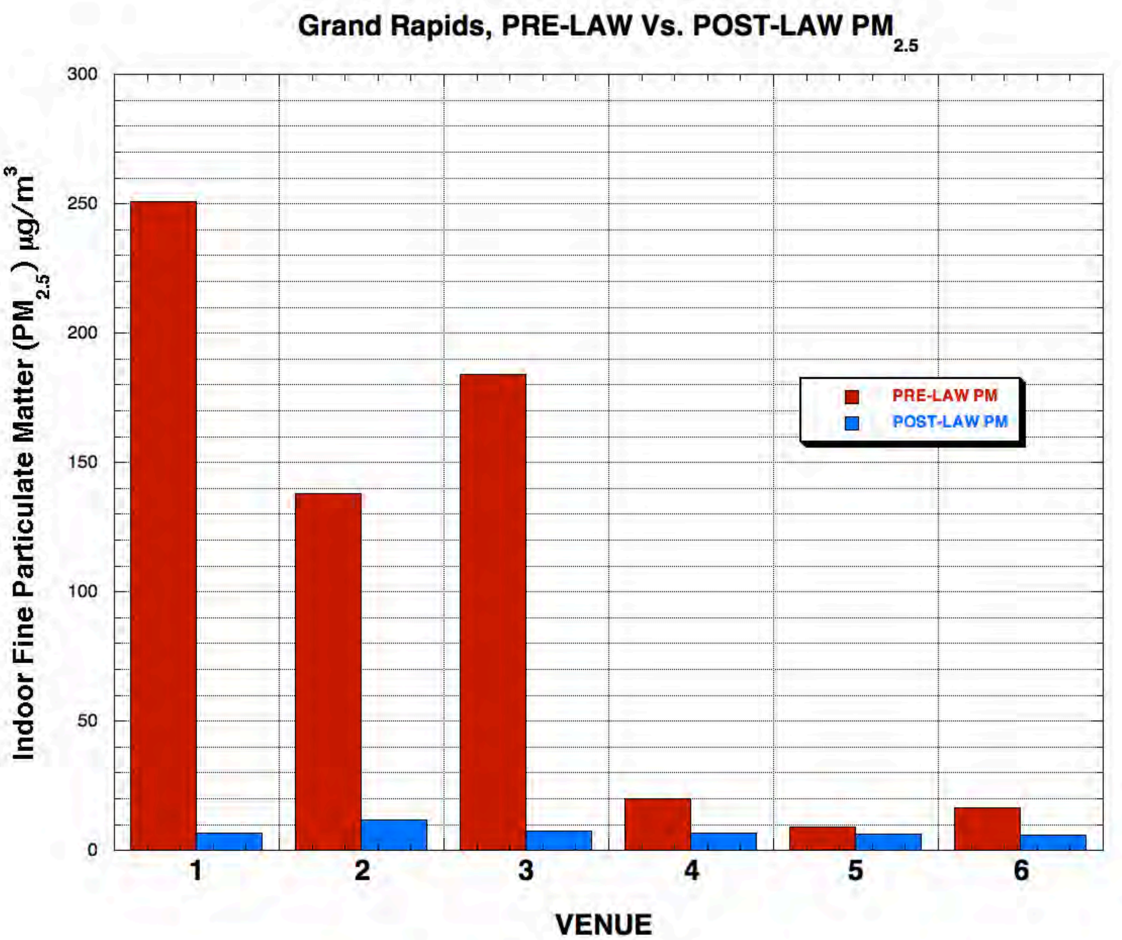

Figure 2. Mean air pollution levels in 6 restaurant bar venues, pre-and-post Smoke-free Air Law.

The reported estimated adult smoking prevalence for Michigan in 2009 was 19.6% compared to 17.9% for the US (CDC-BRFSS, 2009). However, in 2005-2006, when these data were collected, it was 22.1% for Michigan and 20.6% for the US. The total number of persons present pre-law for all 6 venues was P_{tot} = 104.3, and the total active number of cigarettes was Ns_{tot} = 11.7. The total number of smokers present in these 6 venues, averaged over the sampling time, is estimated as $3Ns_{tot}$ = 35, for an estimated overall smoking prevalence for the patrons of these 6 venues of (35/104)(100%) = 33.5%, or 71% higher than the Michigan adult smoking prevalence in 2009, and 52% higher than the State average in 2005.

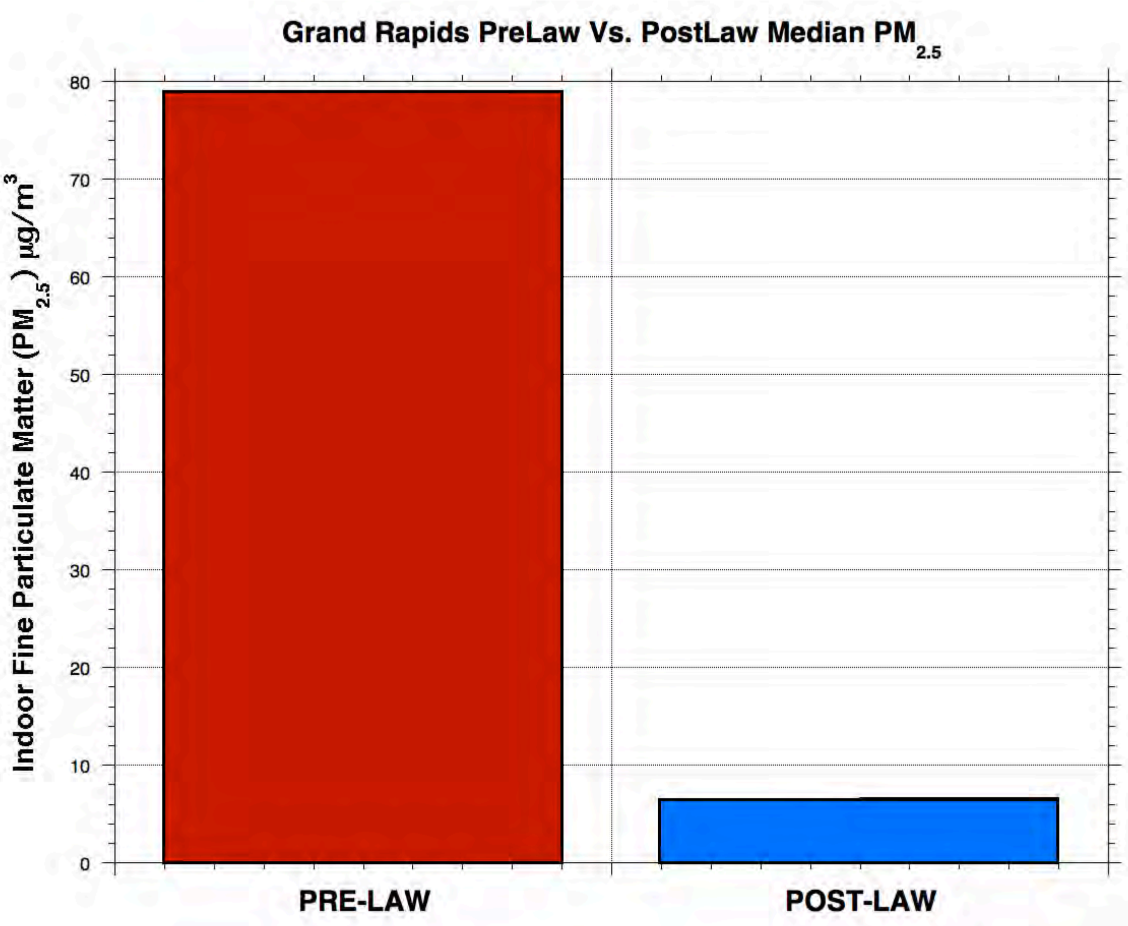

Figure 3. Combined median $PM_{2.5}$ level for 6 Grand Rapids restaurant bars drops an average of 92% due to Michigan's Dr. Ron Davis Indoor Air Law.

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 same 6 venues without smoking (post-law). Three of six restaurants had very polluted indoor air pre-law, ranging from Unhealthy to Very Unhealthy, while the remaining 3, one of which had no observed smoking, and had good air quality. Of the remaining two, one had no recorded smoking data, and the other one, which did, were both moderately polluted (Overall geometric mean, Unhealthy for Sensitive Groups, 51.7 $\mu g/m^3$). However, all 6 venues had good air quality post-law (Geometric mean, Good, 7.36 $\mu g/m^3$), an 86% decrease in the Geometric Mean $PM_{2.5}$ for these 6 venues.

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 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 Grand Rapids 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 estimate the corresponding horizontal axis value, 30%. If the venues selected were to be considered as representative of the distribution to be found for all Grand Rapids restaurants pre-law, this suggests that 100% - 30% = 70% of the venues would be at or above 25 $\mu g/m^3$. Similarly, about 40% of the venues would be below 35 $\mu g/m^3$, so 60% 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 Grand Rapids 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).

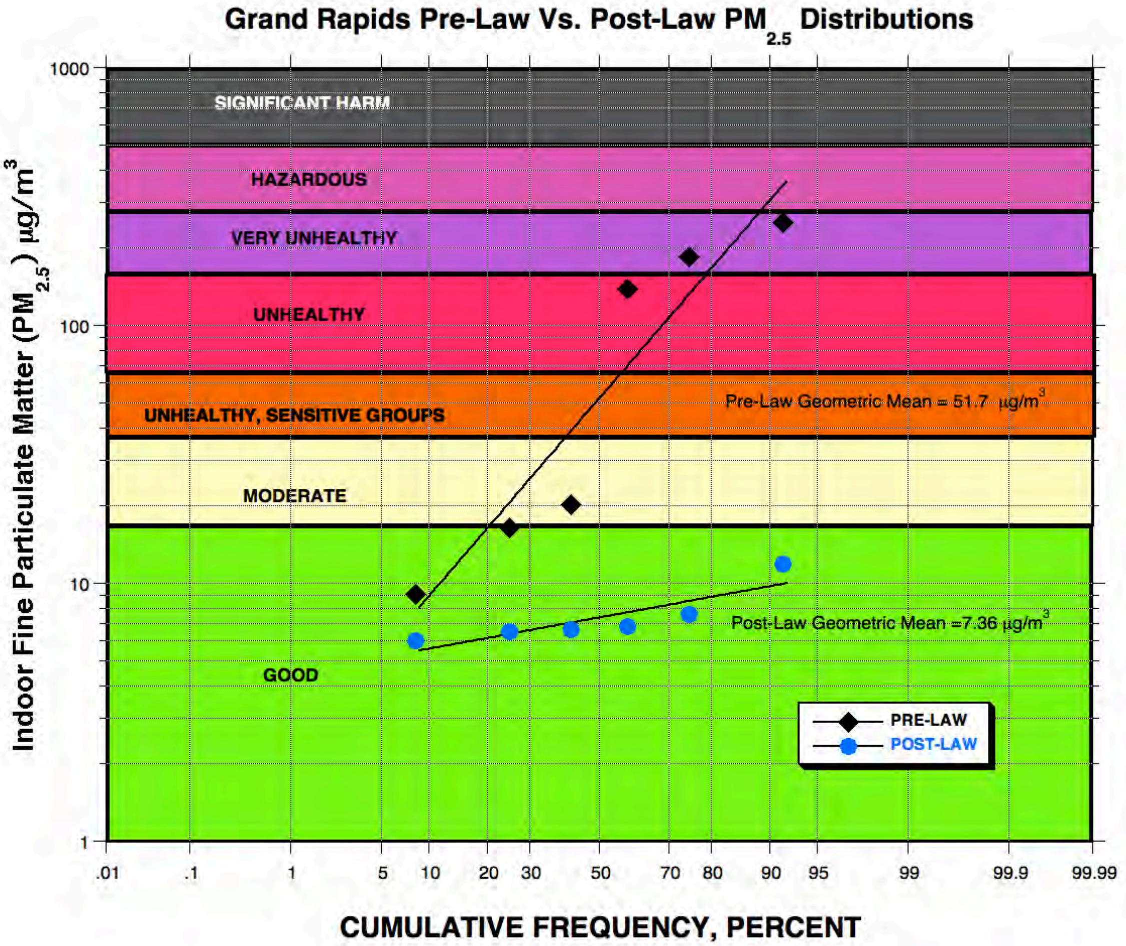

Figure 4. $PM_{2.5}$ frequency distributions for 6 Grand Rapids restaurant bars vs. the Michigan AQI. Pre-law, 3 of 6 venues have very poor air quality. Post-law, all 6 venues have very good air quality.

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 Grand Rapids restaurant bars were monitored for fine particulate air pollution before and after Michigan's Dr. Ron Davis Smoke-free Air Law, using real-time air quality monitors for fine particulate air pollution ($PM_{2.5}$).
2. The Dr. Ron Davis Law succeeded in reducing geometric mean levels of harmful secondhand smoke fine particle air pollution ($PM_{2.5}$) by 86% for a six-restaurant

sample of Grand Rapids Hospitality establishments.
3. Three of six restaurant bars studied had very bad air quality on average prior to the smoke-free law's enactment, caused by secondhand smoke pollution.
4. The remaining three restaurant bars had good to moderate air quality; however of the three, smoking was not observed in one, and data on smoking was not recorded for another.
5. All six restaurant bars had good $PM_{2.5}$ air quality subsequent to the smoke-free law's enactment.
6. For Grand Rapids, Michigan's Dr. Ron Davis Clean Indoor Air Law, by eliminating secondhand smoke, was effective in reducing $PM_{2.5}$ air pollution from secondhand smoke to the low levels found outdoors.

References

American Nonsmokers' Rights Foundation. (2010). Chronological Table of U.S. Population Protected by 100% Smokefree State or Local Laws. July 5, 2010. http://www.no-smoke.org/goingsmokefree.php?id=519#venues. Downloaded 09/20/2010.

CalEPA. 2005. Proposed identification of environmental tobacco smoke as a toxic air contaminant. Part b: Health effects. California Environmental Protection Agency, 2005.

CDC. 2006. Sustaining State Programs for Tobacco Control; Data Highlights, 2006. www.cdc.gov/tobacco/data.../**state**.../**2006**/.../dataHighlights06rev.pdf

Hecht, S.S. 1999. Tobacco smoke carcinogens and lung cancer. JNCI 91, 1194–1210.

Hoffmann, D. and Hoffmann, I. 1998. Chemistry and Toxicology, in *Smoking and Tobacco Control Monograph* 9. Cigars: Health Effects and Trends. National Institutes of Health, National Cancer Institute, Bethesda, MD.

IARC, 2004. IARC monographs on the evaluation of carcinogenic risks to humans ; Volume 83, Tobacco smoke and involuntary smoking /IARC Working Group on the Evaluation of Carcinogenic Risks to Humans (2004) Lyon, France.

Jiang, R-T., Cheng, K-C., Acevedo-Bolton, V., Klepeis, N.E., Repace, J.L., Ott, W.R., Hildemann, L.M. 2010. Measurement of fine particles and smoking activity in a statewide survey of 36 California Indian casinos. J. Exp. Sci. and Env. Epi. (open access), 2010, 7 February 2010; doi:10.1038/jes.2009.75 http://www.nature.com/jes/journal/vaop/ncurrent/abs/jes200975a.html.

Johnson, K.C., Miller, A.B., Collishaw, N.E., et al. 2011. Active smoking and secondhand smoke increase breast cancer risk: the report of the Canadian expert panel on tobacco smoke and breast cancer risk (2009). Tobacco Control 2011. 20, e2, open access, originally published online December 8, 2010 doi: 10.1136/tc.2010.035931.

2009. ENROLLED HOUSE BILL No. 4377, Act No. 188 Public Acts of 2009 Approved by the Governor December 18, 2009, the *Dr. Ron Davis Law.* http://www.legislature.mi.gov/documents/2009-2010/publicact/pdf/2009-PA-0188.pdf.

MICHIGAN BRFSS SURVEILLANCE BRIEF, CHRONIC DISEASE EPIDEMIOLOGY SECTION, MDCH. February, 2010, Vol. 4, #1.
http://www.michigan.gov/documents/mdch/MIBRFSS_Surveillance_Brief_Jan2010_Vol4No1_FINAL_313804_7.pdf

MDEQ, 2011a. Michigan Department of Environmental Quality (2011) PM2.5 Network. http://www.michigan.gov/documents/deq/deq-aqd-aqe-pm25network_258529_7.pdf

MDEQ, 2011b. Michigan Department of Environmental Quality (2011). http://michigan.gov/documents/deq/deq-aqd-air-2008-Air-Quality-Report_296426_7.pdf

MMWR (2009). State-Specific Prevalence and Trends in Adult Cigarette Smoking --- United States, 1998—2007. March 13, 2009 / 58(09);221-226. Accessed 6/14/2011. < http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5809a1.htm>
.

Moraros, J, Bird, Y, Chen, S, Buckingham, R, Meltzer R.S., Prapasiri, S, Solis, L.H. 2010. The impact of the 2002 Delaware smoking ordinance on heart attack and asthma. Int. J. Environ. Res. Public Health 7, 4169-4178; doi:10.3390/ijerph7124169.

NAS. 2010. Secondhand Smoke Exposure and Cardiovascular Effects: Making Sense of the Evidence. Committee on Secondhand Smoke Exposure and Acute Coronary Events; Institute of Medicine. National Academy of Sciences, Washington, DC.

NIEHS. 2000. National Toxicology Program. *9th Report on Carcinogens 2000*. Research Triangle Park, NC: US Dept. of Health & Human Services, National Institute of Environmental Health Sciences.

Pope, C.A., Burnett, R.T., Krewski, D., Jerrett, M., Shi, Y., Calle, E.E., Thun, M.J. 2009. Cardiovascular mortality and exposure to airborne fine particulate matter and cigarette smoke: shape of the exposure-response relationship. Circulation 120, 924-927.

Pritsos, C.A., Pritsos, K.L., Spears, K.E. 2008. Smoking rates among gamblers at Nevada casinos mirror US smoking rate. Tobacco Control 17, 82-85.

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

Repace JL. and Johnson KC. Can Displacement Ventilation Control Secondhand ETS? Technical Feature, ASHRAE IAQ Applications, 7: 1-6 (Fall, 2006).

Repace JL, Hyde JN, Brugge D. Air Pollution in Boston Bars Before and After a Smoking Ban. Open Access, on-line journal: <http://www.biomedcentral.com/1471-2458/6/266>, BMC Public Health 2006, 6:266 (27 Oct 2006).

Repace JL, Ott WR, and Klepeis NE. Indoor Air Pollution from Cigar Smoke. Chapter 5, In *Smoking and Tobacco Control Monograph 9. Cigars - Health Effects and Trends.* National Institutes of Health, National Cancer Institute, Bethesda, MD (1998).

Repace JL. 2007. Exposure to secondhand smoke. In: W Ott, A Steinemann, and L Wallace (Eds), Exposure Analysis, Chapter 9, CRC Press, Boca Raton FL.

Repace JL. Respirable Particles and Carcinogens in the Air of Delaware Hospitality Venues Before and After a Smoking Ban. Journal of Occupational and Environmental Medicine, 46:887-905 (2004).

Repace, J.L. 2009. Secondhand smoke in Pennsylvania casinos: a study of nonsmokers' exposure, dose, and risk. Am. J. Public Health 99, 1478–1485.

Repace JL, Jiang RT, Cheng K-C, Acevedo-Bolton V, Klepeis NE, Ott WR, and Hildemann LM. Fine Particle and Secondhand Smoke Air Pollution Exposures and Risks Inside 66 US Casinos. Environmental Research 111: 473–484 (2011a).

Repace JL, Jiang RT, Cheng K-C, Acevedo-Bolton V, Klepeis NE, Ott WR, and Hildemann LM. PM2.5 Air Pollution and Secondhand Smoke in 94 US Casinos. To be presented at the 12th International Conference on Indoor Air Quality & Climate • June 5-10 (2011b), Austin, Texas.

Surgeon General, 2006. The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General. US Department of Health and Human Services, Centers for Disease Control and Prevention, Coordinating Center for Health Promotion, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, Atlanta, GA.

Surgeon General. 2010. How tobacco smoke causes disease: the biology and behavioral basis for smoking-attributable disease: a report of the Surgeon General. Rockville, MD. U.S. Dept. of Health and Human Services, Public Health Service, Office of Surgeon General.

Travers M, Higbee C, Hyland A. *Michigan Air Monitoring Study – Grand Rapids*. Roswell Park Cancer Institute, June 2006.

Travers MJ, KM Cummings, A Hyland, J Repace, S Babb, T Pechacek, PhD, R Caraballo. Indoor Air Quality in Hospitality Venues Before and After Implementation of a Clean Indoor Air Law — Western New York, 2003. MMWR Vol. 53 / No. 44 1038-104, November 12, 2004.

USEPA, 2011. Policy Assessment for the Review of the Particulate Matter National Ambient Air Quality Standards. U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Health and Environmental Impacts Division Research Triangle Park, North Carolina. EPA 452/R-11-003 April 2011.

USEPA, 2006. FACT SHEET FINAL REVISIONS TO THE NATIONAL AMBIENT AIR QUALITY STANDARDS FOR PARTICLE POLLUTION (PARTICULATE MATTER). downloaded 5/20/2011<http://www.epa.gov/air/particlepollution/pdfs/20060921_factsheet.pdf>.

USEPA, 1992. RESPIRATORY HEALTH EFFECTS OF PASSIVE SMOKING: LUNG CANCER AND OTHER DISORDERS, Office of Health and Environmental Assessment Office of Research and Development U.S. Environmental Protection Agency Washington, D.C. EPA/600/6-90/006F December 1992.

WHO, (2005). WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, Global update 2005, Risk Assessment. Accessed 6/14/2011. < http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf>.

WHO (2010). Guidelines for indoor air quality: selected pollutants. The WHO European Centre for Environment and Health, Bonn Office. http://www.euro.who.int/__data/assets/pdf_file/0009/128169/e94535.pdf, Accessed 6/14/2011.

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).

Repace JL, Ott WR, and Klepeis NE. Indoor Air Pollution from Cigar Smoke. Chapter 5, In *Smoking and Tobacco Control Monograph 9. Cigars - Health Effects and Trends.* National Institutes of Health, National Cancer Institute, Bethesda, MD (1998).

Repace JL. Flying the Smoky Skies: Secondhand Smoke Exposure of Flight Attendants. *Tobacco Control* 13(Suppl 1):i8-i19 (2004).

Travers MJ, KM Cummings, A Hyland, J Repace, S Babb, T Pechacek, PhD, R Caraballo. Indoor Air Quality in Hospitality Venues Before and After Implementation of a Clean Indoor Air Law — Western New York, 2003. *MMWR* Vol. 53 / No. 44 1038-104, November 12, 2004.

Repace JL. Respirable Particles and Carcinogens in the Air of Delaware Hospitality Venues Before and After a Smoking Ban. *Journal of Occupational and Environmental Medicine*, 46:887-905 (2004).

Mulcahy M, Evans DS, Hammond SK, Repace JL and Byrne M. Secondhand smoke exposure and risk following the Irish smoking ban: an assessment of salivary cotinine concentrations in hotel workers and air nicotine levels in bars. *Tobacco Control* 14: 384-388 (2005).

Repace JL, Hyde JN, Brugge D. Air Pollution in Boston Bars Before and After a Smoking Ban. Open Acess, on-line journal: <http://www.biomedcentral.com/1471-2458/6/266>, *BMC Public Health* 2006, 6:266 (27 Oct 2006).

Repace JL. Exposure to Secondhand Smoke. Chapter 9, In: *Exposure Analysis,* W Ott, A Steinemann, and L Wallace, Eds. CRC Press (2007).

Bauer U, Juster H, Hyland A, Farrelly M, Engelen M, Weitzenkamp D, Repace J, Babb, S. Reduced Secondhand Smoke Exposure After Implementation of a Comprehensive Statewide Smoking Ban — New York, June 26, 2003–June 30, 2004, *MMWR* 56, No. 28: 705-706 (2007).

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).

Repace JL. Secondhand Smoke in Pennsylvania Casinos: A Study of Nonsmokers' Exposure, Dose, and Risk. *AMERICAN JOURNAL OF PUBLIC HEALTH* 99: 1478–1485 (2009).

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>).

Repace JL, Jiang RT, Cheng K-C, Acevedo-Bolton V, Klepeis NE, Ott WR, and Hildemann LM. Fine Particle and Secondhand Smoke Air Pollution Exposures and Risks Inside 66 US Casinos. ENVIRONMENTAL RESEARCH *2011, (in press).*

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:

Air Quality Index

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

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

Table 4.1: BREAKPOINTS FOR AQI POLLUTANT CONCENTRATIONS

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

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

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.

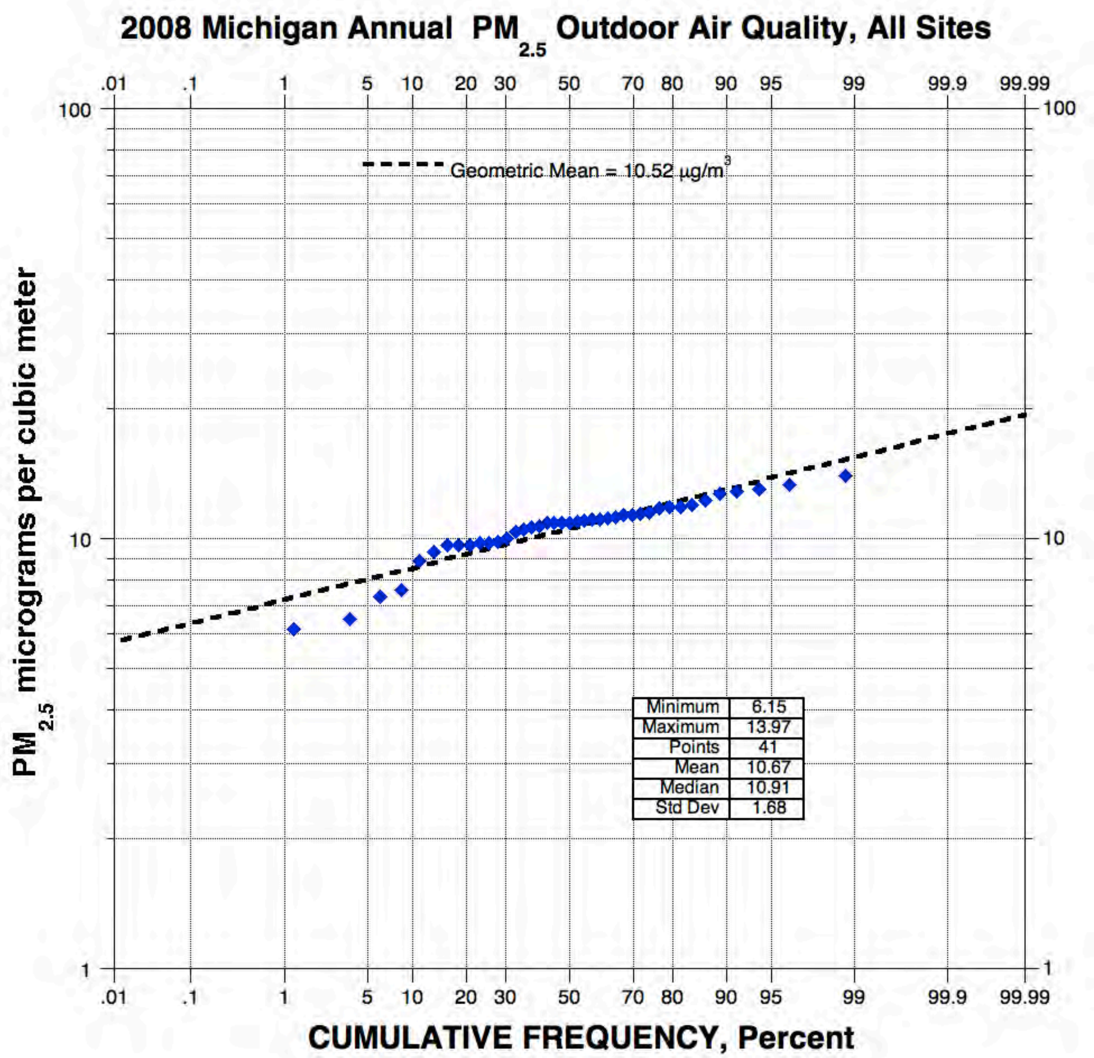

Figure C-1. A log-probability plot of outdoor $PM_{2.5}$ for all 41 sites in the State of Michigan in 2008 (MDEQ, 2011a).

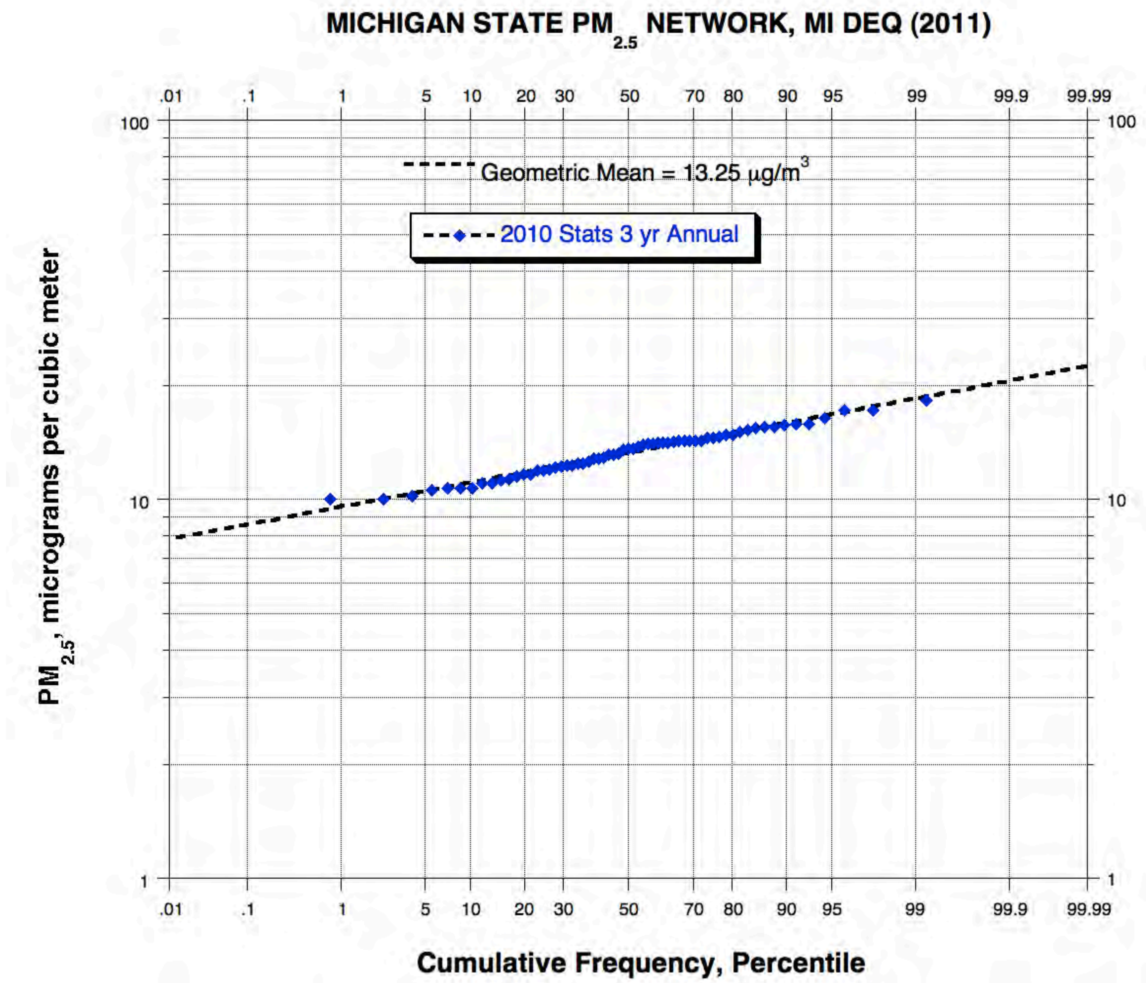

Figure C-2. A log-probability plot of 3-year average outdoor $PM_{2.5}$ for 63 sites in the State of Michigan, 2007-2010 (MDEQ, 2011a).

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