CSSS - 055M
C.P. – P.L. 44
Lutte contre le
tabagisme

TESTIMONY OF JAMES L. REPACE BEFORE THE QUEBEC NATIONAL ASSEMBLY, ON BILL 44, *AN ACT TO BOLSTER TOBACCO CONTROL*

SEPTEMBER 3, 2015

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EXECUTIVE SUMMARY

1. **Field studies and experiments conducted in Canada, the USA, Austria, France, Ireland, Italy, Denmark, Poland, Portugal, Slovak Republic, Australia, New Zealand, and Spain, the levels of fine particulate matter ($PM_{2.5}$) on outdoor terraces are significantly increased as a result of secondhand smoke. Studies in California, Italy, Finland, and Denmark indicated that these levels are much higher than those due to vehicular traffic.**

2. **A U.S. dosimetry study in a bar and restaurant, plus the numerous outdoor studies in several countries shows that nonsmokers exposed to outdoor secondhand smoke absorb tobacco smoke carcinogens, and are exposed to very unhealthy levels of fine particulate matter from secondhand smoke.**

3. **This dosimetry study also shows that exposure on outdoor terraces poses a significant risk of material impairment of health for the estimated 16,625 nonsmoking Quebec wait staff who work in bars.**

4. **Establishing smoking sections will increase the exposure and risk to Quebec wait staff exposed on bar terraces.**

5. **There is a scientific consensus on the danger of secondhand smoke for the estimated wait staff in outdoor terrace settings.**

6. **Because elevated levels of harmful secondhand smoke fine particles and carcinogens from a single cigarette have been measured at distances in three studies ranging from 4 meters to 13 meters, and because modeling shows that cigarette smoke from multiple smokers will increase the distance at which smoke concentrations remain excessive, the separation distance of 1.5 meters proposed by the study commissioned by l'Union des tenanciers de bars du Québec (UTBQ) must be rejected.**

INTRODUCTION

I have been asked by the Conseil québécois sur le tabac et la santé to comment from a scientific perspective on certain provisions of Bill 44 amending the Tobacco Act to present testimony concerning outdoor tobacco smoke on bar and restaurant terraces. I am a consultant on both indoor and outdoor air pollution from secondhand smoke, with 56 peer-reviewed research publications on the hazard, exposure, dose, risk, and control of secondhand smoke both indoors and out. I am a retired civil servant with the United States Government in Washington, DC, with 19 years at the Environmental Protection Agency as a senior air pollution policy analyst, and 11 years with the Naval Research Laboratory as a Research Physicist. I have also served as an advisor to the U.S. Occupational Health and Safety Administration on secondhand smoke in workplaces and to the U.S. Department of Transportation on smoking on aircraft. I have advised government authorities in numerous countries in the United States and Canada, as well as and South America, Europe, and the Pacific Rim, as well as the World Health Organization. I hold a Masters' Degree in Physics. A brief précis of my curriculum vitae is appended.

BACKGROUND

The proposed bill 44 amends the Tobacco Act to further restrict tobacco use both in enclosed spaces and outdoors on terraces of bars and restaurants. It prohibits smoking in motor vehicles in which a minor under 16 years of age is present and on terraces. It prohibits smoking within a nine-metre radius from any door leading to enclosed spaces that are open to the public. The bill extends the scope of the Act by considering electronic cigarettes to be tobacco and sets rules for tobacco use in certain places, in particular by determining standards for outdoor smoking shelters. I strongly support all of these provisions, which are necessary to protect both occupational and public health.

PRINCIPLES OF AIR POLLUTION CONTROL

Air pollution control involves six distinct principles: Hazard Identification, Exposure Assessment, Dose Assessment, Dose-Response Relationships, Risk Assessment, and Control to within an acceptable level of risk.

Hazard Identification: Tobacco smoke contains at least 172 toxic substances, including 3 regulated outdoor air pollutants, 33 Hazardous Air Pollutants, 47 Chemicals restricted as Hazardous Waste and 67 Known Human or Animal Carcinogens (Repace, 2006). This is true whether tobacco smoke is inhaled in the act of smoking, or inhaled by nonsmokers out of the air indoors or outdoors.

Chronic Risk. The Canadian Centre for Occupational Health and Safety declares "Environmental tobacco smoke (ETS) exposure increases the number of lung cancers in non-smokers. Studies show that exposure to ETS may increase the risk of cancer at sites other than the lung; associations have been found with cancers such as cervical, bladder, nasal-sinus, and brain. Non-smoking co-workers of smokers have a relative risk of approximately 1.39. Among non-smokers exposed to ETS, there is an estimated 20 to 30% increase (relative risk of 1.2 to

1.3) in the risk of death from myocardial infarctions (heart attacks) or ischemic heart disease (group of diseases caused by inadequate oxygen supply to the heart caused by constricted blood vessels and resulting decreased blood supply). In addition, it was found in experimental studies on the effects of ETS on the heart, that ETS exposure has damaging effects on blood platelets (needed for clotting) and the endothelium (tissues lining the heart, blood vessels, lymph vessels, etc.) The Report of the Canadian Expert Panel on Tobacco Smoke and Breast Cancer Risk (2009) concluded that "the relationship between SHS and breast cancer in younger, primarily premenopausal women is consistent with causality (2009)."

The 13th Report on Carcinogens of the U.S. National Toxicology Program (2014) states that "Environmental tobacco smoke is *known to be a human carcinogen* based on sufficient evidence of carcinogenicity from studies in humans." The IARC Monograph on the Evaluation of Carcinogenic Risk to Humans (2004) concluded that "Involuntary smoking (exposure to secondhand or 'environmental' tobacco smoke) is carcinogenic to humans (Group 1)." The California Air Resources Board declared that "Environmental Tobacco Smoke is a Toxic Air Contaminant in both indoor and outdoor air for which there is no identified threshold (2006)."
The U.S. Surgeon General (2006) concluded that "Exposure of adults to secondhand smoke has immediate adverse effects on the cardiovascular system and causes coronary heart disease and lung cancer, and that the scientific evidence indicates that there is no risk-free level of exposure to secondhand smoke." **Thus there is an international scientific consensus that secondhand smoke (SHS) or environmental tobacco smoke (ETS) is a human health hazard for which there is no known safe level.**

Acute Irritation. The Canadian Centre for Occupational Health and Safety stated that "Many of the substances in cigarette smoke are very irritating to the eyes, throat and respiratory mucous membranes. A high proportion of non-smokers report eye irritation, headache, nasal discomfort, cough, sore throat, or sneezing when exposed to cigarette smoke." Junker et al. (2000) In addition to posing a chronic health risk, secondhand smoke is highly irritating: nearly three-fourths of nonsmokers are disturbed by smoky air (Weber and Grandjean, 1987). The median threshold for sensory (eye, nose, and throat) irritation, is 4.4 micrograms per cubic meter ($\mu g/m^3$). This means that half of an exposed nonsmoking population will exhibit acute irritation symptoms of SHS exposure, at less than 4.4 $\mu g/m^3$ for SHS-$PM_{2.5}$ (Junker, et al., 2001). At this median level of SHS-$PM_{2.5}$, 67% of the nonsmokers judged the air quality to be unacceptable. The median odor-detection threshold for healthy normal nonsmoking adults is ~1 $\mu g/m^3$. So that nonsmokers will find levels of secondhand smoke particles offensive at levels below ~1 $\mu g/m^3$ (Junker et al., 2001). In fact Biener et al. (1999) in a study of a representative sample of nearly 5000 Massachusetts adults found that 46% of non-smokers reported having avoided a smoky place. Reasons were aversion to the lingering smell (34.8%) and health issues (31.9%). Many adults avoid restaurants and bars because of the expectation of excessive environmental tobacco smoke. In fact, Biener et al.'s results showed that there the number of nonsmokers who avoided smoky restaurants and bars exceeded the number of smokers in the entire state. **Thus, there is both evidence from field surveys and controlled experimental studies that secondhand smoke is exceedingly annoying to nonsmokers.**

Exposure Assessment:

Exposure is defined as the product of concentration times time. The two prime atmospheric markers for secondhand smoke are nicotine and fine particles ($PM_{2.5}$). Nicotine cannot be measured in real time, i.e., instantaneously, but real-time fine particle monitors are generally used to quantify exposure to secondhand smoke in outdoor settings. Such monitors have been widely used to measure secondhand smoke concentrations in bars, restaurants, discos, casinos, homes, and in outdoor locations such as patios or terraces (Repace and Lowrey, 1980; Repace, 2004; 2007; Repace et al., 2010).

Airborne Particulate Matter, or PM, is a complex mixture of extremely small solid particles and liquid droplets. Smoke particles 10 micrometers in diameter or smaller pass right through the nose and throat, penetrating into the lungs. By contrast, the thinnest human hair is about 17 micrometers. Once inhaled, particulate air pollution affects the heart and lungs and can cause serious health effects, such as heart disease, respiratory disease, and cancer. Environmental authorities in North America and Europe regulate two kinds of particulate pollution. Inhalable coarse particles, or PM_{10}, typically found near roadways and dusty industries, are between 2.5 micrometers and 10 micrometers in diameter. Fine particles, or $PM_{2.5}$, such as those found in smoke and haze, are 2.5 micrometers in diameter and smaller and are more harmful than PM_{10}. EPA's 24-hour PM_{10} standard is 150 micrograms per cubic meter ($\mu g/m^3$), the 24-hour $PM_{2.5}$ standard is 35 $\mu g/m^3$ and the annual standard is 12 $\mu g/m^3$. Depending upon particle size, inhaled particulate matter may persist in the lungs for hours, days, weeks, or months, and some remains for years. The finest particles are the most persistent; PM_1 migrates into the bloodstream. Fine particles are emitted from combustion sources such as forest fires, power plants, incinerators, industrial smoke stacks, as well as trucks and autos, and of course, cigarettes, pipes, and cigars. Cigars emit three to five times the fine particle pollution than cigarettes or pipes, and thirty times the carbon monoxide emissions.

The concentration of outdoor secondhand tobacco smoke (SHS) is determined by the density of smokers, the wind velocity (direction and speed), distance from the source, and the stability of the atmosphere. The highest secondhand smoke concentrations are produced by high smoker density, close proximity, low wind velocity, and stable atmospheric conditions. A number of studies have explored the concentration of tobacco smoke in outdoor hospitality settings as well as experimentally (Repace, 2008).

- California. The California Air Resources Board study (CARB, 2006), measured SHS nicotine concentrations outside an airport, a college, a government center, an office complex, and an amusement park. CARB, which regulates outdoor air pollution in California, found that at these typical outdoor locations, Californians may be exposed to SHS levels as high as indoor SHS concentrations. CARB found that SHS was strongly affected by counts of the number of smokers and moderately affected by the size of the smoking area and the measured wind speed. The CARB study indicated that the number of cigarettes being smoked (i.e., total source strength), the position of smokers relative to the receptor, and atmospheric conditions can lead to substantial variation in average exposures. **CARB declared that outdoor SHS is a "toxic air contaminant**."

- Denmark. Boffi et al. (2006) measured SHS respirable particle pollution in a car park outdoors in front of a conference center with smokers under a roof (18 smokers during a measurement time of 35 min), indoors in the nonsmoking conference center, along the motorway to Copenhagen city centre, and inside a Copenhagen restaurant where smoking was allowed. Boffi et al. (2006) found that mean values observed with smokers in front of the conference center were significantly higher than the outdoor parking place, the indoor conference center, the motorway and the Copenhagen outdoor air quality data.

- Finland. Repace and Rupprecht (2006) measured SHS respirable particle pollution in five outdoor cafes and on city streets in downtown Helsinki. They found that air pollution levels in Helsinki outdoor cafes with many smokers during August 2003 were 5 to 20 times higher than on the sidewalks of busy streets polluted by bus, truck, and auto traffic.

- Caribbean. Repace (2005) conducted field measurements on a cruise ship underway at 20 knots at sea in the Caribbean the cruise-ship experiments showed that SHS carcinogens (carcinogenic polycyclic aromatic hydrocarbons) in various smoking-permitted outdoor areas of the ship tripled the level of carcinogens to which nonsmokers were exposed relative to indoor and outdoor areas in which smoking did not occur, despite the strong breezes and unlimited dispersion volume. Moreover, outdoor smoking areas were contaminated with carcinogens to nearly the same extent as a popular casino on board in which smoking was permitted as shown in Figure 0 below.

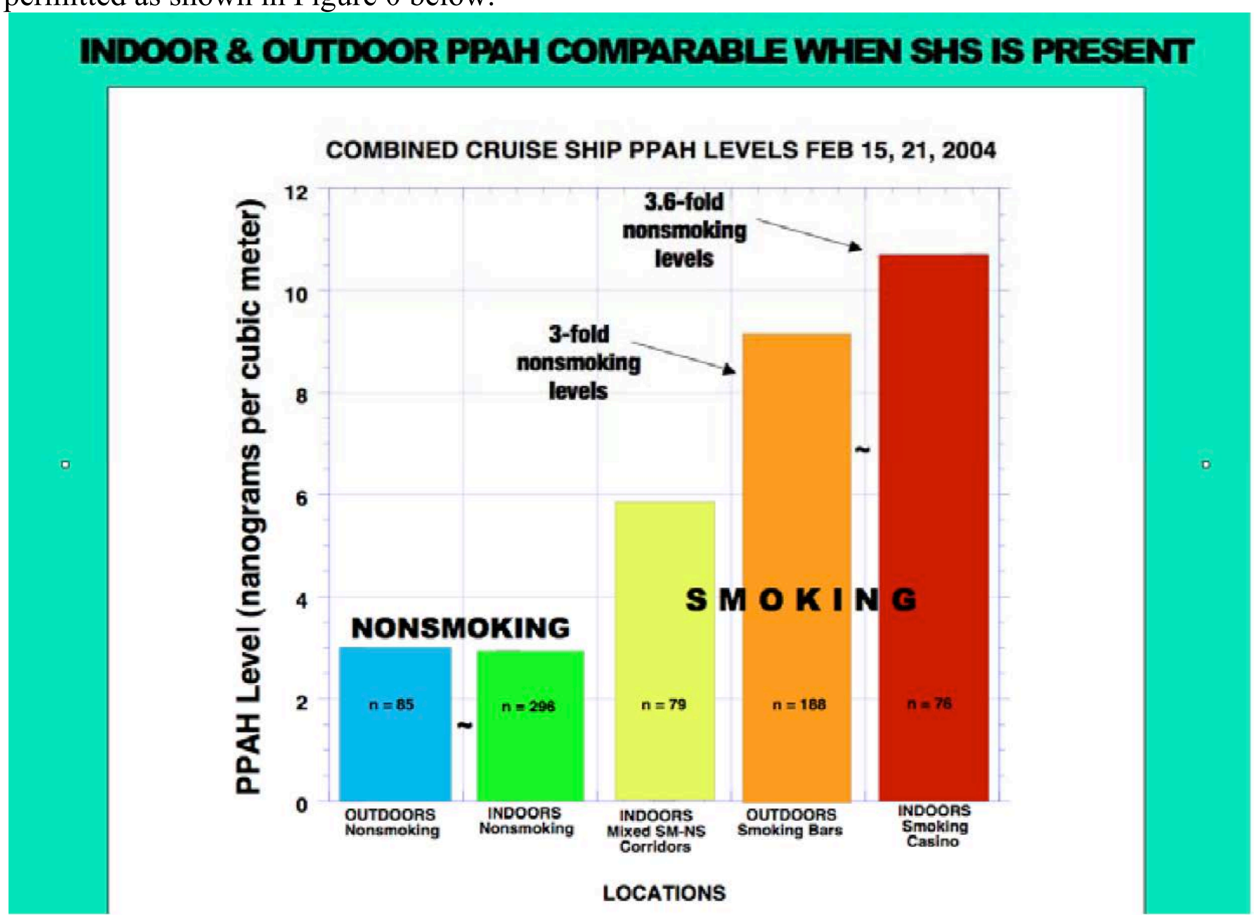


Figure 0. Indoor and Outdoor Carcinogen Pollution on a Cruise Ship (Repace, 2005).

- California. Klepeis, et al. (2007) measured SHS respirable particle concentrations in outdoor patios, on airport and city sidewalks, and in parks. They also conducted controlled experiments of SHS both indoors and outdoors. Klepeis et al. (2007) found that mean SHS particle concentrations outdoors can be comparable to SHS indoors. **Within about 1.5 meters of a single smoker SHS was quite high and comparable to SHS concentrations measured indoors. <u>They also found that SHS levels from a single smoker measured in two sidewalk cafés were detectable at distances beyond 4 meters at wind speeds of 1 m/s as shown in the figure below</u>.** They found that SHS peaks are sensitive to source-receptor proximity and wind velocity. Thus, long-term averages for SHS concentrations are averaged over a large number of transient peaks, which only occur when smokers are active. Klepeis et al. (2007) found that particle concentrations declined approximately inversely with increasing distance from a single smoker, and that lower wind speeds led to higher downwind concentrations.

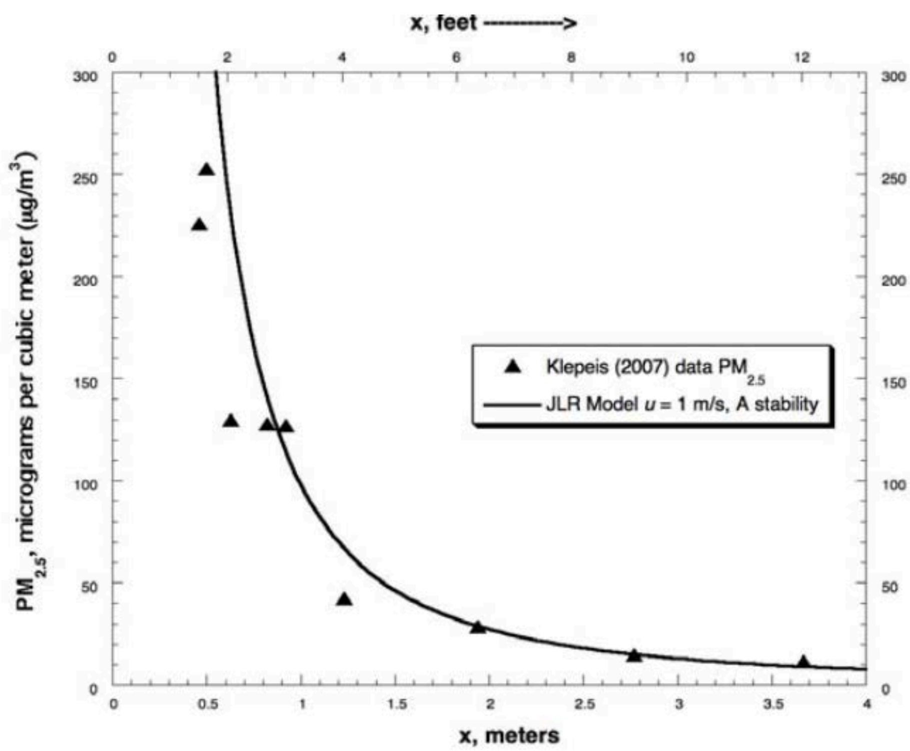


Figure 1. Outdoor Tobacco Smoke (OTS) in Two Sidewalk Cafes vs. Repace Model (Eq. 1) for strong sun and a wind speed of 1 m/s (Klepeis, et al., 2007; Birke v. Oakwood 2010).

- Maryland. Repace (2005) measured outdoor fine particle and carcinogen concentrations from SHS on the campus of the University of Maryland at Baltimore. Using controlled experiments, Repace (2005) found that cigarette smoke fine particle concentrations decline approximately inversely with distance downwind from the point source, whereas cigarette smoke carcinogen concentrations decline approximately inversely as the square of the distance from source to receptor. **The experiments with average wind speeds of 5 m/s with gusts to 10 m/s, showed that SHS smoke levels from just a single cigarette did not approach background levels either for fine particles or carcinogens until**

about 7 meters from the source as shown in Figure 2 below.

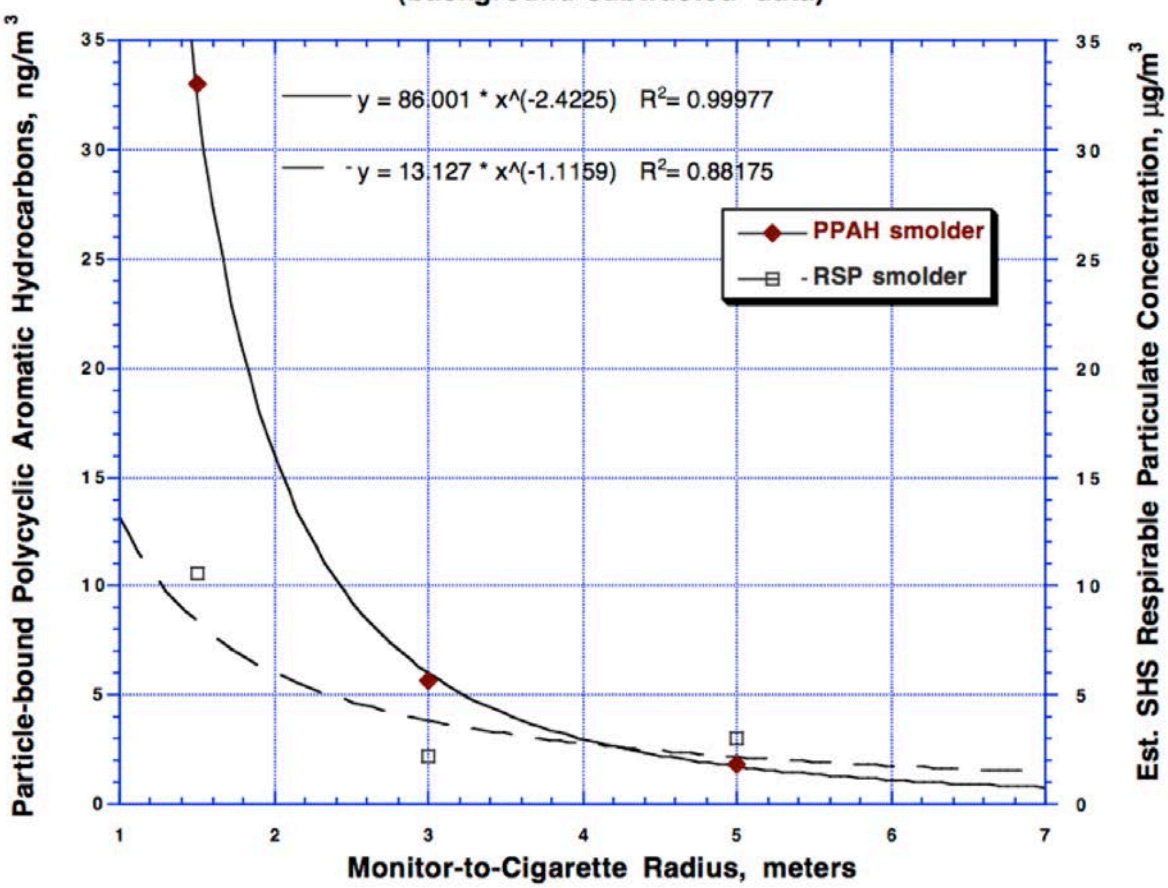


Figure 2. Fine particle (RSP) and Carcinogen (PPAH) levels from a single cigarette in an outdoor patio, shown below (Repace UMBC Report, 2005).

Figure 3. Monitors located in luggage in center of outdoor patio.

- Australia, Canada, New Zealand, United States, Denmark, and Spain. Sureda et al. (2013) reviewed 18 studies of SHS in outdoor settings. Most studies used $PM_{2.5}$ concentration as a SHS marker. Mean $PM_{2.5}$ concentrations reported for outdoor smoking areas when smokers were present ranged from 8 to 124 $\mu g/m^3$ at hospitality venues, and ~5 to 18 $\mu g/m^3$ at other outdoor locations. Mean $PM_{2.5}$ concentrations in smoke-free indoor settings near outdoor smoking areas ranged as high as 121 $\mu g/m^3$ due to infiltration from outdoor smoking. SHS levels increased when smokers were present, and outdoor and indoor SHS levels were related. Most studies reported a positive association between SHS measures and smoker density, enclosure of outdoor locations, wind conditions, and proximity to smokers. **They conclude that their review clearly indicates the potential for high SHS exposures at some outdoor settings and indoor locations adjacent to outdoor smoking areas.**

- California. Acevedo-Bolton, et al. (2013) performed experiments in 16 outdoor locations, each with 2 to 4 non-smokers sitting near a cigarette smoker. **Their measurements show that non-smokers were exposed to high $PM_{2.5}$ concentrations (one-quarter were above 33 $\mu g/m^3$ outdoors, as well as very high 10-s peak concentrations (> 1000 $\mu g/m^3$) in close proximity to an active smoker.**

- Canada. Kaufman et al. (2010) measured respirable particulate matter (PM2.5) pollutant as a marker for tobacco smoke, outside 28 entrances to office buildings in downtown Toronto, Ontario, in May and June 2008. Measurements were taken when smoking was and was not present within 9 m of entrances. Background levels of $PM_{2.5}$ were also measured for each session. Peak levels (10 s averages) of $PM_{2.5}$ were as high as 496 $\mu g/m^3$ when smoking was present. Average outdoor $PM_{2.5}$ with smoking was significantly higher than the background level ($p<0.0001$), and significantly and positively associated with the number of lit cigarettes ($p<0.0001$). **The average level of $PM_{2.5}$ with 5 or more lit cigarettes was 2.5 times greater than the average outdoor background level.**

- USA, Australia, New Zealand, Canada, Spain, Denmark. Licht et al. (2013) reviewed 16 peer-reviewed studies plus 7 unpublished studies, focusing on SHS exposure levels observed at outdoor areas of hospitality, and hospitality-like settings. Using the data obtained from the experimental and observational studies in the peer-reviewed literature, estimates of excess $PM_{2.5}$ exposure were calculated. These estimates were meant to approximate the above-background $PM_{2.5}$ exposure levels that may be experienced by employees working at typical smoking-allowable outdoor hospitality venues. Licht et al. concluded that typical outdoor dining or drinking areas of bars and restaurants can lead to elevated levels of SHS exposure for both patrons and workers. Further, they found that exposure of patrons and staff is increased by denser table placement, greater numbers of active smokers, steady wind directions and lighter wind speeds, and other factors such as partial wall or roof coverings. **They conclude that partial smoke-free policies may be inadequate in limiting SHS exposures for both patrons and workers in settings where patrons are such as beer gardens or outside areas of bars.**

- California. Ott et al. (2014) Measured $PM_{2.5}$ at six sidewalk bus stops located 1.5–3.3 m from the curb of two heavily traveled California arterial highways with 3300–5100 vehicles per hour. At each bus stop, a smoker in the group smoked a cigarette. **The results indicate that a single cigarette smoked outdoors at a bus stop can cause $PM_{2.5}$ and ultra-fine particle concentrations near the smoker that are 16–35 and 6.2 times, respectively, higher than the background concentrations due to cars and trucks on an adjacent arterial highway.**

- Italy. Demarco and Rupprecht (2014) compared the $PM_{2.5}$ emissions of a 450 horsepower diesel truck to that of two cigarettes over a 20 minute interval in a test building**. They found that the cigarette produced six times the $PM_{2.5}$ as much pollution as the truck.**

- Australia. Stafford et al. measured fine particulate matter ($PM_{2.5}$) in the alfresco areas of 28 cafes and pubs. They found that $PM_{2.5}$ concentrations were significantly increased when there was at least one smoker compared to periods with no smoking (14.25 $\mu g/m^3$ and 3.98 $\mu g/m^3$, respectively). There was evidence of a dose response increase with mean concentrations for none, one and two or more smokers of 4, 11 and 17 $\mu g/m^3$, respectively. When two or more people were smoking, average $PM_{2.5}$ reached levels the US Environmental Protection Agency warns may put particularly sensitive people at risk of respiratory symptoms. **They concluded that smoking increases $PM_{2.5}$ concentrations in outdoor areas to levels that are potentially hazardous to health.**

- Austria, France, Ireland, Italy, Poland, Portugal, Slovak Republic, and Spain. Lopez, et al. assessed the level of SHS exposure in terraces and other outdoor areas of hospitality venues of eight European countries by measuring nicotine and $PM_{2.5}$ concentrations, and to evaluate their potential displacement to adjacent indoor areas. They found that gathered 142 $\mu g/m^3$ measurements during the study. The median indoor SHS concentration was significantly higher in venues where smoking was allowed (121 $\mu g/m^3$) than in those where smoking was banned (37 $\mu g/m^3$). Among the different types of outdoor areas, the highest median outdoor SHS $PM_{2.5}$ levels (44 $\mu g/m^3$) were found in the semi-closed outdoor areas of venues where indoor smoking was banned. **The authors conclude that this study shows that SHS levels in the semi-closed outdoor areas of hospitality venues may constitute an unacceptable risk, especially for hospitality workers and that partially restricting indoor SHS levels appears insufficient to protect hospitality workers – and patrons – from SHS exposure. They assert that smoke-free terraces for hospitality venues should ensure effective protection.**

<u>**Summary of Outdoor Studies**</u>

Based on field studies and experiments conducted in Canada, the USA, Austria, France, Ireland, Italy, Denmark, Poland, Portugal, Slovak Republic, Australia, New Zealand, and Spain, the levels of fine particulate matter ($PM_{2.5}$) on outdoor terraces are significantly increased as a result of secondhand smoke. Studies in California, Italy, Finland, and Denmark indicated that these levels are much higher than those due to vehicular traffic. <u>Thus there is a scientific consensus on the high levels of secondhand smoke in outdoor areas of hospitality venues.</u>

Secondhand Smoke Dose

St. Helen et al. (2012) characterized the exposure of nonsmokers to secondhand smoke (SHS) outside a restaurant and bar in Athens, Georgia, USA in 2010, where indoor smoking was banned, using salivary cotinine and urinary 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL), a secondhand smoke carcinogen. These outdoor patios were frequented by both smokers and nonsmokers. They assigned 28 participants to outdoor patios of a restaurant and a bar with smokers, and used an open-air site with no smokers for a control, on three weekend days; participants visited each site once and stayed for 3 hours. Cigarettes were counted every 10 minutes for 3 hours. The bar had 6 tables, and 145 cigarettes were smoked (86 to 202 cigarettes per 10 minute period), while the restaurant had 17 tables and 34 cigarettes were smoked (12 to 86 cigarettes per 10 minute period). The control with open-air seating, had zero cigarettes smoked. The bar area was 176 m^2 and was abutted by two walls of adjacent buildings, while the restaurant patio was 549 m^2 and completely open to the air. Thus, the restaurant and bar studied appear to be typical of the sort of hospitality venues encountered outdoors.

St. Helen et al. (2012) found that Post-exposure differed from pre-exposure geometric mean salivary cotinine concentrations by $\Delta S = 0.115$ nanograms per milliliter (ng/mL) [95% confidence interval (CI): 0.105, 0.126)] for bar and restaurant visits. There were no significant post- and pre-exposure differences in cotinine levels after control site visits, and changes after bar and restaurant site visits were significantly different from changes after control site visits ($p < 0.001$). Results comparing next-day and pre-exposure salivary cotinine levels were similar. Next-day creatinine-corrected urinary NNAL concentrations also were higher than pre-exposure levels following bar and restaurant visits, and were significantly different from changes after the control visits ($p = 0.005$). The authors conclude that salivary cotinine and urinary NNAL increased significantly in nonsmokers after outdoor SHS exposure, indicating that outdoor secondhand smoke exposures on restaurant and bar patios may increase risks of health effects associated with tobacco carcinogens.

Using the Rosetta Stone Equations of Repace et al. (2006; 2012), the dosimetry in the St. Helen study may be analyzed to estimate actual personal dose of secondhand smoke fine particulate matter in outdoor terraces for bar wait staff. The Rosetta Stone Equation relating secondhand smoke $PM_{2.5}$ (SHS $PM_{2.5}$) to saliva cotinine S is given by the expression: SHS $PM_{2.5} = 1440\ S/\rho H$, where $S = 0.115$ ng/mL, ρ is the respiration rate of the person which is taken a 0.5 m^3/hour for sedentary adults, and H = 3 hours is the duration of exposure. Thus, SHS $PM_{2.5} = 1440\ S/\rho H = (1440)(0.115\ \text{ng/mL})/\{(0.5\ m^3/h)(3\ h)\} = 110\ \mu g/m^3$. By comparison, as the chart below shows in Figure 4, the Canadian Air Quality Index for $PM_{2.5}$ defines a 3-hour concentration of greater than 90 $\mu g/m^3$ as Very Poor Air Quality (Code Red). In 2013, for Montreal, outdoor background fine particle air pollution averaged 25 $\mu g/m^3$ by comparison.

Canadian Air Quality Index (AQI) Break points for $PM_{2.5}$ (Ontario Environment, 2012)

Fine particulate matter ($PM_{2.5}$)

AQI category	$[PM_{2.5}]$ 3-h average ($\mu g/m^3$)
Very Good (Code Blue)	<12
Good (Code Green)	12–22
Moderate (Code Yellow)	23–45
Poor (Code Orange)	46–90
Very Poor (Code Red)	>90

Figure 4. Canadian Air Quality Index, 3-hour averages for fine particle pollution ($PM_{2.5}$).

Thus, it appears that the equivalent air pollution dose on a restaurant-bar terrace to the cotinine measured by St. Helen et al. (2012) constitutes Very Poor, or Code Red Air Quality, and is accompanied by a measurable dose of a tobacco-specific carcinogen. This indicates that wait staff in outdoor terraces are at considerable risk of air-pollution-related diseases from secondhand smoke exposure.

Dose-Response

Repace et al. (1998) estimated an increased lifetime mortality risk of 1 per 1,000 persons for lung cancer and 1 per 100 persons for heart disease from an average salivary cotinine of 0.4 nanograms per milliliter (ng/mL). This method has also been used to estimate risks from secondhand-smoke induced urinary cotinine in Hong Kong catering workers, and Toronto bartenders (Hedley et al., 2006; Repace et al., 2012). Geometric mean salivary cotinine levels from SHS exposure for the bar and restaurant studied by St. Helen et al. (2012) were 0.115 ng/mL (95% CI 0.105 - 0.126) and one participant had an increase of 0.4 ng/mL. Applying this dose-response relationship to the workplace dose in the bars and restaurants yields: Risk = [(1/1000)/(0.4 ng/mL)](0.115 ng/mL) = ~3 lung cancer deaths per 10,000 workers and ~3 heart disease deaths per 1000 workers for a working lifetime of 40 years. Combined, this is ~3.3 deaths per 1000 workers from outdoor secondhand smoke. **To put this into perspective, the dose of secondhand smoke in outdoor patios of the bar and restaurant in the St. Helen Study is equivalent to a risk that is more than three times the level that the US Occupational Safety and Health Administration (OSHA) defines as "significant risk of material impairment of health."**

Risk

There are approximately 47,500 Food and Beverage Servers in Quebec in 2011-2012 (Statistics Canada, 2015). Assuming conservatively that 50% are nonsmokers (Repace et al., 2012), there are 23,750 nonsmokers among these. According to the Corporation des proprietaires de bars, brasseries, et tavernes du Quebec (2015) 70% of bars operate patios. Assuming 70% of these workers are exposed in outdoor settings, there are approximately 16,625 workers at risk from secondhand smoke on bar and restaurant terraces. Over a working lifetime, an estimated (16625)(3.3/1000) = 55 nonsmoking workers would die from secondhand smoke exposure over a working lifetime, constituting a "significant risk of material impairment of health" by US OSHA criteria. **While this estimate is based on limited data, taken together with the numerous outdoor studies in several countries cited above, it suggests that secondhand smoke exposure on outdoor terraces poses a significant risk of excess mortality for Quebec waiters and bartenders.**

Control

Workers: The obvious method of control is to ban smoking on terraces for the health and safety of the workers who have to work in a sea of secondhand smoke. According to the Montreal Gazette (2015), Quebec's association of bar owners says it wants to compromise the proposed provincial smoking ban on terraces by separating terraces into smoking and non-smoking sections. **This of course, would force wait staff to work in an area almost entirely populated by smokers, posing an even greater risk of material impairment of health. This is in fact the primary reason why smoking on terraces must be prohibited: to protect the health and lives of wait staff.**

- Maryland. Repace (2010) measured **carcinogenic polycyclic aromatic hydrocarbon (PAH) concentrations from two cigarettes smoked over a 20 minute period by a single smoker outdoors that were double background levels 13 meters distant from the smoker -- and were irritating to human observers through an open window in a neighboring home.** Using a Gaussian air pollution plume dispersion model (Turner,1994), that incorporated wind speed and direction, common daytime and nighttime atmospheric stability conditions, and typical cigarette $PM_{2.5}$ emissions, the predicted range bounded the observed values, indicating that outdoor secondhand smoke carcinogen concentrations can be successfully modeled (Figure 5 below).

- California. Klepeis et al. (2006) **Predicted that a cigarette smoker outdoors would cause average fine particle levels ($PM_{2.5}$) of approximately 70–110 $\mu g/m^3$ at horizontal distances of 0.25–0.5 m.** Measured average concentrations of carbon monoxide (CO) from a point source were approximately inversely proportional to distance. Average CO concentrations rose significantly as average air speed decreased. The model predicts outdoor concentrations as a function of source emission rate, source–receptor distance, air speed and wind direction. Average CO levels were approximately proportional to source strength, supporting generalization of their results to different source strengths.

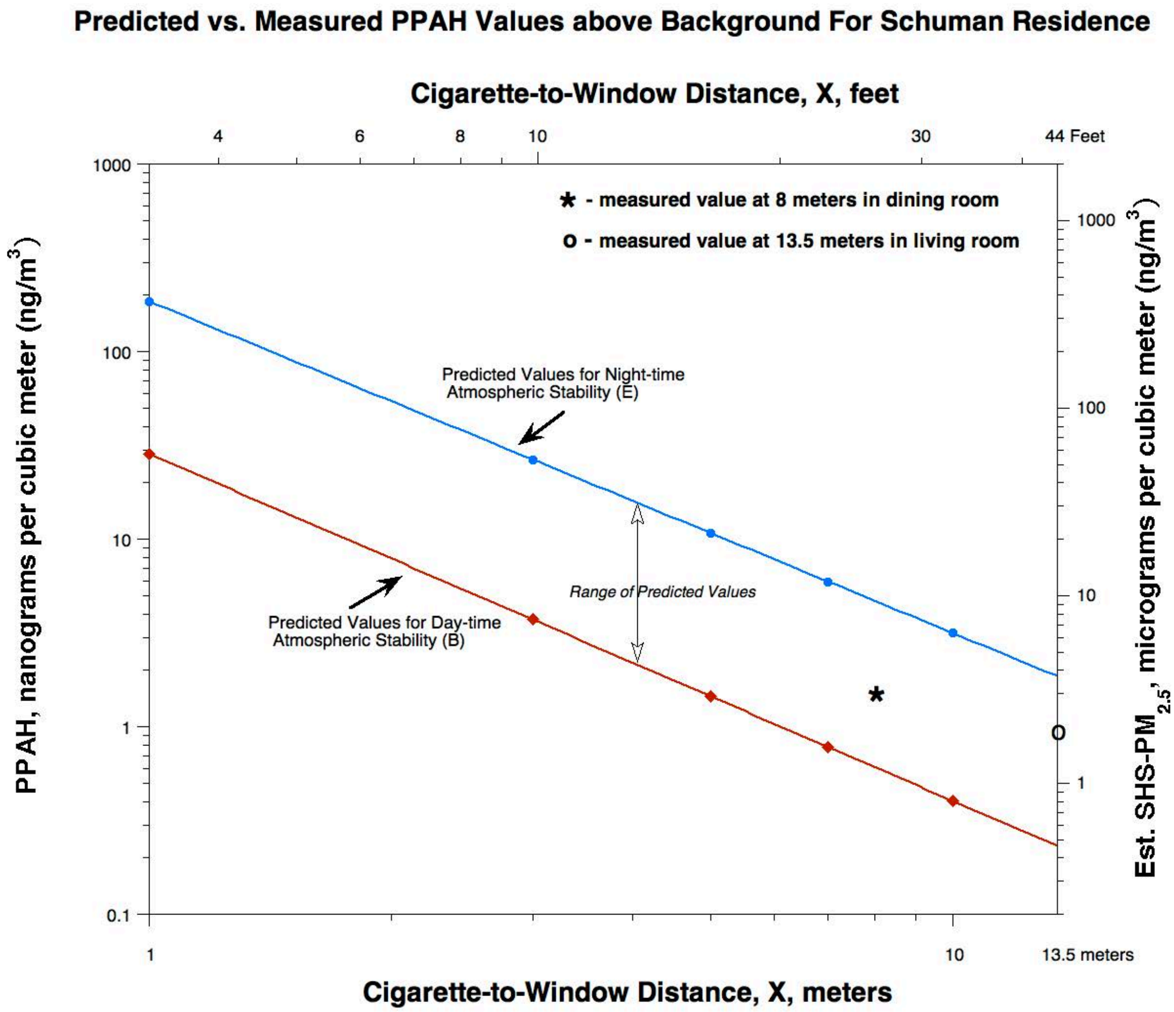


Figure 5. Plot of the expected range of carcinogenic PPAH concentrations from a single cigarette smoked outdoors from outdoor cigarette smoking, respectively 8 and 13 meters distant downwind. The upper (blue) curve shows the expected value for very stable night-time conditions, while the lower (red) curve shows the expected value for less stable daytime conditions, using the Gaussian plume model applied to a cigarette point source (Schuman v. Greenbelt Homes, et al, 2010). The fine particle concentrations are shown on the right axis. The * and the ^{o} show the actual measured PPAH data, showing that the model predictions span the actual data.

Patrons: Moreover, the nonsmoking patrons who sit in the non-smoking sections of the terraces would not be protected against the irritation and malodors of drifting secondhand smoke blown by the wind. The Union of Bar Owners of Quebec asserts that "Air quality on open-air terraces is not significantly affected by smokers," who cited a survey they commissioned to measure second-hand smoke on terraces. Unlike the vast majority of independent studies around the world the Bar Owners' survey concludes that smoking sections separated by 1.5 meters from the non-smoking zones on bar terraces be allowed on terraces. As shown above, this is assuredly wrong. Field studies by Klepeis et al.(2006) and Repace (2010) show clearly that secondhand smoke from just a single smoker have been measured at distances from 4 to 13 meters. Multiple smokers on a terrace constitute an area source of smoke which would be much higher and penetrate to greater distances, as shown in Figure 6 due to overlapping smoke plumes. **Thus a separation of 1.5 meters between the smoking and nonsmoking sections on terraces would utterly fail to protect nonsmokers in the nonsmoking section from the toxins and irritants in secondhand smoke**.

For example, in the study by St. Helen et al., the bar terrace had 6 tables, and 145 cigarettes were smoked in a three hour period , or an average of 48 cigarettes per hour. Since it takes 10 minutes to smoke a cigarette, and there are 6 ten-minute intervals in an hour, this means that 8 cigarettes being smoked at any one time. Since each cigarette would emit 14 milligrams (14,000 micrograms) of secondhand smoke tar particles (Repace, 2007), such the smokers would generate (14,000 μg/cigarette)(48 cigarettes/hour) = 672,000 μg of $PM_{2.5}$ per hour, an enormous cloud of toxic tobacco smoke. Since this constitutes an area source, many individual plumes would overlap in the nonsmoking section, when it is downwind.

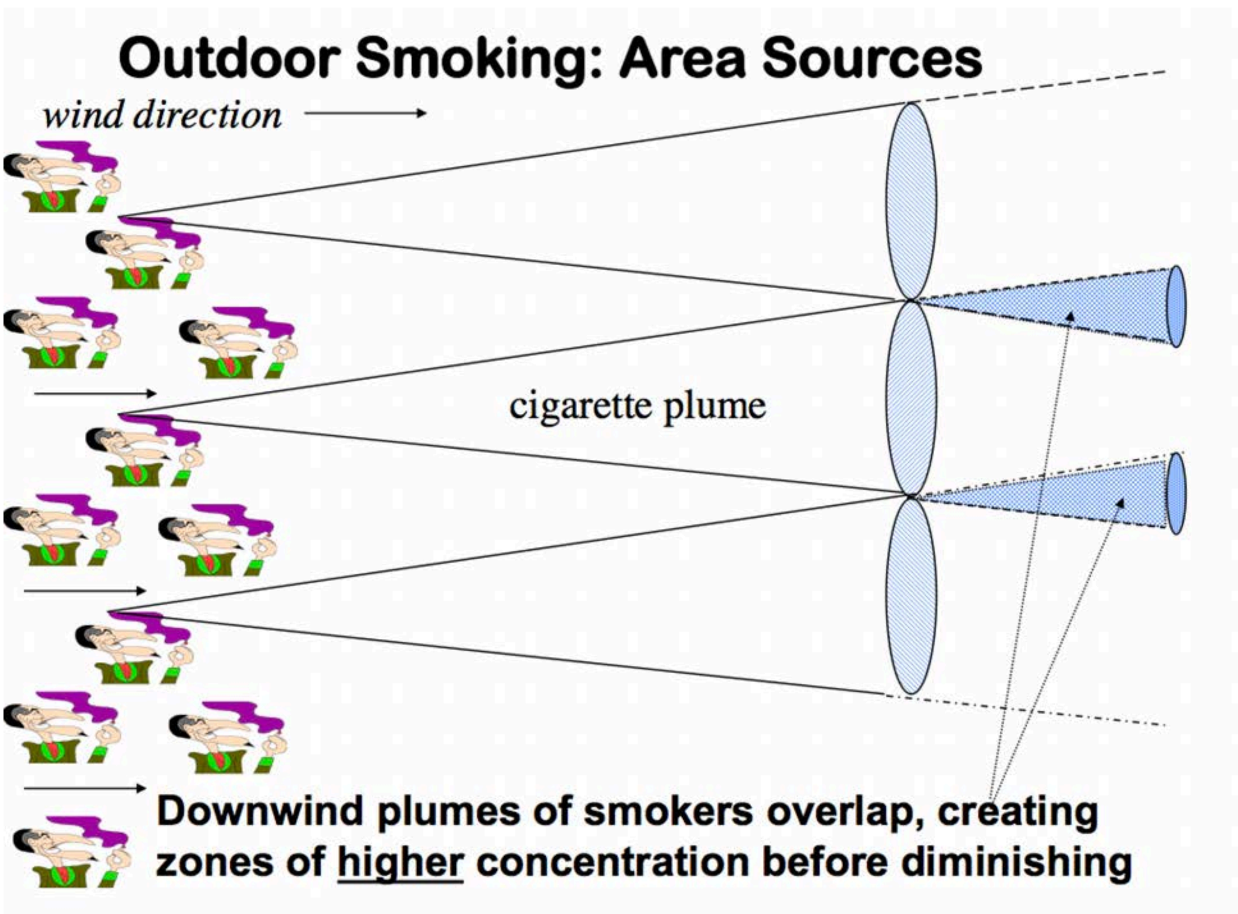


Figure 6. Downwind cigarette plumes, which approximate cone-shapes, are shown for 3 of the 11 cigarette smokers. Overlapping plumes will create zones of higher pollution downwind, before dissipating at greater distances.

Figure 7 shows the effect of increased wind speeds on the altitude of the smoke plume.

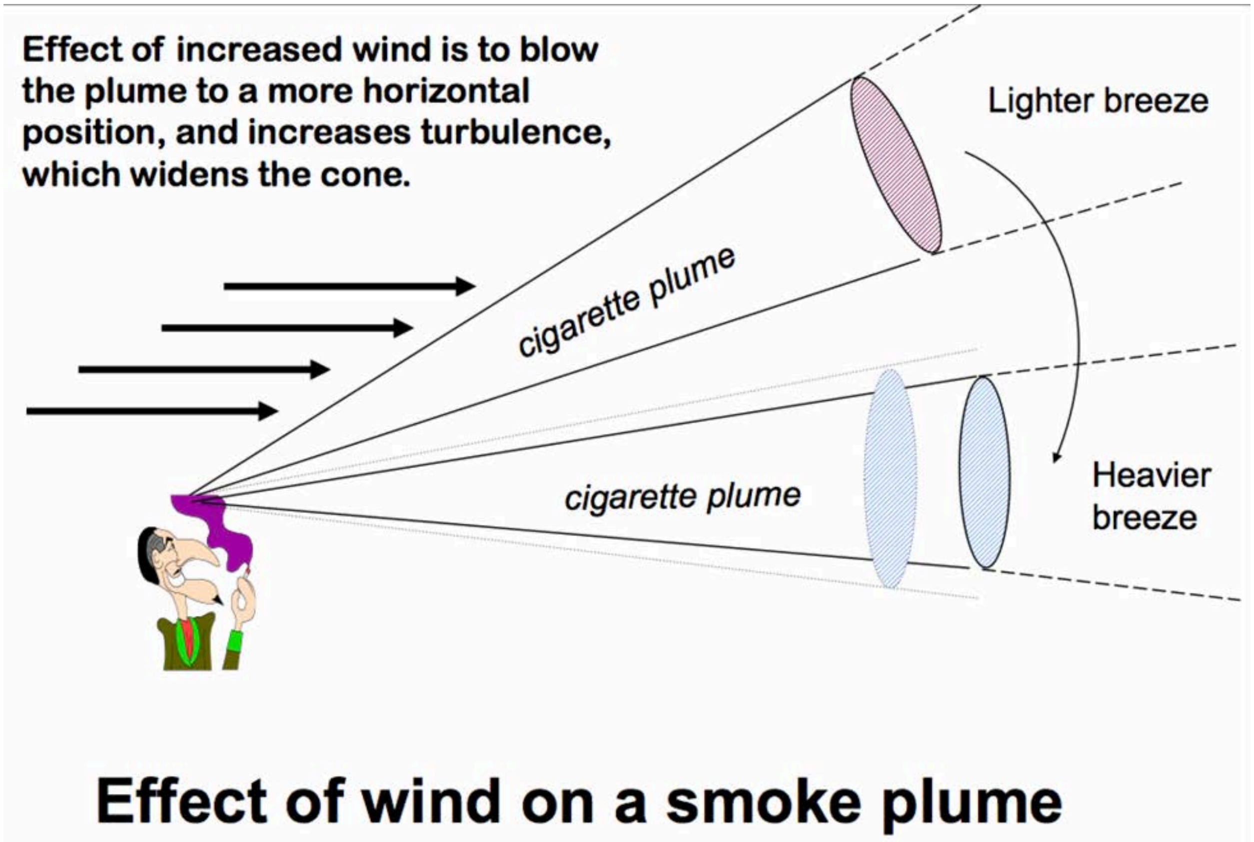


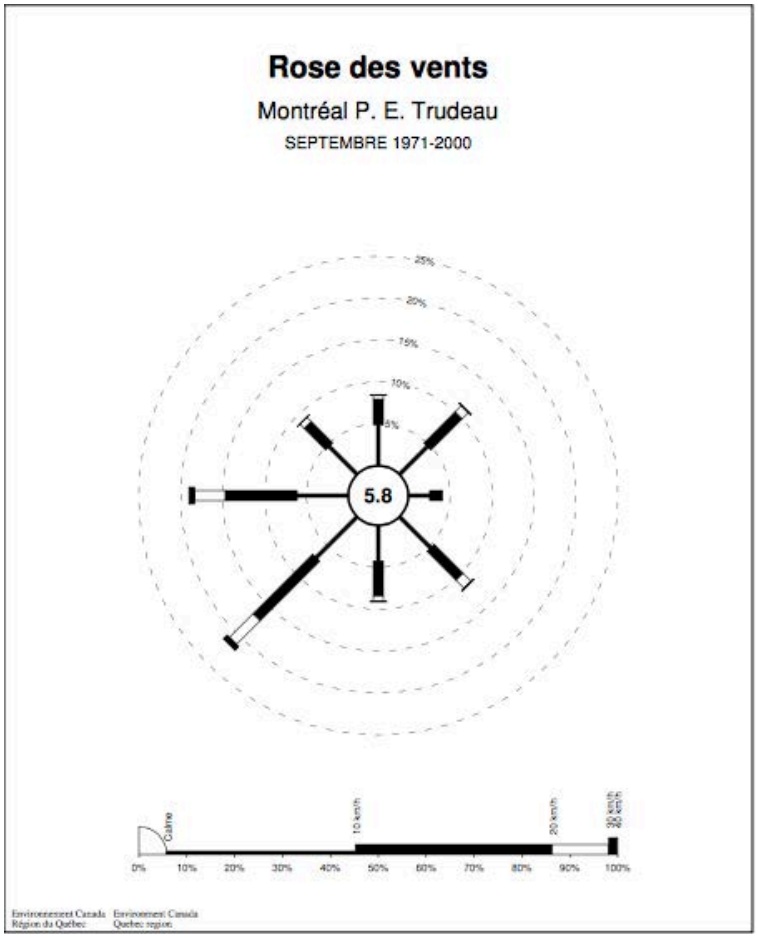
Figure 7. Effect of increasing wind speed on a cigarettes smoke plume. When there is no wind, the plume will rise until it cools, and then subside, leading to the highest local concentrations.

The modeling of outdoor secondhand smoke shown in Figures 1 and 5 was accomplished application of the ground-level release model given in Turner's Workbook of Atmospheric Diffusion Estimates (Turner, 1994). This yielded reasonably accurate results as shown in those graphs. The model used to estimate outdoor secondhand smoke is given below (Schuman v. Greenbelt Homes, Inc., 2010).

Dispersion Equation:

$$C = Q/[\pi \sigma_y(x)\ \sigma_z(x)\ u] \quad \text{Equation (1)},$$

where C is the pollution concentration in units of micrograms per cubic meter ($\mu g/m^3$), Q is the source strength, u is the wind speed in m/s, for an outdoor ground level pollutant release along the center of the plume line. The concentration in the downwind direction, x, is a function of the wind speed and dispersion coefficients, $\sigma_y(x)$ and $\sigma_z(x)$. Values for these coefficients are obtained from *Turner's Workbook of Atmospheric Diffusion Estimates*, 2nd Edition, 1994. Wind speed u is estimated from a wind rose. Unless there is no wind, Eq. 1 shows three things: first that downwind concentrations are higher with lower wind speeds. Second, the plume is approximated by a cone of elliptical cross-section, that increases as the plume travels downwind, as shown in Figure 7. The dispersion coefficients, which are determined by atmospheric stability and distance x, are smaller for more stable air, leading to higher downwind concentrations than less stable air. These coefficients are obtained from a Table in the Workbook. Third, the source strength Q increases with the number of cigarettes smoked. Thus, ten smokers will produce ten times the downwind concentration as one smoker at a given distance with the same atmospheric conditions. So field data can be scaled by the number of smokers and the smoking rate observed.



ENVIRONNEMENT CANADA - RÉGION DU QUÉBEC
DIVISION DES SERVICES SCIENTIFIQUES

Rose des vents   Montréal P. E. Trudeau   SEPTEMBRE 1971-2000

FRÉQUENCE DES VENTS PAR DIRECTION A 8 POINTS DE COMPAS
(Vitesses en km/h; Fréquences en pourcentage)

	NE	E	SE	S	SW	W	NW	N	
CALME									5.8
1- 10	4.7	2.6	5.2	4.2	6.9	6.1	4.7	4.9	39.4
11- 20	5.3	1.4	4.9	4.2	10.1	8.6	3.6	3.0	41.1
21- 30	1.0	0.1	1.3	0.6	4.0	3.6	0.7	0.5	11.8
31- 40	0.1	0.0	0.1	0.1	0.6	0.6	0.0	0.1	1.6
41+	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.2
Toutes	11.1	4.1	11.6	9.1	21.6	19.0	9.1	8.5	
Vit moy.	12.4	9.4	12.4	11.6	14.8	15.0	11.0	10.3	12.2

Nombre d'observations: 21573
Nombre d'invalides: 0

Figure 8. Wind Rose for Trudeau Airport, Montreal. http://www.climat-quebec.qc.ca/htdocs/data_fixe/rose_des_vents/RDVT_7025250.pdf

Figure 8 above, shows the wind rose (Rose des vents) for Montreal's Trudeau Airport for the month of September, incorporating 21,573 observations from 1971 to 200. The wind rose shows the wind frequency by speed and direction. For example, as the chart below shows, the wind blows from the west 19% of the time. When there is a west breeze, 39.4% of the time, the wind speed ranges from 0 to 10 kilometers per hour (km/h), from 11 to 20 km/h 8.6% of the time, between 21 and 30 km/h 3.6% of the time, and 0.6% of the time the wind blows between 31 and 40 km/h. 5.8% of the time, the wind is calm. The wind rose may differ significantly from month to month. Meteorological data, such as wind direction and velocity, are essential to validate and interpret air quality data. Below, Figure 9 shows a more detailed plot of wind velocity for December. Calm winds have declined to only 0.54%, and west winds have increased to 24.2%.

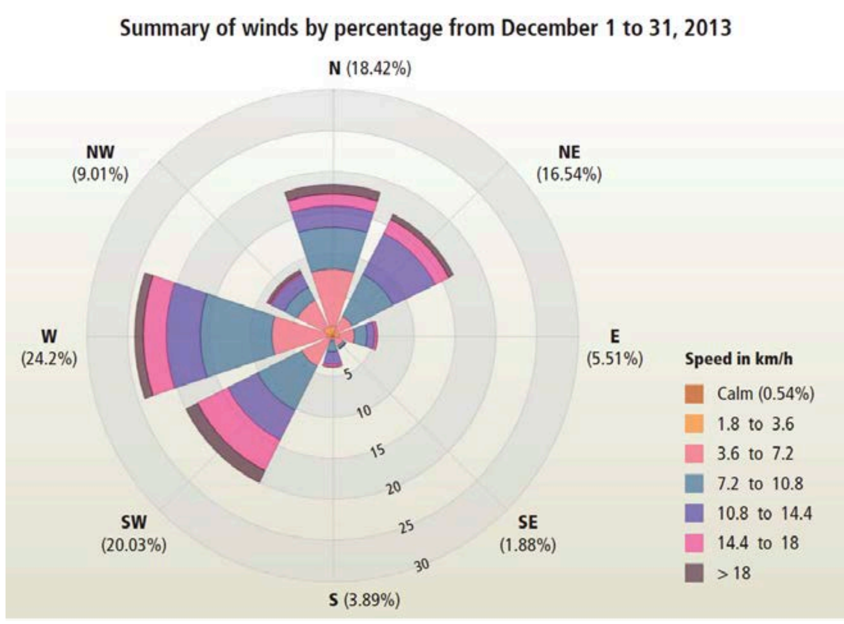


Figure 9. Wind Rose for Trudeau Airport, December 2013.

Figure 9 below shows a scene from a Montreal sidewalk dining terrace. The effect of multiple smokers on each table will be to expose wait staff to very high concentrations of outdoor secondhand smoke, no matter which way the wind blows, creating a significant occupational health risk. And if nonsmoking sections were established, the smoke could not be contained in the smoking section.

MONTREAL TERRASSE, PHOTO CREDIT, CBC, 2013.

Figure 9. A Montreal Sidewalk Bar Terrace. The umbrellas act to limit the rise of smoke and contain it on the terrasse, where it can blow into nonsmokers' faces. Note the presence of ashtrays on each table.

Discussion

Outdoor tobacco smoke concentrations are determined by the number of smokers, the wind speed and direction, and the stability of the atmosphere. Daytime conditions are more turbulent with higher wind speeds, while nighttime conditions typically have lower wind speeds and more stable atmospheres, leading to higher down wind concentrations. Exposure of nonsmokers depends on the distance between the smokers and nonsmokers, with wait staff being the exposed to secondhand smoke at distances typically less than 1 meter being at the greatest risk of the diseases of secondhand smoke inhalation (passive smoking). Establishment of smoking and nonsmoking sections increases the exposure of wait staff, as they must work in the smoking section surrounded by smokers. As my analysis of the St. Helen et al. study shows, this can lead to a significant risk of material impairment of health for wait staff. Smoking and nonsmoking sections even separated by distances as large as 13 meters cannot limit the exposure of nonsmoking patrons to less-than-irritating concentrations of secondhand smoke. The only control measure that will protect both nonsmoking workers and patrons in outdoor cafes is a complete ban on smoking, as proposed by Bill 44 in the Quebec National Assembly. I reach these conclusions to a reasonable degree of scientific certainty.

Conclusions

1. **Based on field studies and experiments conducted in Canada, the USA, Austria, France, Ireland, Italy, Denmark, Poland, Portugal, Slovak Republic, Australia, New Zealand, and Spain, the levels of fine particulate matter ($PM_{2.5}$) on outdoor terraces are significantly increased as a result of secondhand smoke. Studies in California, Italy, Finland, and Denmark indicated that these levels are much higher than those due to vehicular traffic.**
2. **The dosimetry study in a bar and restaurant, plus the numerous outdoor studies in several countries cited above, suggests that secondhand smoke exposure on outdoor terraces poses a significant risk of excess mortality for the estimated 16,625 nonsmoking Quebec wait staff working in bars.**
3. **Thus there is a scientific consensus on the danger of secondhand smoke for wait staff in outdoor terrace settings.**
4. **Modeling of secondhand smoke outdoors indicates that downwind concentrations are proportional to the number of smokers, inversely proportional to the wind speed and are higher when the atmosphere is more stable. A large number of smokers concentrated in a smoking section increases the exposure of wait staff.**
5. **Establishing smoking sections will increase the exposure and risk to the Quebec wait staff exposed on bar terraces.**
6. **Because elevated levels of harmful secondhand smoke fine particles and carcinogens from a single cigarette have been measured at distances in three studies ranging from 4 meters to 13 meters, and because modeling shows that cigarette smoke from multiple smokers will increase the distance at which smoke concentrations remain excessive, the separation distance of 1.5 meters proposed by the study commissioned by l'Union des tenanciers de bars du Québec (UTBQ) must be rejected.**

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APPENDIX

James Repace Biosketch: I hold a MSc. in physics from the Polytechnic Institute of Brooklyn, and currently perform research on indoor and outdoor air pollution, especially from secondhand smoke. I have advised government authorities in numerous countries in North and South America, Europe, and the Pacific Rim, as well as the World Health Organization. I have published 56 peer-reviewed scientific research papers on the hazard, exposure, dose, risk, and control of secondhand smoke (SHS), and have conducted numerous field studies of SHS. For my work on SHS, I have received several national honors, including the Flight Attendant Medical Research Institute Distinguished Professor Award, the Robert Wood Johnson Foundation Innovator Award, the Surgeon General's Medallion, a Lifetime Achievement Award from the American Public Health Association and the Constance Mehlman Award from the International Society for Exposure Science.

From 2007 to 2013, I was a consultant to the Stanford University Department of Civil and Environmental Engineering, conducting research on secondhand smoke in multi-unit housing and in casinos. From 2004 to 2011, I held an appointment as Visiting Assistant Clinical Professor at the Department of Public Health and Community Medicine at the Tufts University School of Medicine in Boston. From 1998 to 2015, I have been the President of Repace Associates, Inc., a secondhand smoke consulting firm. I am a former senior air policy analyst and staff scientist with the U.S. Environmental Protection Agency in Washington, DC (1979-1998). During the 1980's and 1990's, I served as a consultant to the Occupational Safety and Health Administration, U.S. Department of Labor, the U.S. Department of Health & Human Services, the U.S. Department of Transportation, and committees of both the U.S. Senate and House of Representatives. During the 1970's, I served as a research physicist at the Naval Research Laboratory in the Ocean Sciences and Electronics Divisions, and in the 1960's, I was employed as a health physicist at Delafield Hospital on the health physics staff of the City of New York, and in the Thyromedical Clinic at Grasslands Hospital, Westchester County, NY.

I am a member of the American Public Health Association, the International Society of Indoor Air Quality and Climate, the International Society of Exposure Science, the American Society of Heating, Refrigeration, and Air Conditioning Engineers, and was elected to Sigma Xi, the Scientific Research Society, in 1970. A current CV, a list of my publications and presentations, and numerous downloadable reports on secondhand smoke are available on my website: www.repace.com. In addition, downloadable copies of all of my publications are available on Research Gate, or through Google. Citations to my publications are listed on Google Scholar.

Education

Polytechnic Institute of Brooklyn, BSc., Physics, 1962;
Polytechnic Institute of Brooklyn, MSc., Physics 1968
University of Maryland Post-masters study, Physics, 1969
Catholic University 1970-1972 Pre-Doctoral study, Physics, ABD.

EMPLOYMENT

1963 Sr. Laboratory Technician	Radioisotope Laboratory, Grasslands Hospital, N.Y.
1964 Jr. Physicist	Dept. of Physics, New York City Dept. of Hospitals, New York, NY
1965-1968 Research Associate	Insulator Physics Group, RCA David Sarnoff Laboratory, Princeton, NJ
1969-1971 Research Physicist	Ocean Science Division, Naval Research Laboratory, Washington, DC
1971-1979 Research Physicist	Electronics Division, Naval Research Laboratory, Washington, DC
1979-1986 Policy Analyst	Science Policy Staff; Office of Air & Radiation, U.S. EPA, Washington, DC
1986-1993 Policy Analyst	Indoor Air Division, Office of Radiation & Indoor air; U.S. EPA, Washington, DC
1993-1994 Physicist	Exposure Assessment Group, Office of Research & Development, U.S. EPA, Washington, DC
1994-1995 Policy Analyst (on detail)	Health Standards Division, OSHA, U.S. Dept. of Labor, Washington, DC
1995-1997 Policy Analyst	Indoor Air Division, Office of Radiation & Indoor Air; U.S. EPA, Washington, DC
1998- Scientific Consultant	Repace Associates, Inc., *Secondhand Smoke Consultants*

RESEARCH AREAS, IN CHRONOLOGICAL ORDER

- RADIATION DOSIMETRY
- HIGH VACUUM TECHNOLOGY
- NUCLEAR ACTIVATION ANALYSIS
- RADIATION EFFECTS IN SOLID STATE DEVICES
- OUTDOOR AIR POLLUTION MODELING
- REAL TIME PARTICULATE MEASUREMENTS OF SECONDHAND SMOKE
- SECONDHAND SMOKE MODEL RESEARCH
- INDOOR AIR POLLUTION POLICY DEVELOPMENT
- RISK ASSESSMENT OF SECONDHAND SMOKE
- ELECTROMAGNETIC FIELD POLICY DEVELOPMENT
- OCCUPATIONAL EXPOSURES TO SECONDHAND SMOKE
- PHARMACOKINETIC MODELING OF SECONDHAND SMOKE COTININE
- OUTDOOR AIR POLLUTION STUDIES OF SECONDHAND SMOKE
- FIELD STUDIES OF SECONDHAND SMOKE IN CASINOS
- FIELD STUDIES OF SECONDHAND SMOKE IN MULTI-UNIT HOUSING

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AWARDS

1984	U.S. EPA Award for Exceptional Performance ($)
1988	Dr. Luther L. Terry Award, U.S. Public Health Professional Association
1989	Surgeon General's Medallion, U.S. Public Health Service
1990	Certificate of Appreciation, U.S. Department of Transportation
1991	Certificate of Appreciation, U.S. Dept of Health & Human Services
1994	OSHA *IMPACT* Award, U.S. Dept. of Labor (IAQ Team Award)
1994	U.S. Dept. of Labor Secretary's Excellence Award (IAQ Team Award)
1995	U.S. OSHA Outstanding Performance Rating
1998	Action on Smoking and Health Certificate of Appreciation
1998	Americans for Nonsmokers' Rights Plaque of Appreciation
1998	Prince Georges' County Civic Federation President's Award
1998	American Public Health Association, Lifetime Achievement Award
2002	Flight Attendant Medical Research Institute Distinguished Professor Award ($)
2002	Robert Wood Johnson Foundation Innovator Award ($)

2003	American Lung Association of Maryland Distinguished Service Award
2003	Natl. Cancer Institute of Milan (Italy), Recognition for Excellence in Smoke Studies
2015	Mehlman Award, International Society of Exposure Science ($)

MEMBERSHIPS

American Physical Society 1964 - 1979
Air Pollution Control Association 1979 - 1986
American Association for the Advancement of Science 1976 – 1990
American Public Health Association 1996 –
International Society for Exposure Science 1997 -
International Society of Indoor Air Quality and Climate 2002 -
American Society of Heating, Refrigerating and Air Conditioning Engineers 2003 -

POLICY OUTREACH

From 1980 to 2014, I gave 48 scientific conference presentations, presented 58 invited talks before medical and scientific groups, gave 121 television, radio, newspaper and magazine interviews, and presented 155 pieces of testimony at the international, federal, state, and local level that contributed to policies for reducing exposure secondhand smoke in the US and abroad. These presentations included four invited appearances before Congressional committees to testify on secondhand smoke risks and control, including testimony before the House Aviation Subcommittee in 1989 that helped increase the federal smoking ban on aircraft from flights less than two hours to flights less than six hours. In addition, I testified before the legislatures of Australia, New Zealand, Hong Kong, Canada, Ireland, The United Kingdom, and many US States and Canadian Provinces. Among the TV appearances on the lung cancer risks to the US nonsmoking population were CBS Evening News, ABC's Good Morning America, 60 Minutes, NOVA, and CNN. This outreach helped change public policy that reduced public exposure to secondhand smoke, and much of it was vigorously opposed by the tobacco industry, which made a major sustained effort to attempt to discredit my work.*

*Tobacco Memos Detail Passive-Smoke Attack, *The Wall Street Journal*, B1, Monday, April 28, 1998.