Risk Assessment of Secondhand Smoke Infiltration in a Greenbelt MD Town home: Located at 11 Ridge Road Q Part II, Outdoor Smoke

View of Unit Q (right) and Unit R (left) from garden side.

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PREPARED FOR MR. DAVID SCHUMAN

BACKGROUND: Mr. David Schuman resides at 11 Q Ridge Road, Greenbelt, MD 20770, in a cooperative association, Greenbelt Homes, Inc. (GHI). His unit is one of eight individual units in a connected row, brick construction with slate roof, built in the late 1930s. His unit adjoins the unit of his neighbors, the Mr. and Mrs. Popovic, who own Unit R. These neighbors are smokers. Mr. Schuman does not smoke. Nor does his neighbor on the other side of Mr. Schuman's unit.

Mr. Schuman relates that for many years, his neighbors have smoked inside and outside their unit. Conditions have been very bad on occasion but inconsistently so. In recent months, particularly over the winter, conditions became intolerable for him on a more regular basis. He complains of a heavy smoke smell on most nights. On occasion, he was forced to open his windows during winter to dissipate accumulating secondhand smoke (SHS) infiltrating from Unit R. He became ill with bronchitis-like symptoms for several months and visited the doctor twice.

Subsequently, Mr. Schuman filed suit against Mr. and Mrs. Popovic, and their cooperative association, Greenbelt Homes, Inc. In a preliminary court hearing, Mr. Popovic announced that he and his wife agreed not to smoke inside their residence, but insisted on the right to continue to smoke outside their residence on their own property. However, Mr. Schuman and the Popovic's neighbor in Unit S both stated that outdoor smoking by the Popovics penetrated into their homes when windows were opened.

Accordingly, in order to estimate the level of smoke that might penetrate the open windows of Mr. Schuman, I have conducted the following analysis. My scientific credentials to perform such an analysis are appended in About The Author.

Determinants and Measurements of Outdoor Secondhand Smoke Concentrations

1. The concentration of tobacco smoke pollution in buildings and in vehicles is proportional to the density of smokers, and inverse to the ventilation rate. Tobacco smoke pollution outdoors (outdoor secondhand smoke), is far more complicated, being determined by a combination of the density and distribution of smokers, the wind velocity (direction and speed), and the stability of the atmosphere. High outdoor SHS exposures are produced by high smoker density, low wind velocity, close proximity, and stable atmospheric conditions. SHS concentrations persist for hours after smoking ceases indoors, while SHS concentrations dissipate rapidly after smoking ceases outdoors. However, during smoking, SHS levels outdoors may be as high as SHS indoors, especially in close proximity to smokers.

2. Repace (2005; 2008) studied SHS outdoors on the campus of the University of Maryland, Baltimore County (UMBC) and also on a cruise ship in the Caribbean. Figure 1 shows the experimental array for the detection of particulate matter 2.5 microns in diameter or less ($PM_{2.5}$) and carcinogenic particulate polycyclic aromatic hydrocarbon (PPAH) from 8 smoldered cigarettes arrayed in a ring around the monitor such that the monitor detected the smoke of a single cigarette no matter what the wind direction.

Figure 1. Smoldering cigarettes arrayed on 8 chairs in a ring about the air quality monitors in luggage bags at the center, such that no matter which way the wind blows in any of 8 compass directions, the smoke from one cigarette will be detected by the monitors (Repace, 2005). Atmospheric conditions were turbulent, with strong sun and high wind speeds, ranging from 5 m/s to 10 m/s (11 MPH to 23 MPH).

3. Figure 2 shows a graph of the outdoor SHS concentrations (labeled Fig. 6 in Repace, 2005), indicating that the SHS concentration decreases roughly inversely with distance. On this day there was strong sun, high wind speeds 5 m/s (11 mph) with frequent gusts to 10 m/s (23 mph), temperature 62^{o}F, 30% RH (Repace, 2005). In response to this report, the UMBC Faculty Senate restricted outdoor smoking: "Smoking is prohibited within 20 feet of all building openings including walkways, doorways, air or ventilation intake systems, entryways, and windows. Smoking is also prohibited on UMBC's mainstreet area (from the entrance to the Kuhn Library to the street adjacent to the Administration and Recreational Activity Center), and the patio area outside the Commons."

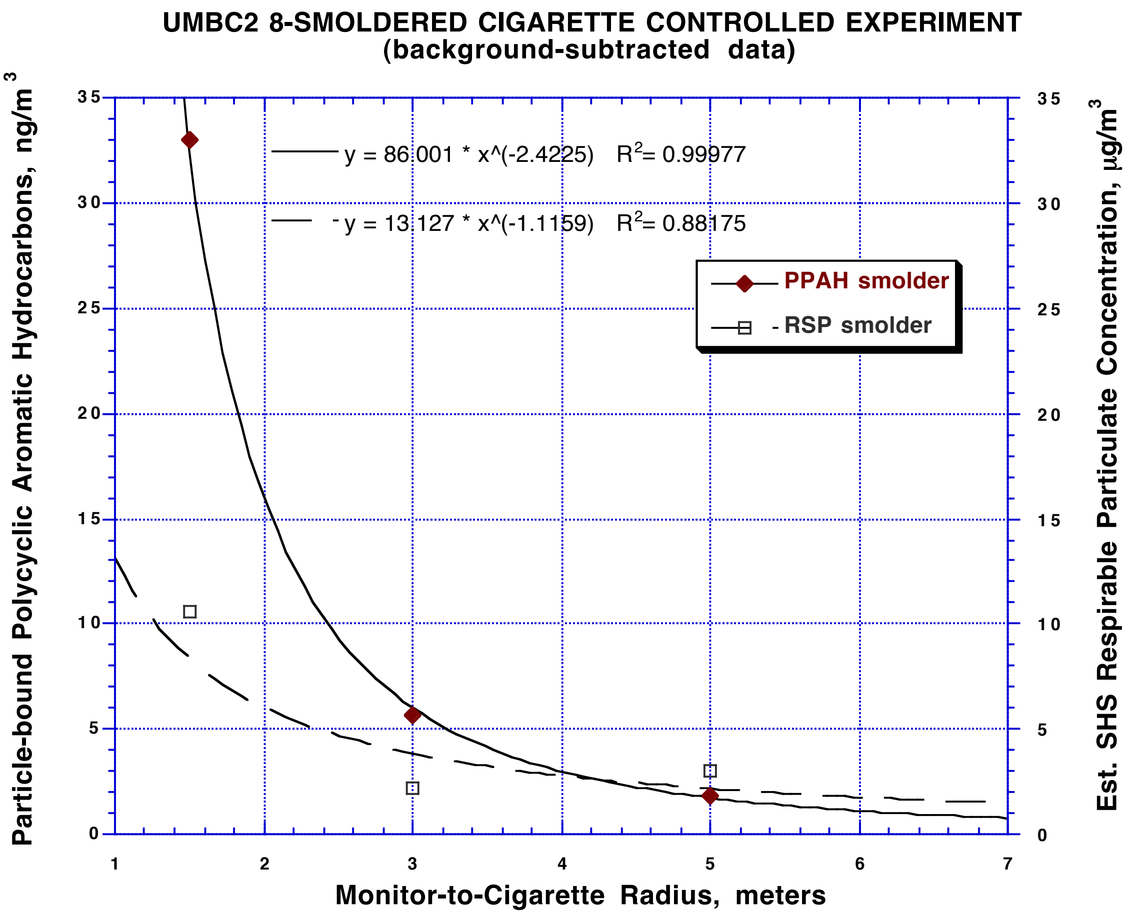

Figure 2. Plot of data from experiment shown in Figure 1 (Repace, 2005) showing that cigarette smoke respirable particle (RSP) concentration varies approximately inversely with the distance from the cigarette. These levels are background-subtracted, showing that $PM_{2.5}$ and PPAH from SHS were detected at distances 7 meters or more from a single cigarette even under turbulent conditions.

4. Klepeis et al. (2007) made real-time measurements of outdoor SHS under controlled and field conditions, where they visited parks, sidewalk cafes, and restaurant and pub patios with smokers. They found that during periods of active smoking, SHS levels near smokers rivaled indoor concentrations of SHS indoors. They concluded that SHS could present a nuisance or hazard under certain conditions of wind and smoker proximity. Their controlled experiments used the same concentric ring protocol as shown in Figure 1. Klepeis et al. (2007) reported that SHS $PM_{2.5}$ levels ranged from 6 to 67 $\mu g/m^3$ with an overall average of 30 $\mu g/m^3$. Where wind effects were present, levels ranging from 106 to 133 $\mu g/m^3$ were observed for all distances, close to levels observed indoors in a small bedroom during smoking. During outdoor patio experiments, downwind levels of SHS were detectable at distances 3 to 4 meters from a single cigarette, similar to the results shown in Figure 2 by Repace (2005). Klepeis et al. (2007) observe that their results agree with the CARB (2005) study, i.e., that Californians who spend time close to outdoor smokers could potentially be exposed to SHS levels similar

to those associated with indoor SHS.

5. **Adverse reaction thresholds.** Junker et al. (2001) investigated the effect of sidestream SHS on 24 female nonsmokers aged 18 - 35 years. Subjects were healthy, non-allergic persons. Observed median threshold concentrations causing eye, nasal, and throat irritation corresponded to an estimated SHS-$PM_{2.25}$ concentration of 4.4 μg/m^3. The median threshold signifies that half of the subjects found levels of cigarette smoke irritating below 4.4 μg/m^3, and the remaining half found it irritating above that level. At this concentration, the percentage of occupants judging the quality of air to be acceptable was only 33%. Odor thresholds of SHS obtained from the olfactory experiments showed that a median odor sensation was perceived at very low concentrations equivalent to an SHS-$PM_{2.25}$ concentration of approximately 0.6–1.4 μg/m^3. The study of Junker et al. (2001) gives guidance on the irritation and odor aversion levels to SHS for healthy nonsmokers, and will be used in this work to assess the nuisance potential for SHS outdoors.

6. Figure 3 shows a satellite view of Unit 11 Ridge Road, Greenbelt, MD in August 2010, made using Google Earth, with Units Q (Schuman) and R (Popovic) indicated. North is at the top of the picture. The 16 points of the compass rose are shown in the insert at the upper right. The long axis of the Unit 11 building is oriented parallel to the North (N) and North-Northeast (NNE) compass sector.

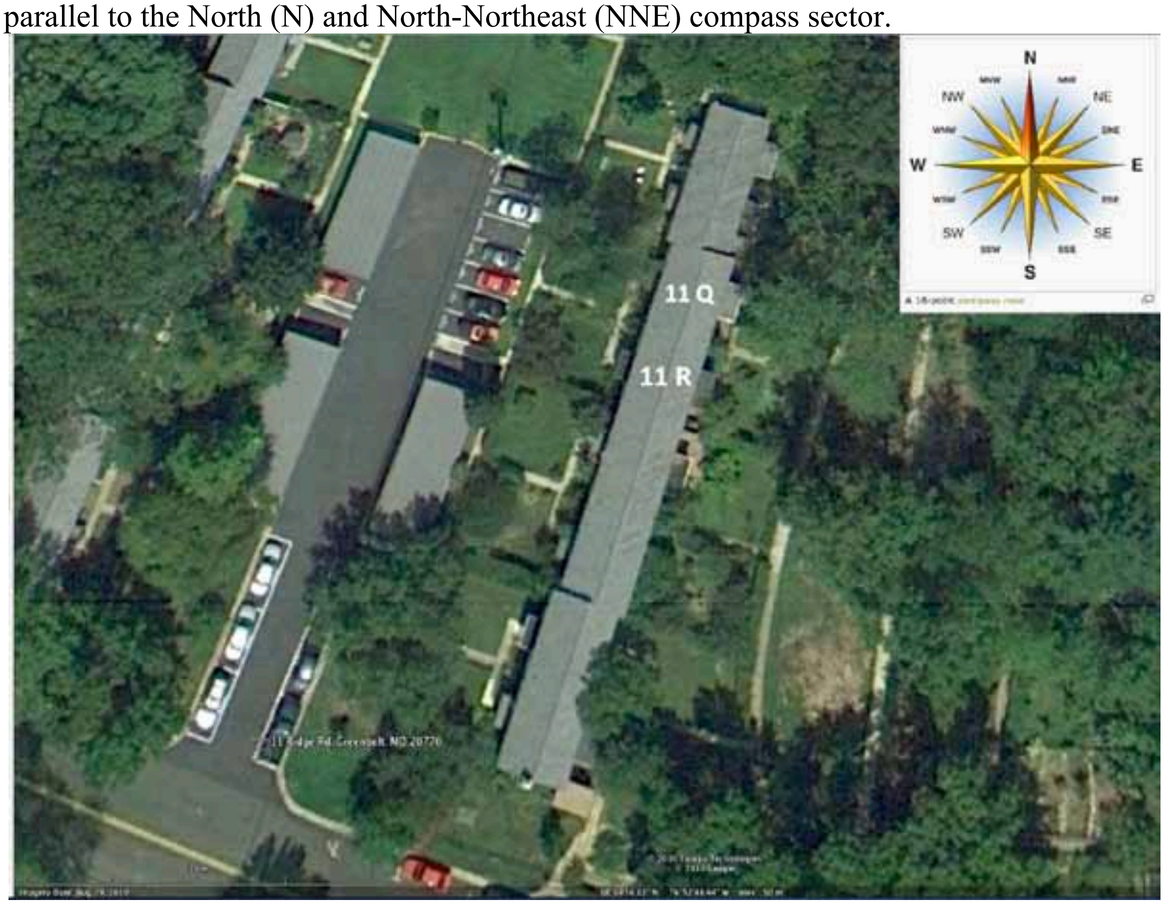

Fig. 3. 11 Ridge Road, Greenbelt MD, View from Google Earth, August 2010. The Service side of Unit 11 is on the left side where cars are parked; the Garden side is on the opposite side where the curving sidewalk limits the yards of Unit 11.

7. The smoke plume from a cigarette smoked either on the Service side or Garden side yards of Unit R will only impact Unit Q when the wind is blowing from the smoker in the yards of Unit R towards the windows and doors of Unit Q. A device known as a wind rose is used to estimate the wind direction, speed, and frequency for Unit Q. A wind rose is a graphic tool used by meteorologists to show how wind speed and direction are typically distributed at a particular location over a long time period. The percentage of calm conditions is represented by the size of the center circle -- the bigger the circle, the higher is the frequency of calm conditions. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. The branches are divided into segments of different thickness and color, which represent wind speed ranges from that direction. The length of each wind rose segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds <u>from</u> that direction showing wind speed ranges in either in m/s or in knots. The compass direction with the longest spoke shows the wind direction with the greatest frequency. Wind roses are typically compiled for airports, in order to site runways and inform pilots of the range of expected seasonal wind conditions.

8. The closest local wind rose for Greenbelt, MD is for Baltimore-Washington International Airport, and is shown in Figure 4 for April 1st thru October 31 for 1987-88 and 1990 to 1992; the 360 degrees of the compass rose are divided into the same 16 sectors as the compass rose in Figure 3, each sector covering a 22.5^{o} arc.

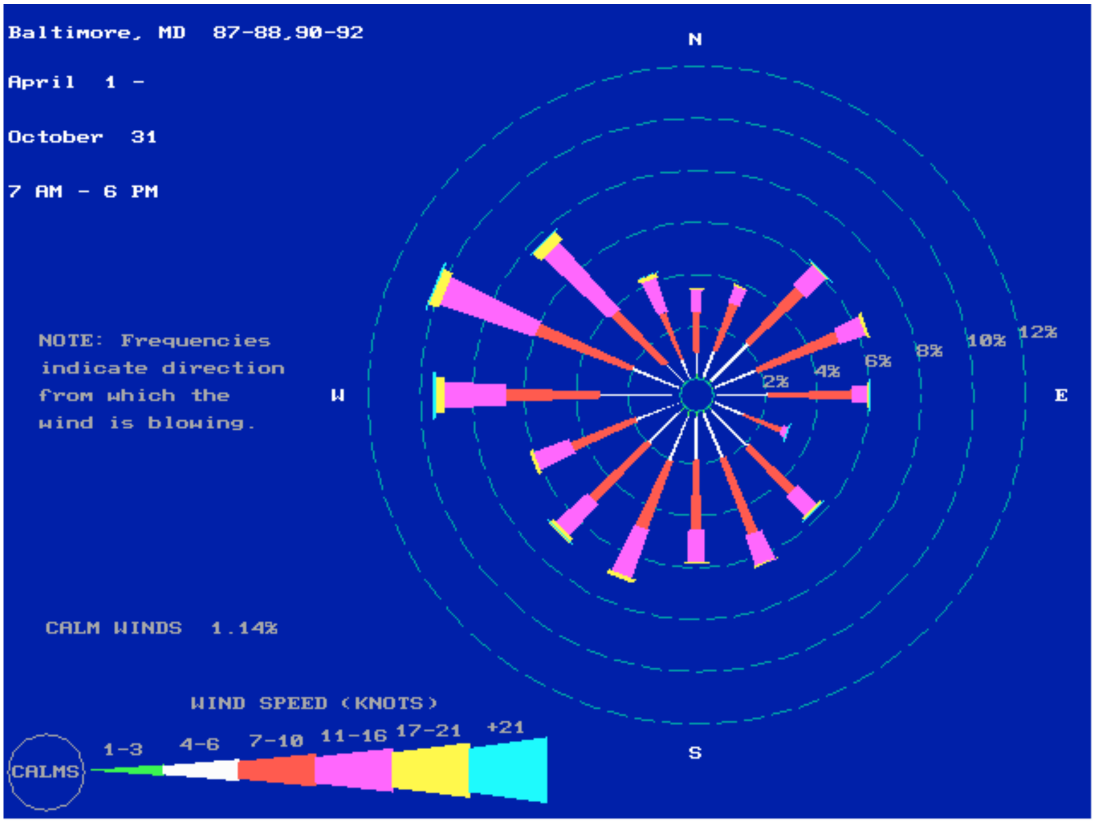

Fig. 4. Baltimore Wind rose http://home.pes.com/windroses/wrgifs/93721.GIF.

Figure 4 shows that the wind blows from the East-Southeast (ESE) approximately 3% of the time, from the Southeast (SE) about 6% of the time, from the South-Southeast (SSE) about 6% of the time, and from the Southeast (SE) about 6% of the time, and from the South (S) about 6% of the time. Thus, on the Garden Side of Mr. Schuman's home, from ESE to S, the wind blows about 28% of the time, from April 1st to October 31st, the time when windows are most likely to be open. Winds are calm 1.14% of the time (Pacific Environmental Services, downloaded 19 November 2010). Similarly, on the Service or Parking side, the wind blows from the West (W) 9.5% of the time, from the West Southwest (WSW) 6% of the time, from the SW 7% of the time, from the SSW 7% of the time, and from the South 6% of the time for a total of 36% of the time for the West to South sectors.

9. Wind speeds range from calm to about 16 knots for those sectors. The table below shows the average wind speeds from April through October for 59 years of data through 2009 range from 10.1 miles per hour (MPH) to a low of 7.5 MPH, and average 8.2 MPH. [1 mile per hour = 0.44704 meters per second], thus the wind speed ranges from 3.35 m/s to 4.5 m/s, and averages 3.65 m/s. The default anemometer height is 10 meters (m) (32.8 ft), since these are typically located on top of a building or on a tower. However, we are interested in a smoke plume near the surface at the height of about 1.5 m. Therefore the anemometer wind speed must be adjusted for surface roughness (trees, buildings, bushes, etc.) according to the equation $u_z = u_a (z/z_a)^p$, where u_z is the wind speed at the surface height z = 1.5 m, z_a = 10m is the height of the anemometer, and u_a =

3.65 m/s is the windspeed at anemometer height, and p is a surface roughness parameter ranging from 0.07 for unstable air to 0.55 for stable air (Turner, 1994). Then for unstable air, the adjusted windspeed at 1.5 m is $u_{z\ (unstable)} = 3.6\ m/s(1.5/10)^{0.07} = 3.19\ m/s$, and for stable air, air, it is $u_{z\ (stable)} = 3.65\ m/s(1.5/10)^{0.55} = 1.3\ m/s$ (2.9 MPH). I shall choose a very conservative value of 3 m/s (6.7 MPH).

Table 1. Average Wind speeds Baltimore, 1950-2009

Average Wind Speed- (MPH) 93721BALTIMORE, MD

http://www.ncdc.noaa.gov/oa/climate/online/ccd/wndspd.txt

DATA TO 2009	YRS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
	59	9.1	9.7	10.5	10.1	8.6	8.2	7.5	7.3	7.6	7.9	8.6	8.8	8.7

http://www.ncdc.noaa.gov/oa/climate/online/ccd/avgwind.html

DATA TO 2002	YRS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
93721BALTIMORE, MD	52	9.4	9.9	10.7	10.2	8.9	8.2	7.6	7.5	7.7	8.1	8.8	8.9	8.8

10. Figures 5a and 5b show the superposition of Figures 3 and 4. Secondhand smoke emanating from a smoker or smokers smoking in the back yard of 11 R would blow toward the garden side door and window of 11 Q whenever the wind blows from the East Southeast to the South Southwest sectors, i.e., within the zone bounded by the two white arrows of 5a: ESE, 3%; SE, 6%; SSE, 6%; S 6%, and SSW 7%, total 28%. Similarly, the winds would blow smoke from the Service side yard of 11 R toward 11 Q whenever the wind blows from the West to the South-Southwest sectors between the two white arrows of 5b: W, 9.5%, SW, 7%; SSW, 7%; WSW, 6%, and S 6%, total 35.5%. However, when the wind blows from the West and the East Southeast, it will blow the smoke plume against the wall of the house and split it, with only half going toward Unit Q.

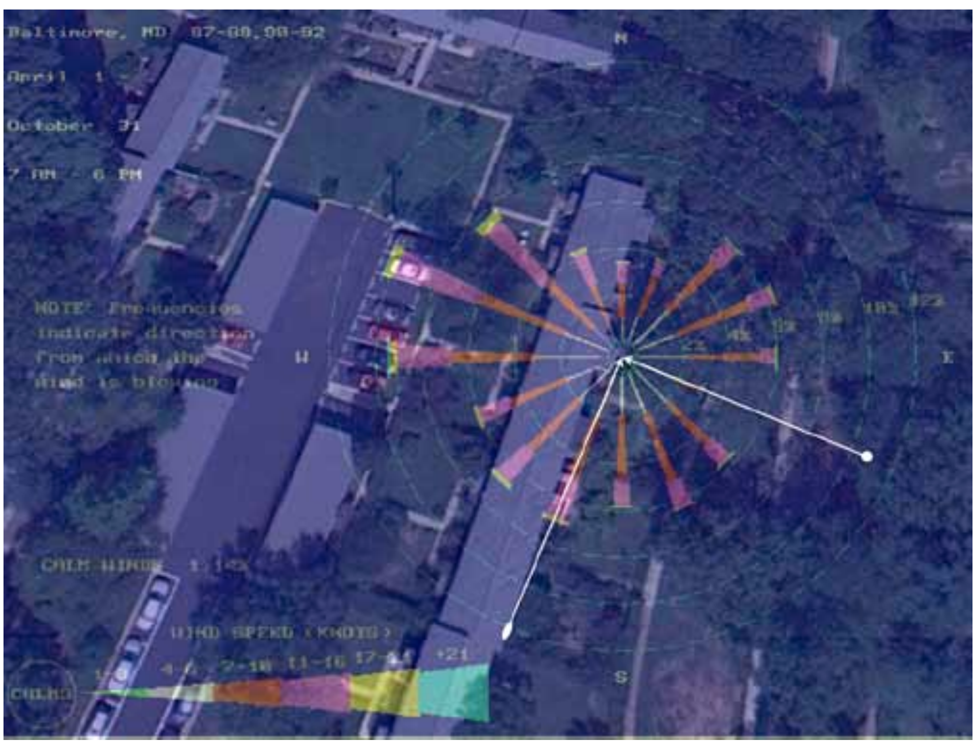

Fig. 5a. Overlap of the Baltimore Wind Rose on the 11 Ridge Road complex, Garden side. Winds blow from Unit R toward Unit Q an average of 28% of

the time.

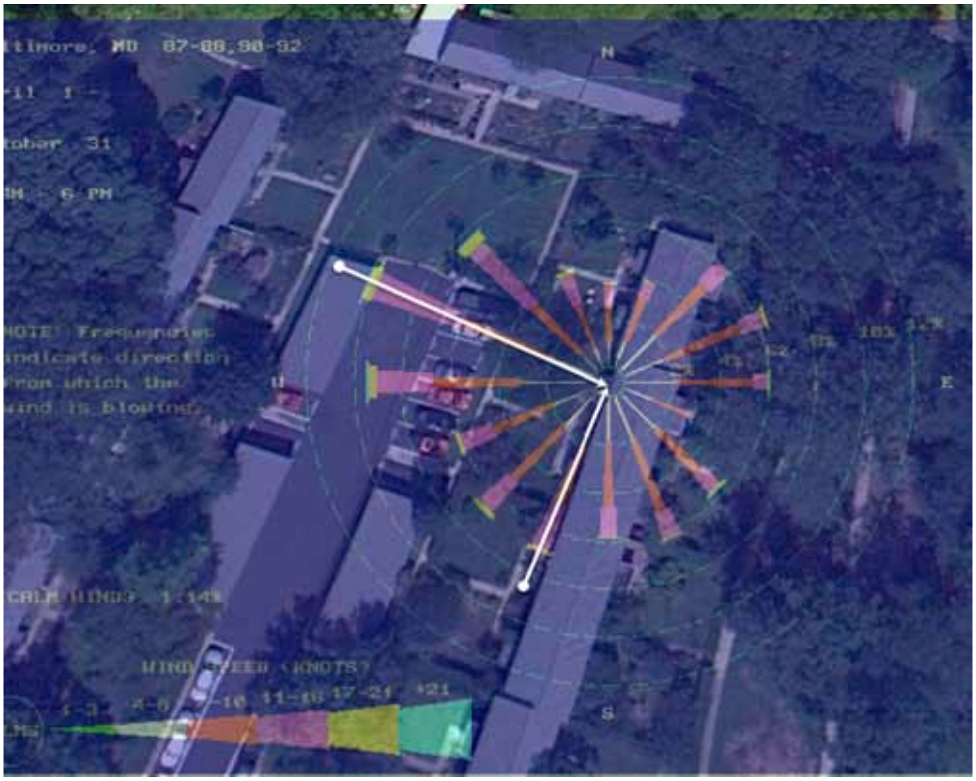

Fig. 5b. Overlap of the Baltimore Wind Rose on the 11 Ridge Road complex, Service side. Winds blow from Unit R toward Unit Q an average of 35.5% of the time.

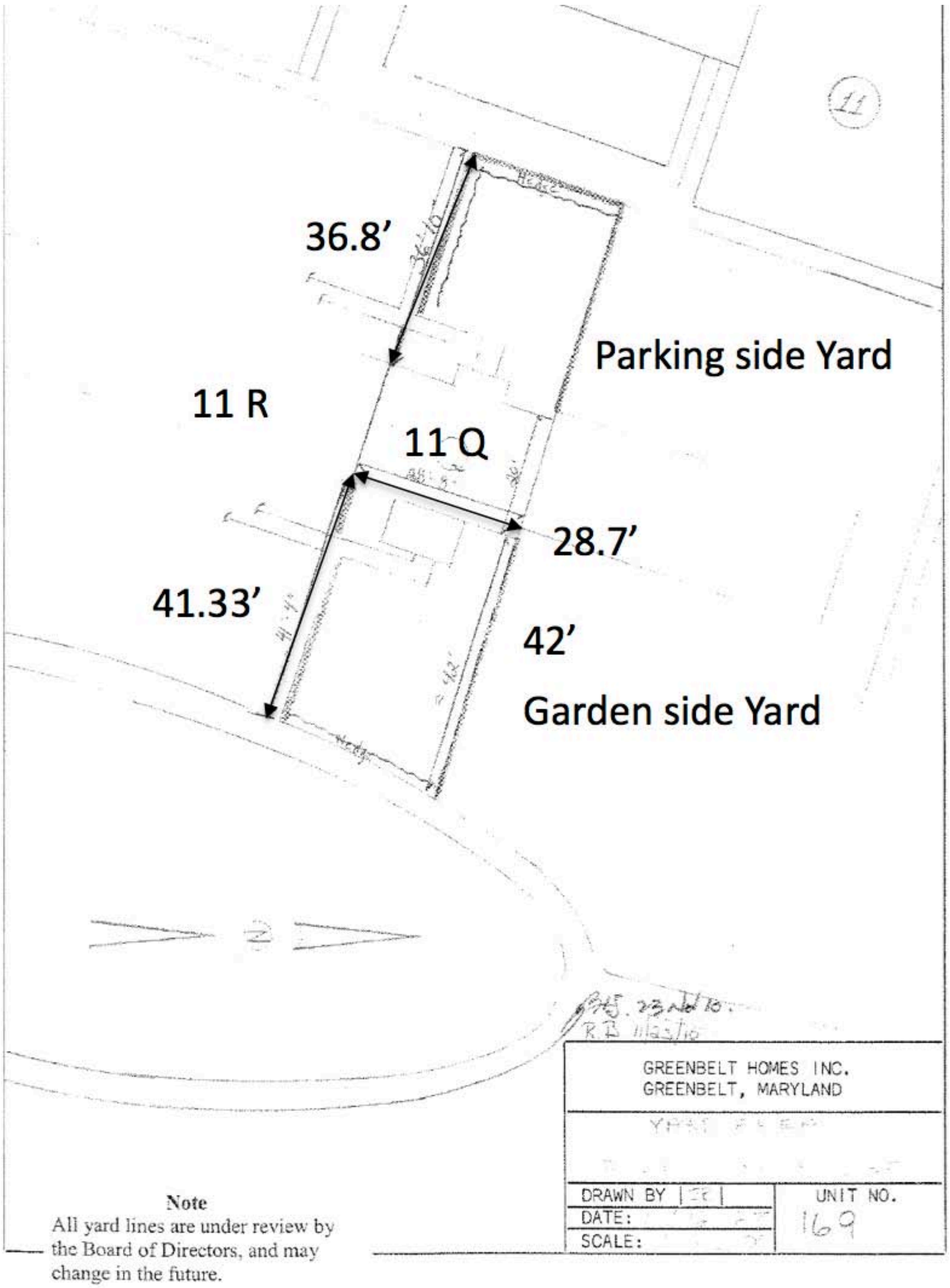

Figure 6. Outside Dimensions of Unit Q, a 3-bedroom unit. The outside dimensions of Unit R, also a 3 bedroom unit, are assumed to be the same: Width = 29’; Length = 42’ on the Garden Side, and Width = 29’; Length = 37’ on the Service or Parking Side (D. Schuman, personal communication).

11. Figure 6 shows a diagram of the outside dimensions of Unit Q provided by Mr. Schuman, and the estimated outside dimensions of the Unit R Garden and Service

(Parking) Side yards. According to the diagram, the width of Mr. Popovic's yard in Unit R is approximately 27 feet to the middle of the sidewalk between the units. Mr. Schuman's yard is about 29 feet wide. The height of the nearest Unit Q window is 4 feet off the ground, and the second story window of Unit Q is 8.5 feet from the ground. The perpendicular depth of the yards from the garden side doors to the common area sidewalk on the Garden Side is about 42' and the width of the yards is about 29'. Thus, on the service side, the furthest distance in the yard of Unit R a smoker could stand from the nearest corner of unit Q is the diagonal, $D = (37^2 + 29^2)^{(1/2)} = 47'$ (14 meters), and on the garden side, $D = D = (42^2 + 29^2)^{(1/2)} = 51'$ (15.5 meters). Similarly, the nearest distance to Mr. Schuman's property line from the common sidewalk is 0 meters. For someone smoking on the back porch of Unit R, the nearest distance to Unit Q's ground floor rear window is about 3 meters, as shown in Figure 7. Therefore the range of interest is from 0 to 15.5 meters.

Figure 7a. Photo of Garden Side Yard between Units R and Q. The distance between the rear porch of Unit R and the nearest window of Unit Q is about 3 meters or 9.84 feet.

Figure 7b. Based on the presence of chairs under the porch roof of Unit R, it appears that smoking is most likely to occur 3 to 4 meters from the Garden-side window of Unit Q.

Modeling of Outdoor Smoke Using the Ground-level Release Model from Turner's Workbook of Atmospheric Diffusion Estimates (Turner, 1994).

12. The concentration of outdoor secondhand smoke from the yards of Unit R impacting on the windows and doors of Unit Q is estimated using a Dispersion Equation. The form of this equation for a ground level release of pollutant is given by Equation (1), and is used to describe the plume concentration downwind from the source, as shown in Figure 8.

Dispersion Equation

$$\mathbf{X(x,y,z,H) = Q/[\pi \sigma_y(x)\ \sigma_z(x)\ u]} \qquad \text{Equation (1),}$$

where X(x,y,z,H) is the pollution concentration in units of micrograms per cubic meter (μg/m^3), u is the wind speed in m/s, for an outdoor ground level pollutant release along the center of the plume line, y = z = H = 0, as shown in Figure 9. Q is the source emission strength in units of micrograms per second. The concentration in the downwind direction, x, is X(x,0,0,0,) which is a function of the dispersion coefficients, $\sigma_y(x)$ and $\sigma_z(x)$. Values for these coefficients are obtained from Table 3-1 (Table 4 below) *Turner's Workbook of Atmospheric Diffusion Estimates*, 2nd Edition, 1994. Wind speed u is typically estimated from a wind rose. Equation 1 shows that the downwind concentration is directly proportional to the source strength Q and inversely proportional to the wind speed u. The atmospheric dispersion parameters $\boldsymbol{\sigma_y(x)}$ and $\boldsymbol{\sigma_z(x)}$ determine the spread (and therefore the dilution) of the plume concentration respectively in the horizontal and vertical directions perpendicular to the axis of the plume, and increase with distance x downwind from the source, as shown in Figure 8.

13. Equation 1, the equation for a ground level release and a ground level receptor, derived from the Gaussian Plume Model (Eq. 3.1 in Turner's Workbook). For all cases, I assume a wind speed u = 3 m/s. Turner indicates the model results are accurate to a factor of 2, since plume height is ground level and wind speed is assumed. The variable *x,y,z* are the standard Cartesian coordinates, where *x* is the wind direction, z is height, and y is horizontal spread, as shown in Turner's Fig 3-1, reproduced as Figure 8 here. In this calculation, I assume that the smokers' cigarette plumes and the target windows and doors of Unit Q are at the same height, and downwind on the plume axis. Figure 9 shows that the closer one gets to the source the smaller the dispersion, and the higher the exposure concentration, as represented by ellipses for which the dispersion coefficients are the length of the semi-major and semi-minor axes, as shown. The product $\pi\sigma_y(x)\sigma_z(x)$ represents the area of the ellipse giving the cross-sectional area of the plume as a function of distance x downwind. The closer to the source, i.e. the smoker, the smaller the cigarette plume cross-sectional area, and hence the higher the concentration of SHS in the plume. Thus, exposure to the cigarette plume for a downwind receptor depends on wind direction and speed, and the amount of turbulence-determining sunlight, which affects the stability or mixing properties of the air by inducing thermal gradients. For the experiments of Figure 2, for example, the strong sun and high winds dictate "B" stability, with occasional excursions into "C" stability.

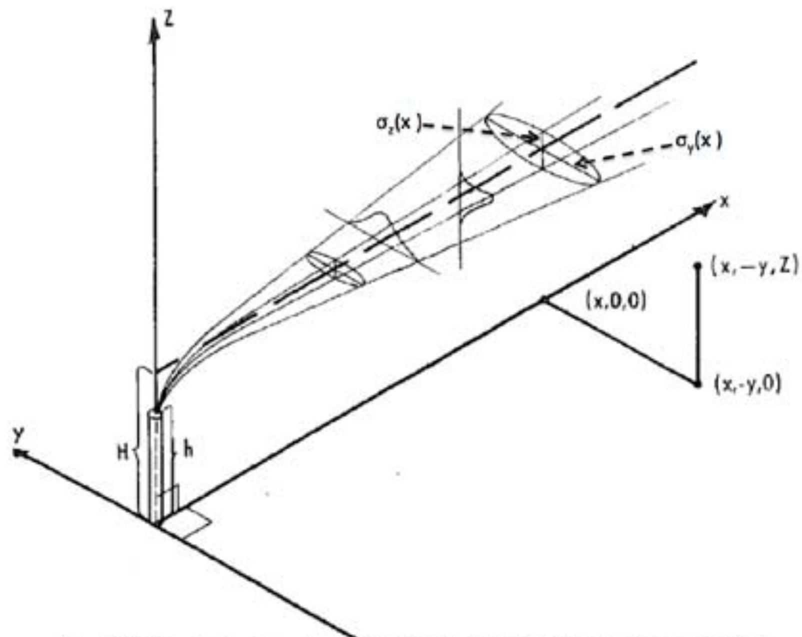

Figure 3-1. Coordinate system showing Gaussian distributions in the horizontal and vertical.

Figure 8. Schematic of the Gaussian Plume Model; dispersion coefficients $\sigma_y(x)$ and $\sigma_z(x)$ are smaller closer to the source, yielding higher plume concentrations at close-in locations enveloped in the plume (Turner, 1994).

Table 2 shows the recommended stability categories for various wind speeds and sunlight for use in the Gaussian Plume Model.

Table 2. Day and Night Wind Speed and Atmospheric Stability Categories for determining Pasquill-Gifford Dispersion Coefficients.

Table 3-1 KEY TO STABILITY CATEGORIES

Surface Wind Speed (at 10 m), m sec^{-1}	Day: Incoming Solar Radiation			Night	
	Strong	Moderate	Slight	Thinly Overcast or ≥4/8 Low Cloud	≤3/8 Cloud
< 2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

The neutral class, D, should be assumed for overcast conditions during day or night.

14. To calculate the concentration downwind from a single smoker in the Service side or Garden side yards of Unit R, I use the following parameter values for Equation 1:

Q: A typical cigarette emits 14,000 micrograms of $PM_{2.5}$ per 10 minutes, or $Q = 23$ micrograms per second (μg/s) (Repace, 2007).

u: the average BWI wind speed ranges from 3 m/s to 4 m/s from Table 3. Atmospheric Stability Category: During daylight hours, B or C Stability for wind speeds ranging from $u = 3$ m/s to 5 m/s (Table 4). Numerical examples of the variation of concentration with stability are given in Case 1 and Case 2 below.

The following dispersion coefficients are taken from Turner's Workbook, Table 2.5 (part 1): Daytime, B or C Stability:
$\sigma_y(x)$: for B stability at x = 0.01 km = 10 meters (32.8 feet) = 2.34 m
$\sigma_z(x)$: for B stability at 10 meters (32.8 feet) = 1.24 m
$\sigma_y(x)$: for C stability at 10 meters (32.8 feet) = 1.47 m
$\sigma_z(x)$: for C stability at 10 meters (32.8 feet) = 0.91 m

Thus, in the daytime, B stability, $\sigma_y(0.01 \text{ km}) = 2.34$ m; $\sigma_z(0.01 \text{ km}) = 1.24$ m is the case with the greatest dispersion (best case).

Case 1, Daytime, B stability: $\sigma_y(0.01 \text{ km}) = 2.34$ m; $\sigma_z(0.01 \text{ km}) = 1.24$ m. Substituting these values into equation 1 yields:
$X(x,y,z,H)_C = Q/(\pi\sigma_y\sigma_z u) =$ (23 μg/s)/[(3.14)(2.34m)(1.24m)(3m/s)] = 0.84 μg/m^3 per cigarette at a distance of 33 feet.

As the atmospheric stability increases, the concentration downwind increases:
Case 2, Daytime, C stability: $\sigma_y(0.01\ km) = 1.47\ m$; $\sigma_z(0.1\ km) = 0.91\ m$.
Substituting these values into equation 1 yields:
$X(x,y,z,H)_D = Q/(\pi\sigma_y\sigma_z u) = 23\ \mu g/s)/[(3.14)(1.47m)(0.91m)(3\ m/s)] = 1.83\ \mu g/m^3$ per cigarette at a distance of 33 feet (10 m).

Note that an increase from B to C stability more than doubles the downwind concentration from 0.84 $\mu g/m^3$ to 1.83 $\mu g/m^3$ at 10 m distance.

Case 3, Nighttime, D and E stability:
The following dispersion coefficients are taken from Turner's Workbook, Table 2.5 (part 1): Nighttime:
$\sigma_y(x)$: for D stability at x = 0.01 km = 10 meters (32.8 feet) = 0.96 m
$\sigma_z(x)$: for D stability at 10 meters (32.8 feet) = 0.63 m
$\sigma_y(x)$: for E stability at 10 meters (32.8 feet) = 0.72 m
$\sigma_z(x)$: for E stability at 10 meters (32.8 feet) = 0.51 m

Thus, at night, E stability $\sigma_y(0.01\ km) = 0.72\ m$; $\sigma_z(0.01\ km) = 0.51\ m$ is the case with the least dispersion (worst case).
$X(x,y,z,H)_E = Q/(\pi\sigma_y\sigma_z u) = (23\ \mu g/s)/[(3.14)(0.72\ m)(0.51\ m)(3m/s)] = 6.65\ \mu g/m^3$ per cigarette at a distance of 10 m or 32.8 feet.

15. In the case of David Schuman's exposure to SHS at Unit 11 Q, as a practical matter, we are interested in distances from about 2 meters (~6-1/2 feet) to 15 meters (49.2 feet) from a smoker in either the Service-side or Garden-side yards. However, Turner's Workbook does not give values for the dispersion coefficients for distances less than 10 meters, so they must be extrapolated using curve-fitting.

Estimation of Smoke Concentration on the plume axis for distances less than 10 meters from a single smoker smoking a cigarette for B (best case) and E Stability (worst case).

16. In the case of Unit 11 Q's exposure, it is necessary to derive the dispersion coefficients for B (daytime best case) and E stability (nighttime worst case) using the same curve fit technique, yielding extrapolation equations from their values from 10 to 50 meters. Table 3 gives the values for x, the product $\sigma_y\sigma_z$, for B and E stability, and the equations for $X(x,y,z,H)$ (chi) for x = 10 to 50 meters, from Turner, Table 2.5, using Q = 23 µg/s, and u = 3 m/s.

Table 3. Estimated secondhand smoke concentrations from 10 to 50 meters.

x, meters	$\sigma_y\sigma_z$, B Stability	$\sigma_y\sigma_z$, E Stability	$X_B=Q/(\pi\sigma_y\sigma_z u)$	$X_E=Q/(\pi\sigma_y\sigma_z u)$
10	2.9	0.37	0.84138	6.5946
20	10.5	1.26	0.23238	1.9365
30	22.1	2.58	0.11041	0.94574
40	37.7	4.29	0.064721	0.56876
50	56.9	6.37	0.042882	0.38305

Equations 2 and 3 below give those equations, curve-fitted from the data in Table 3.

for B and E Stability:

$$X_B = 59.32 * x^{-1.849} \qquad \textbf{Equation 2.}$$

$$X_E = 386.1 * x^{-1.768} \qquad \textbf{Equation 3.}$$

Table 4 gives the values for Equations 2 and 3 for 1 to 10 meters.

Table 4. Estimated secondhand smoke concentrations from 1 to 15 meters.

x, meters	$X_B = Q/(\pi\sigma_y \sigma_z u)$	$X_E = Q/(\pi\sigma_y \sigma_z u)$
1	59.32	386.61
3	7.7804	55.427
5	3.0256	22.464
7	1.6241	12.392
10	0.83985	6.5959
15	0.39683	3.2207

Figure 9 shows a plot of the data in Table 4, derived from Equations 2 and 3.

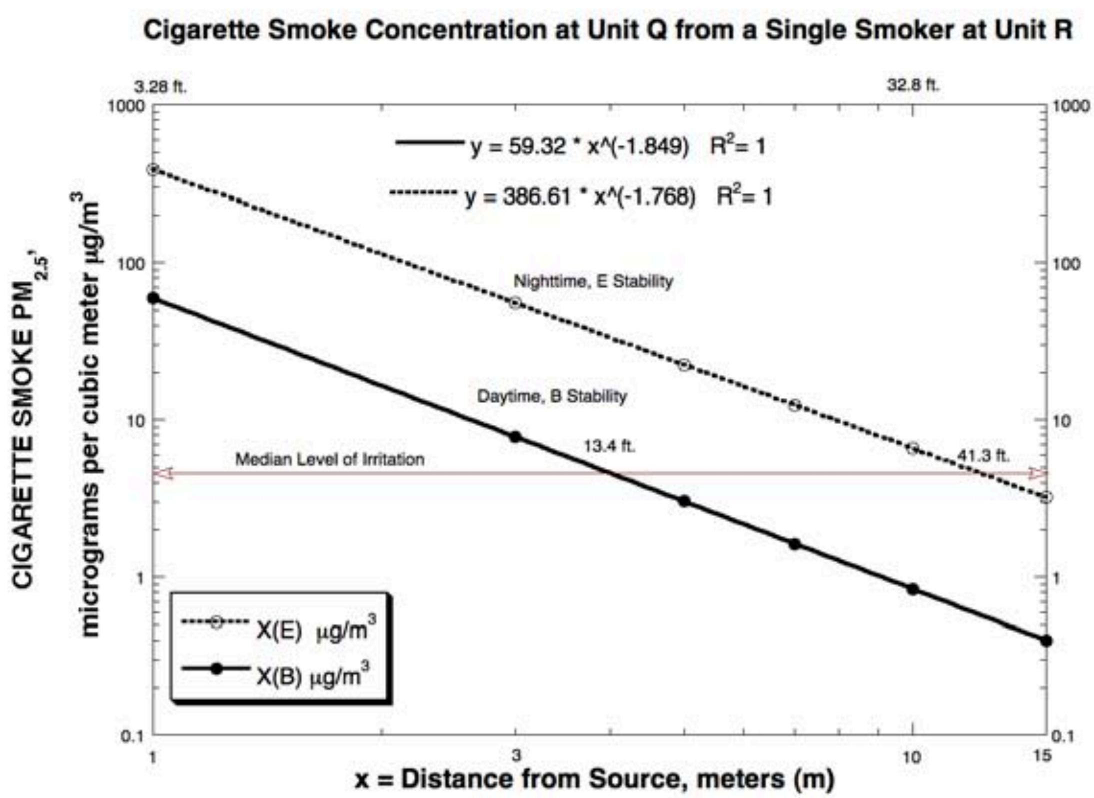

FIGURE 9. Estimated exposure to fine particle air pollution ($PM_{2.5}$) from secondhand smoke as a function of downwind distance for Unit Q from 1 cigarette smoker for B stability to 1 smoker for E atmospheric stability at a mean wind speed of 3 m/s using Method 2. The nearest window of Unit Q, would encounter median irritating levels of SHS

(4.4 μg/m^3 -- double arrow) at distances ranging from 4 meters (13.4 feet) downwind from 1 smoker to 41.3 feet, downwind of 1 cigarette smoker at night.

17. Figure 9 shows the expected SHS $PM_{2.5}$ concentration as a function of distance from 1 to 10 meters for a single smoker, for daytime atmospheric stability B and nighttime atmospheric stability E, for a wind speed of u = 3 m/s. The Junker et al. (2001) threshold irritation level of 4.4 μg/m^3 is exceeded at distances closer than 13.4 feet for B stability during the daytime (best case) and at distances closer than 41.3 feet during the evening (worst case). If there are two smokers, the concentration at 13.4 feet becomes 8.8 μg/m^3, and the 4.4 μg/m^3 crossover point shifts to the right as the entire line shifts vertically. This may be read directly off the graph with a ruler, by doubling the end-point values in Table 4 for B stability from 59.32 to 118.6 at x = 1 m on the left axis of Figure 9, and from 0.39683 to 0.794 at x = 15 m on the right axis, and read off the crossover point at slightly less than 6 meters, or roughly 19 feet. Thus for 2 smokers, the irritation median shifts from about 13 feet to about 19 feet.

Comparison with the Outdoor SHS findings of Klepeis et al (2007; 2009):

18. Klepeis et al. (2007) measured outdoor $PM_{2.5}$ from SHS for Sidewalk Cafés and in a backyard patio in California, shown in Figure 10 for distances ranging from 0.5 to 4 m, finding overall average outdoor SHS concentrations ranging from 6 to 67 μg/m^3 and averaging 33 μg/m^3. Figure 10 shows the outdoor tobacco smoke (OTS) $PM_{2.5}$ values Klepeis et al. measured as a function of distance from a single smoker in controlled experiments where distances from a smoker were measured accurately.

Klepeis et al. (2009) in a second study, investigated concentrations of air pollutants at ground-level outdoor environments within a few meters of point sources, in order to better understand outdoor exposure to tobacco smoke from cigarettes or cigars, and other types of outdoor point sources. Using carbon monoxide (CO) as a tracer gas, they observed that average concentrations were approximately inversely proportional to distance, and average wind speed. Average CO levels were approximately proportional to source strength. They develop a regression model from their data that predicts downwind SHS $PM_{2.5}$ concentrations as a function of distance from 0.25 m to 2 m for a cigarette smoker emitting 1.4 mg/min (23 μg/s) of $PM_{2.5}$.

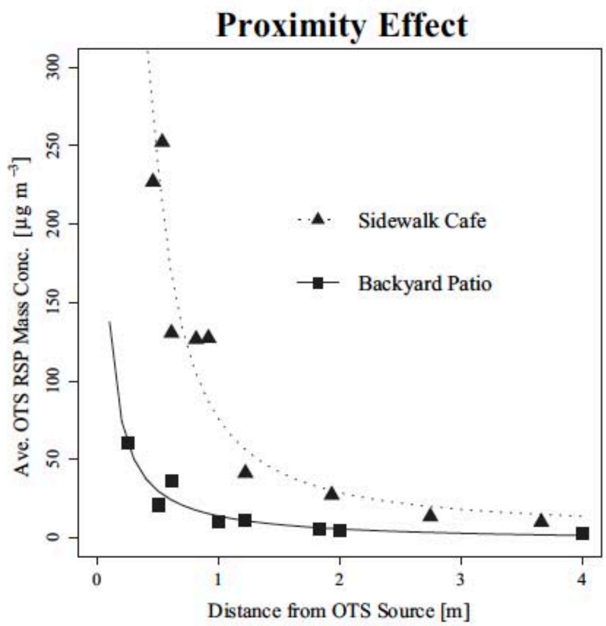

Figure 3. Overall average OTS RSP mass concentrations across all of the instruments as a function of proximity to the OTS source, calculated using levels measured during experiments on a backyard patio and two sidewalk cafés for which source proximity was recorded precisely (see E1–E4 and OP1–OP3 in Table 3). Background RSP levels were subtracted from all of the measurements. The backyard patio experiments used smolder-smoked cigarettes in an area shielded by fences and trees. The sidewalk café experiments used smolder- or human-smoked cigarettes.

FIGURE 10. OTS (outdoor tobacco smoke) data measured by Klepeis et al. (2007) for two situations: a Backyard patio and a Sidewalk Cafe for wind speeds ranging up to 1 m/s and under conditions of strong sun, i.e., corresponding to "A" stability.

Therefore, I plotted the dispersion coefficients from Turner's Workbook for distances 10 meters to 50 meters and fit equations to the data. I used these equations to estimate the product of the y and z dispersion coefficients for distances less than 10 meters. From Turner's workbook,

$\sigma_y(x)$: for A stability at 10 meters (32.8 feet) = 2.34 m
$\sigma_z(x)$: for A stability at 10 meters (32.8 feet) = 1.24 m

19. I digitized the Sidewalk Cafe $PM_{2.5}$ and distance (x) data in Figure 10, as shown in columns C0 and C1 in Table 5. For each digitized distance value x, I calculated a corresponding modeled $PM_{2.5}$ value, given in column 3, using the dispersion values given in column 2 of Table 3, and Equation 1 for distances less than 10 meters, in C2. Column C2 is derived from the equation $\sigma_y(x)\sigma_z(x) = 0.07562\ x^{1.8478}$, which gives the product of the dispersion coefficient equations for A stability for distances x = 10 to 50 meters. These interpolated values may be compared to the values generated by the Gaussian Plume Model for a ground level release (Equation 1) for A Stability, which I will call the JLR Model for simplicity. The model-calculated $PM_{2.5}$ values as a function of distance with real-world data measured by Column C3 gives the modeled value (JLR

Model) for Q =23.3 μg/s in the numerator of Equation 1 and $\pi\sigma_y(x)\sigma_z(x)u$ in the denominator, where u =1 m/s. To estimate error rate, I compare the prediction of the Gaussian model for a ground level release to data collected by Klepeis et al. (2007) for California sidewalk patios (KOS data). Figure 11 shows, for 3 to 13 feet (1 to 4 m) agreement is excellent. A comparison of the concentration calculated from the Gaussian Plume model (col. c3) with the data measured by Klepeis et al. (2007) (col. C1) for distances from 0.82 m to 3.67 m (col. C0), yields close agreement: JLR model = 4.6 + 0.99 KOS data (c1), R^2= 0.94.

Table 5. Estimated $PM_{2.5}$ vs. Distance x, A Stability, 1 m/s wind speed

x, meters C0	PM2.5 ug/m3 C1	σy(x)(σz(x) A C2	JLR Model C3
3.67	11.8	0.83565	8.8752
2.77	14.9	0.49688	14.926
1.94	28.5	0.2573	28.825
1.23	42.5	0.11086	66.903
0.92	127	0.064822	114.41
0.82	128	0.052406	141.52
0.63	130	0.0322	230.33
0.5	253	0.021008	353.03

20. The digitized data points (▲) measured by Klepeis et al. (2007) from Figure 11 (digitized as columns C0 and C1, Table 5) are superimposed on the plot of the modeled values (columns C0 and C3, Table 5), as shown in Figure 11. This also serves as an estimation of the error rate of the Gaussian Plume model. Figure 12 shows that real-world data measured for outdoor smoking can be accurately predicted by the plume dispersion model for a ground level release using extrapolated values of the dispersion coefficients given in Turner's Workbook, Table 2.5.

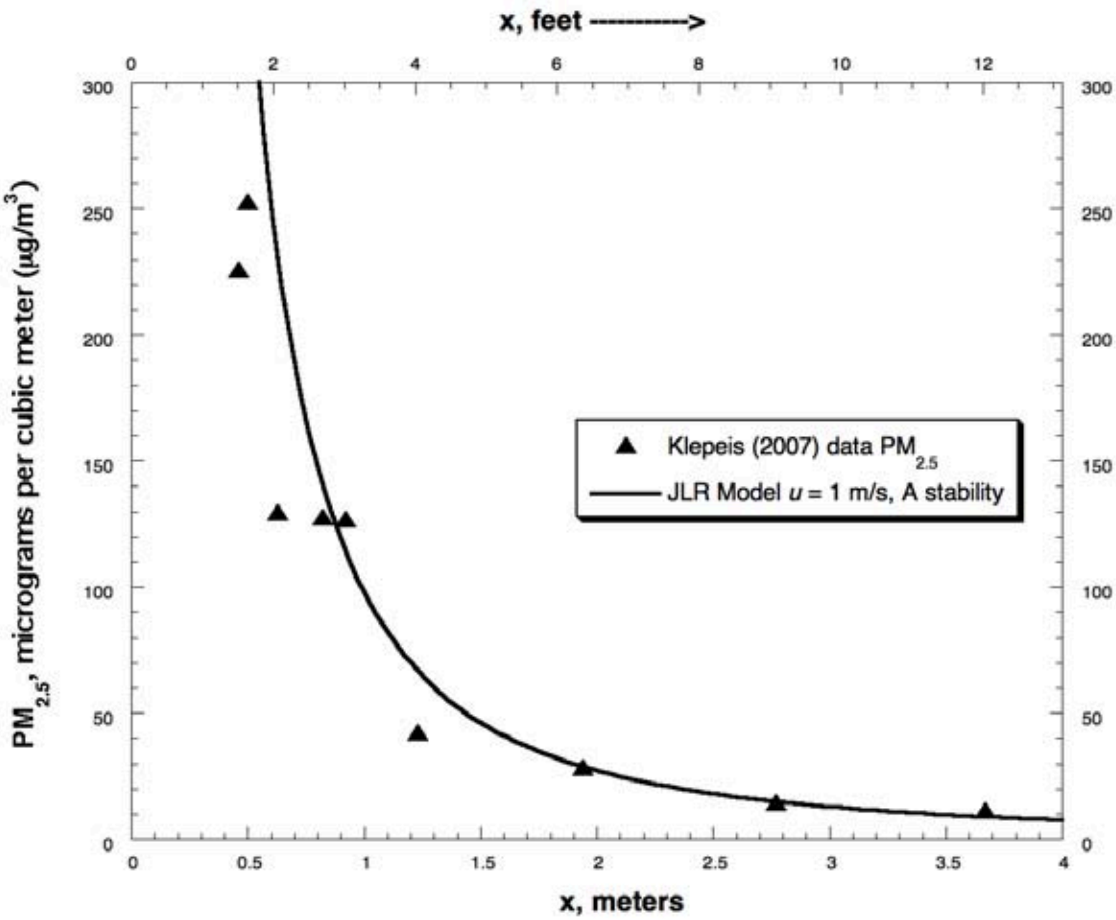

Figure 11. Model-calculated SHS $PM_{2.5}$ concentration versus distance from a smoker for A Stability, wind speed 1 m/s superimposed on measured data (▲) from Klepeis et al. (2007). The model (solid curve) gives an excellent fit to the independently measured data. One meter = 3.28 feet.

21. Klepeis et al. (2009) fit a multiplicative regression model to their empirical data that predicts outdoor concentrations as a function of source emission rate, source–receptor distance, air speed and wind direction. They report that model described the data reasonably well, accounting for 50% of the variability in the data. For any wind speed, the model of Klepeis et al. (2009) predicts along a single direction on the plume axis for a rectangular patio of dimensions 45' x 21' (13.7 x 6.4 m), whose long axis runs in a North-South direction with a house wall along one side and a fence on the other. Table 6 below shows the predictions of their regression model for 2 conditions: downwind of a North wind, and in the "maximum direction," (averaging across the maximum 5-min average concentrations occurring in any given direction at a given height and distance from the source). Their model and the Gaussian plume model give similar results.

Table 6. Model Comparison: Klepeis et al. vs Gaussian Plume. Normalized CO concentration parameter 2 to 5 feet off the ground as a function of distance for all wind speeds >0.2 m/s in μg/m³/mg/min. To convert to SHS $PM_{2.5}$ concentration the CO parameter is multiplied by 1.4 mg/min for a standard cigarette SHS $PM_{2.5}$ emission. Values selected are for a <u>North wind, 15 cm above the plume axis for a single smoker</u> (Table 2 from Klepeis et al. (2009).

Horizontal Distance from source [m]	**$PM_{2.5}$ concentration in the maximum direction**	**$PM_{2.5}$ concentration South of the source (North Wind)**	***Gaussian Plume Model $PM_{2.5}$ concentration**
1.0	43	25	33
2.0	17	13	9

*The Gaussian plume model, used here yields: $y = 32.7\ x^{-1.8478}$ gives the following predictions for the same distances for A Stability for Q = 23 μg/s; *u* = 3 m/s.
$y = 32.7\ x^{-1.8478}$ for x = 1, $X(x=1)_A = 33$ μgm³; x = 2, $X(x=2)_A = 9$ μgm³.

Table 4. Estimated secondhand smoke concentrations X in units of μg/m³ at smoker-to target distances ranging from 1 to 15 meters.

x, meters	$X_B=Q/(\pi\sigma_y\sigma_z u)$	$X_E=Q/(\pi\sigma_y\sigma_z u)$
1	59.32	386.61
3	7.7804	55.427
5	3.0256	22.464
7	1.6241	12.392
10	0.83985	6.5959
15	0.39683	3.2207

22. The Junker et al. (2001) median irritation level of 4.4 μg/m³ is exceeded at a distance of 4 m (13.4 feet) downwind distance from cigarette to window in the most favorable dispersion case, ranging up to a distance of 12.6 meters (41.3 feet) at night in the least favorable dispersion case. In the evening a single smoker at a distance of greater than 40 feet would cause irritation. For multiple smokers, the concentrations at a given distance would increase proportionately. These occasions when the wind blows from Unit R to Unit Q would happen 28% of the time on the garden side and 35.5% of the time on the service side. I conclude that smoking outdoors in the yards of Unit R would be capable of causing a nuisance in Unit Q a significant portion of the time.

23. Figure 12 is a copy of a City of Greenbelt Park and Recreation Advisory Board (PRAB) report dated Sept. 20th 2010, adopting a new secondhand smoking policy. The proposed policy change, unanimously adopted 6-0 by the board, recommended banning smoking within 25 feet of indoor recreation facilities, and within 25 feet of open air outdoor recreational facilities such as ball fields and playgrounds. The advisory board stated that the State of Maryland bans smoking within 25 feet of any public building, and that "accepted research states that you must be 23 feet from a smoker to avoid secondhand smoke." On November 8th, 2010, The Greenbelt City Council accepted the report, 10-2 (Greenbelt News Review, 2010). Thus, the City has acknowledged that

secondhand smoke is something to be avoided as a matter of public policy.

PRAB Report 10-2
September 20, 2010

PARK AND RECREATION ADVISORY BOARD
REPORT TO CITY COUNCIL

SUBJECT: **Proposed Smoking Restrictions in Parks and Recreation Facilities**

DISCUSSION: PRAB reviewed the proposed smoking restrictions in parks and recreation facilities at its regular monthly meeting of September 15, 2010.

Joe McNeal, acting co-director of Recreation stated that in Anne Arundel County smoking is prohibited within 100 yards of outdoor recreation activities. The City of Rockville has a ban 40 feet from a playground. The State of Maryland bans smoking 25 feet from the entrance of any public building. The accepted research states that you must be 23 feet from a smoker to avoid second-hand smoke. Howard County has tobacco free programs but does not have prohibitions on smoking in outdoor areas of parks.

The Greenbelt policy would expand the prohibition on smoking within City Recreation facilities to include fully enclosed fenced areas such as the outdoor pool, tennis courts, dog park, etc. Prohibit smoking within 25 feet of the entrance of indoor Recreation facilities and prohibit smoking within 25 feet of outdoor park facilities not fully enclosed by a fence such as ball fields, playgrounds, outdoor basketball courts, etc. This does not include the path between the tennis courts and the ball fields at Braden Field or the path around Greenbelt Lake.

PRAB requested that the wording be clarified so that it would be clear that smoking would not be allowed within 25 ft. of any sport or activity area, not just the activity itself. It was also noted that cigarette butt receptacles should be adequate and well placed so that the public could comply with the policy.

RECOMMENDATION:
PRAB recommends City Council adopt the smoking restrictions in parks and recreation facilities policy.

Vote 6-0

Respectfully submitted by:
Lola Skolnik, Chairperson
Park and Recreation Advisory Board

Figure 12. City of Greenbelt Park and Recreation Advisory Board (PRAB) report recommending a 25-foot outdoor smoking ban in front of indoor and outdoor recreational facilities to the City Council. Adopted by City of Greenbelt, Nov. 8th, 2010.

25. Finally, I take note of the 2010 Surgeon General's Report, issued on Dec. 9th, which concluded in part: "**There is no safe level of exposure to tobacco smoke.** Any exposure to tobacco smoke – even an occasional cigarette or exposure to secondhand smoke – is harmful." "Low levels of smoke exposure, including exposures to secondhand tobacco smoke, lead to a rapid and sharp increase in dysfunction and inflammation of the lining of the blood vessels, which are implicated in heart attacks and stroke." (SG, 2010).

26. In conclusion, outdoor secondhand smoke will pose a nuisance to Mr. Schuman a significant fraction of the time when the doors and windows of Unit Q are open if his neighbor in Unit R smokes in his yard. I reach these conclusions to a reasonable degree of scientific certainty.

Signed

James Repace, MSc. Dec. 10th, 2010

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Repace JL. *Expert Witness Report and Declaration, in the matter of Birke v. Oakwood, Superior Court of the State of California, County of Los Angeles, Northwest District, Case No. LC 085 905, April 9, 2010.*

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About The Author: I have been studying outdoor and indoor air pollution since 1970. Specifically related to outdoor air pollution issues: In 1971, I became involved in a proposed sewage sludge incinerator in Washington DC, and wrote an expert report on the expected air pollution emissions from this project. I was an expert in a suit against the EPA over sewage sludge incineration in 1973, which resulted in EPA regulating sewage sludge incinerators under Section 112 of the Clean Air Act (National Emissions Standards for Hazardous Air Pollutants.) In 1973, I also testified as an expert witness before the Prince Georges County Council on behalf of the Piscataway Citizens Association in their petition to close a local sewage sludge incinerator. The Council voted to shut this incinerator down. In 1974, I accurately predicted mercury emissions from a trash incinerator located near an elementary school in Washington, DC and testified before the DC City Council. The American Physical Society recognized my work in a June 1974 article in the news magazine, *Physics Today*, on how physicists could work with environmental groups to solve environmental problems. In 1979, I joined the Air Policy Staff of the United States Environmental Protection Agency in Washington, DC, working on stationary source outdoor air pollution issues such as hazardous air pollutant emissions from coke ovens, power plants, incinerators, and smelters. In 1984, I received a U.S. EPA Award for Exceptional Performance for my work on indoor and outdoor air pollution. I retired from EPA in 1998. My full curriculum vitae is downloadable from my website, www.repace.com. Recently, I served as an expert witness on outdoor air pollution issues in 2 legal cases involving outdoor air pollution, in Las Angeles, and in the Faroe Islands, Denmark (Repace, 2010), and submitted invited testimony on the proposed outdoor smoking ban in New York City before the New York City Council (Repace, 2010). I conducted research on outdoor air pollution from secondhand smoke on the campus of the University of Maryland, Baltimore County (UMBC) (Repace, 2005), and on 2 cruise ships in the Caribbean (Repace, 2004), and authored a paper summarizing research on the benefits of banning smoking in certain outdoor settings (Repace, 2008).

OUTDOOR SECONDHAND SMOKE INFILTRATION IN A GREENBELT MD TOWN HOME: 11Q RIDGE ROAD PART III

View of Unit Q (right) and Unit R (left) from garden side.

James L. Repace, MSc.

REPACE ASSOCIATES

Secondhand Smoke Consultants

101 Felicia Lane

Bowie, MD 20720

July 18, 2011*

PREPARED FOR MR. DAVID SCHUMAN

1.0. **BACKGROUND:** Mr. David Schuman resides at 11 Q Ridge Road, Greenbelt, MD 20770, in a cooperative association, Greenbelt Homes, Inc. (GHI). His unit is one of eight individual units in a connected row, brick construction with slate roof, built in the late 1930s. His unit adjoins the unit of his neighbors, the Mr. and Mrs. Popovic, who own Unit R. These neighbors are smokers. Mr. Schuman does not smoke. Nor does his neighbor on the other side of Mr. Schuman's unit.

1.1. Mr. Schuman relates that for many years, his neighbors have smoked inside and outside their unit. Conditions have been very bad on occasion but inconsistently so. In recent months, particularly over the winter, conditions became intolerable for him on a more regular basis. He complains of a heavy smoke smell on most nights. On occasion, he was forced to open his windows during winter to dissipate accumulating secondhand smoke (SHS) infiltrating from Unit R. He became ill with bronchitis-like symptoms for several months and visited the doctor twice.

1.2. Subsequently, Mr. Schuman filed suit against Mr. and Mrs. Popovic, and their cooperative association, Greenbelt Homes, Inc. In a preliminary court hearing, Mr. Popovic announced that he and his wife agreed not to smoke inside their residence, but insisted on the right to continue to smoke outside their residence on their own property. However, Mr. Schuman and the Popovic's neighbor in Unit S both stated that outdoor smoking by the Popovics penetrated into their homes when windows were opened.

1.3 Accordingly, in order to estimate the level of smoke that might penetrate the open windows of Mr. Schuman, I conducted an analysis, described in a previous report, entitled "**RISK ASSESSMENT OF SECONDHAND SMOKE INFILTRATION IN A GREENBELT MD TOWN HOME: LOCATED AT 11 RIDGE ROAD Q PART II, OUTDOOR SMOKE**" (Repace, 2010). This report concluded in part that "The Junker et al. (2001) median irritation level of 4.4 $\mu g/m^3$ is exceeded at a distance of 4 m (13.4 feet) downwind distance from cigarette to window in the most favorable dispersion case, ranging up to a distance of 12.6 meters (41.3 feet) at night in the least favorable dispersion case. In the evening a single smoker at a distance of greater than 40 feet would cause irritation. For multiple smokers, the concentrations at a given distance would increase proportionately. These occasions when the wind blows from Unit R to Unit Q would happen 28% of the time on the garden side and 35.5% of the time on the service side. I conclude that smoking outdoors in the yards of Unit R would be capable of causing a nuisance in Unit Q a significant portion of the time." This conclusion was derived from a calculation of the downwind concentration of cigarette smoke using the Gaussian Plume model.

**This version has several typographical errors corrected from the version originally sent.*

2.0. **CALCULATION OF EXPECTED PPAH LEVELS.** Table 1 gives the estimated fine particle ($PM_{2.5}$) concentration from secondhand smoke versus the estimated particulate polycyclic aromatic hydrocarbon (PPAH) from secondhand smoke. Columns 3 and 4 are calculated in Repace Report #2 (Repace, 2010) in Table 4, and Columns 5 and 6 are calculated respectively by multiplying columns 3 and 4 by 0.05% respectively (Repace et al., 2010).

Table 1. Estimated $PM_{2.5}$ (in micrograms per cubic meter, $\mu g/m^3$) and PPAH concentrations (in nanograms per cubic meter, ng/m^3) from secondhand smoke at smoker-to target distances *x* ranging from 1 to 15 meters, for daytime and nighttime atmospheric stability conditions. PPAH = 0.05% $PM_{2.5}$.

1. x meters	*2. x* feet	*3. $PM_{2.5}$ Day* ($\mu g/m^3$)	*4. $PM_{2.5}$ Night* ($\mu g/m^3$)	*5. PPAH Day* (ng/m^3)	*6. PPAH Night* (ng/m^3)
1	3.28	59.3	387	28.5	186
3	9.84	7.78	55.4	3.73	26.6
5	16.4	3.03	22.5	1.45	10.8
7	23.0	1.62	12.4	0.78	5.95
10	32.8	0.84	6.6	0.403	3.17
15	49.2	0.397	3.22	0.19	1.55

2.1. **MEASUREMENT OF PPAH LEVELS IN THE SCHUMAN RESIDENCE.**

2.11. On Saturday, July 16, 2011, I arrived at Mr. David Schuman's residence at 11Q Ridge Ct., Greenbelt, with two EcoChem PAS 2000ce PPAH monitors. The monitors, labeled "A" (.174 files) and "B" (.159 files) were deployed respectively in Mr. Schuman's living room on the back of the couch in front of the open living room window (Monitor "A"), and on Mr. Schuman's dining room table adjacent to the open dining room window. Figures 1 and 2 show the deployment location of each monitor. Table 2 gives my time-activity pattern during the monitor deployment. For the purposes of comparison between smoking and nonsmoking periods in interpreting the readings, the period approximately from 6:40 to 7:00 PM is designated as a smoke-free period, and approximately from 7:00 PM to 7:20 PM as a smoking period, based on odor detection and observation of activity by Mr. Popovic in his front yard. Mr. Popovic was observed sitting in the chair shown in Figure 3, which is approximately 27 feet (8.2 meters) from the left hand corner of Mr. Schuman's dining room window as viewed from outside the building, and approximately 43 feet (13 meters) from Mr. Schuman's living room window. The PPAH monitors were located inside the open windows as shown in Figures 1 and 2.

Table 2. Time-Activity Pattern for PPAH Monitor Deployment, Sat. July 16, 2011, 11 Q Ridge Ct., Greenbelt, MD.

TIME	SMOKING ACTIVITY
6:40 PM	No odor of smoke, no smoking activity observed. No cooking in Schuman residence. Monitors A and B turned on. Both Mr. Schuman and I are present.
7:01 PM	Schuman dog barks. Smoke odor detected in Schuman living room; Mr. Popovic observed smoking in his front (garden-side) yard, sitting in a chair adjacent to his front porch.
7:15 PM	Stronger smoke odor detected in Schuman living room
7:18 PM	The smoke irritates my lungs, throat, and eyes. I can smell the smoke in Mr. Schuman's living room, kitchen, and upstairs bedroom on the Popovic side of the building.
7:55 PM	Smoke odor detected in kitchen
8:00 PM	Mr. Popovic observed to go into his house. No smoking.
	Greenbelt MD Temperature 80 deg F; RH 50% at 8 PM <wunderground.com>
8:20 PM	Measurements terminated.

Figure 1. Deployment of Monitor B in Mr. Schuman's kitchen.

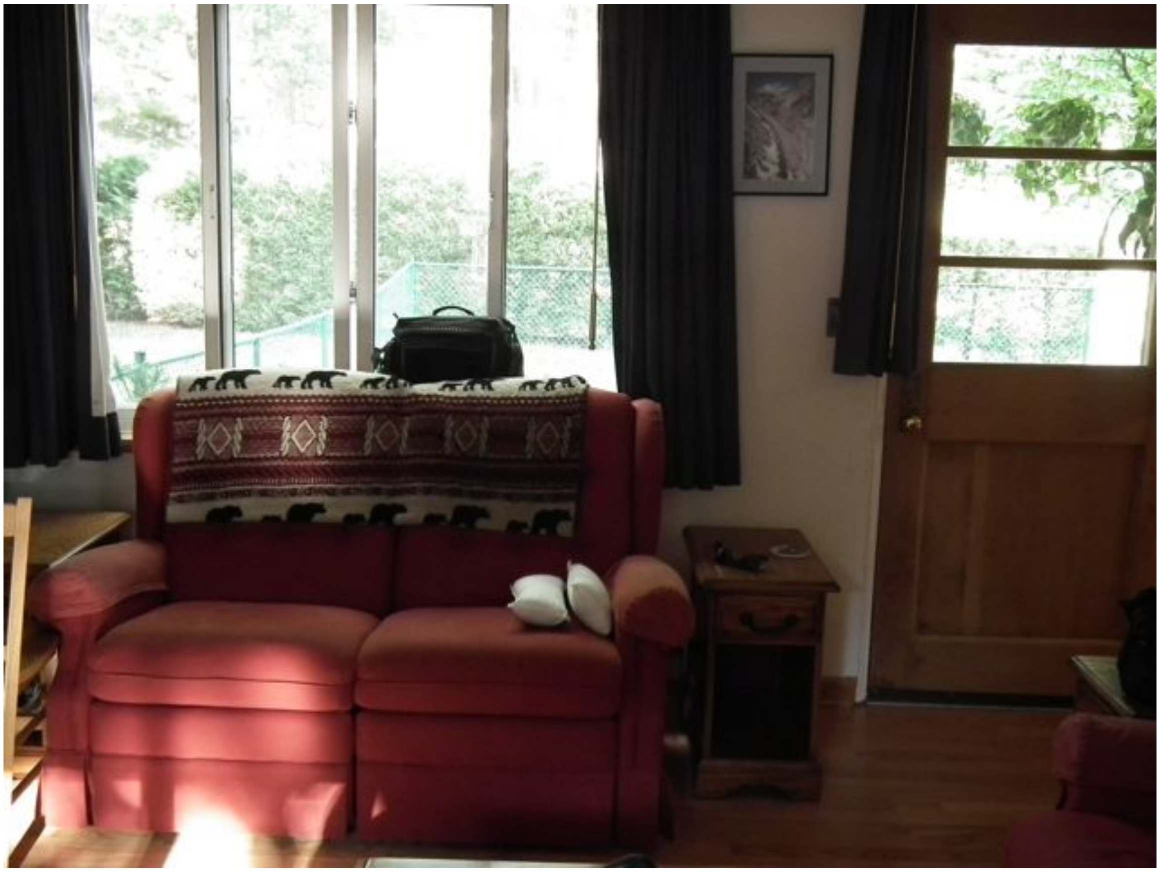

Figure 2. Deployment of Monitor A in Mr. Schuman's living room.

Figure 3. Location of Mr. Popovic's outdoor smoking chair. The chain-link fence borders the common sidewalk between the Popovic and Schuman units.

2.2. Figure 4 shows a plot of predicted PPAH concentrations as a function of downwind distance from the source, where the PPAH values are derived from Table 1 above. Both monitors detected PPAH inside Mr. Schuman's home from Mr. Popovic's smoking at distances ranging from 8 to 13 meters from the cigarette source. The average incremental (background-subtracted) ~20 min ave. PPAH concentration for monitor "B", located in Mr. Schuman's dining room was 1.54 ng/m^3, corresponding to a $PM_{2.5}$ level of 3.1 μg/m^3, while for monitor "A" in Mr. Schuman's living room, the incremental PPAH value was 0.94 ng/m^3, corresponding to a $PM_{2.5}$ level of 1.9 μg/m^3, within the predicted range given in Table 1.

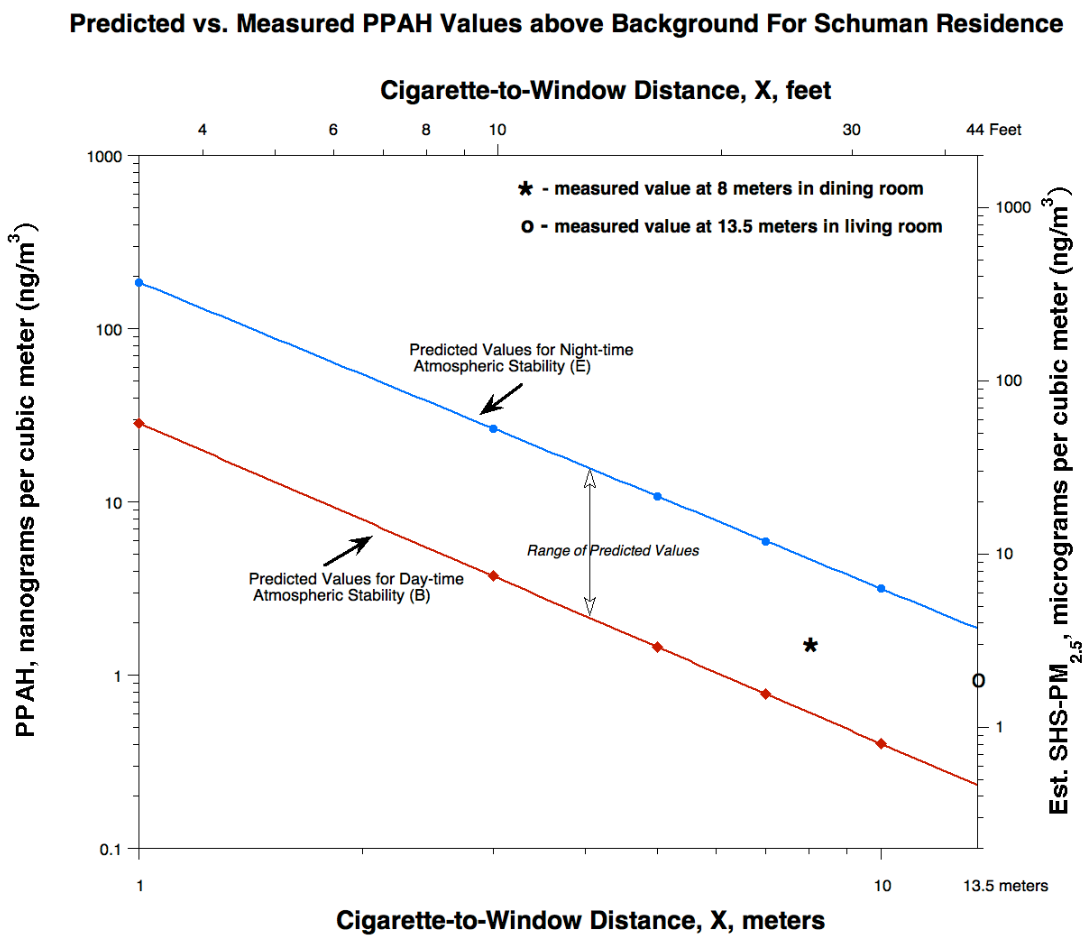

Figure 4. Plot of the expected range of PPAH concentrations from smoking a single cigarette outdoors from the Schuman residence by cigarette smoking in the Popovic yard. The upper (blue) curve shows the expected value for very stable night-time conditions, while the lower (red) curve shows the expected value for less stable day-time conditions, as discussed in Schuman Report #2 (Repace, 2010). The asterisk (*) shows the actual background subtracted PPAH reading of Monitor B between 7:00 and 7:20 PM in the evening inside Mr. Schuman's kitchen. The circle (o) shows the actual background subtracted PPAH reading of Monitor A between ~7:00 and 7:20 PM in the evening inside Mr. Schuman's living room. Both values lie within the predicted range.

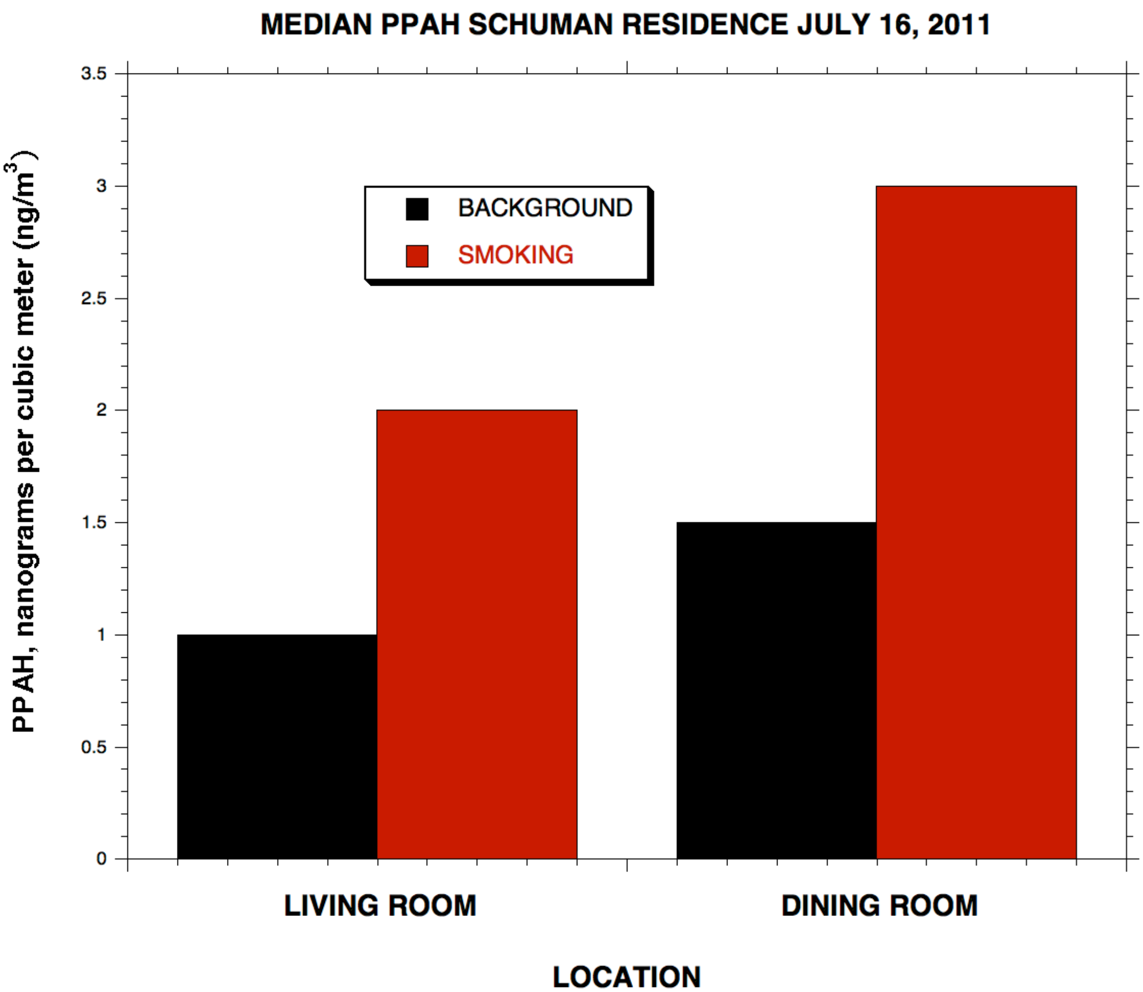

Figure 5. Plot of the median PPAH concentrations before and during smoking a single cigarette outdoors from the Schuman residence by cigarette smoking in the Popovic yard. Carcinogenic PPAH levels are doubled over background levels in Mr. Schuman's dining and living rooms. The smoke levels were also quite irritating to the eyes, nose, throat, and lungs of the investigator during exposure, while the background levels were not.

3.0. DISCUSSION.

I measured 10 second average PPAH with two secondhand smoke-calibrated (Repace, 2004) real-time EcoChem PAS 2000CE® monitors [EcoChem Analytics, League City, TX]. Secondhand smoke is a known human carcinogen (NIEHS, 2000) Polycyclic aromatic hydrocarbons (PAHs) are a diverse group of carcinogens formed in the incomplete combustion of organic material; PAHs are potent animal carcinogens that induce respiratory tract tumors upon inhalation (Hecht, 2003). PAH have been implicated in heart disease and stroke mechanisms as well (Glantz and Parmley, 1991). Particle-bound PAHs (PPAHs) are compounds with 4 or more benzene rings emitted by secondhand smoke, diesel exhaust, incense, wood smoke, and smoky candles; in contrast, burning toast and frying hamburgers do not appear to be important sources of PPAH emissions (Ott and Siegmann, 2006). Thus, measurement of PPAH in conjunction with $PM_{2.5}$ helps confirm the presence of secondhand smoke. Repace et al. (2011) found that incremental (indoor – outdoor) $PM_{2.5}$ was 0.05% PPAH; incremental $PM_{2.5}$ correlated significantly with incremental PPAH (R^2 = 0.79) in 10 smoky casinos in Reno, Nevada.

The classic PPAH compound is benz(α)pyrene, which is a known human lung carcinogen. Total PAH include both gaseous and particulate phase compounds, and are thermally stable. There are more than 100 PAH molecules; measurement of PPAH underestimates the total number of toxic PAH in the air. Portable real-time PAH monitors have been developed, calibrated against standard gas-chromatography/mass spectrometry methods, and deployed in environmental epidemiology studies.

A lightweight battery-powered data logging respirable PPAH monitor, the EcoChem PAS 2000CE, is deployed in these experiments. This monitor operates on the principle of photoelectric charging: airborne particles are drawn into a tube, illuminated with ultraviolet photons, and produce photo-electrons and positive ions which are collected by an alternating electric field, which is measured using a current amplifier. Only fine particles can be charged efficiently by this method, because electron recombination with the positive ions increases with particle size.

Photoelectric charging is surface-sensitive and therefore yields information on the surface concentrations of fine particles suspended in a gas. Particles from other than combustion sources generally cannot be charged photoelectrically due to the absence of PPAH. A linear relation between the photoelectric activity and the PPAH mass concentration in air has been determined. The operating environment for the PAS 2000CE is 5^oC to 40^oC; the fraction of particle mass due to PPAH is independent of location and weather conditions. Outdoors, the major sources of PPAH particles are diesel exhaust and cars with defective catalytic converters. PPAH particles are submicron in size, or "nanoparticles." (Repace, 2004).

Figure 5 shows that the median levels of PPAH in Mr. Schuman's living room and dining room doubled during Mr. Popovic's smoking.

CONCLUSIONS:

1. **I measured particulate polycyclic aromatic hydrocarbons in the living room and dining room of Mr. David Schuman from about 6:30 to 8:00 PM on Saturday, July 16, 2011, in the presence and absence of observed outdoor cigarette smoking by Mr. Darko Popovic, Mr. Schuman's next-door neighbor.**
2. **I smelled and was irritated by cigarette smoke odor emanating from Mr. Popovic's outdoor smoking and infiltrating into Mr. Schuman's living room, dining room, and upstairs bedroom window.**

3. **I confirmed the presence of outdoor cigarette smoke penetrating into Mr. Schuman's residence objectively by measuring particulate carcinogens known to be present in cigarette smoke.**
4. **During the ~20 minute smoking period, median carcinogenic PPAH levels doubled over the previous ~20 minute nonsmoking period background.**
5. **I conclude to within a reasonable scientific certainty, that outdoor smoking by Mr. Popovic penetrated through the open windows of Mr. Schuman's home.**
6. **Due to the irritating nature of the tobacco aerosol and its carcinogenic nature, I conclude to within a reasonable scientific certainty, that outdoor smoking by Mr. Popovic in his front yard at 8 and 13 meters distant from Mr. Schuman's open windows, is both irritating and carcinogenic.**

Signed

James Repace, MSc. July 18, 2011

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About The Author: I have been studying outdoor and indoor air pollution since 1970. Specifically related to outdoor air pollution issues: In 1971, I became involved in a proposed sewage sludge incinerator in Washington DC, and wrote an expert report on the expected air pollution emissions from this project. I was an expert in a suit against the EPA over sewage sludge incineration in 1973, which resulted in EPA regulating sewage sludge incinerators under Section 112 of the Clean Air Act (National Emissions Standards for Hazardous Air Pollutants.) In 1973, I also testified as an expert witness before the Prince Georges County Council on behalf of the Piscataway Citizens Association in their petition to close a local sewage sludge incinerator. The Council voted to shut this incinerator down. In 1974, I accurately predicted mercury emissions from a trash incinerator located near an elementary school in Washington, DC and testified before the DC City Council. The American Physical Society recognized my work in a June 1974 article in the news magazine, *Physics Today*, on how physicists could work with environmental groups to solve environmental problems. In 1979, I joined the Air Policy Staff of the United States Environmental Protection Agency in Washington, DC, working on stationary source outdoor air pollution issues such as hazardous air pollutant emissions from coke ovens, power plants, incinerators, and smelters. In 1984, I received a U.S. EPA Award for Exceptional Performance for my work on indoor and outdoor air pollution. I retired from EPA in 1998. My full curriculum vitae is downloadable from my website, www.repace.com. Recently, I served as an expert witness on outdoor air pollution issues in 2 legal cases involving outdoor air pollution, in Los Angeles, and in the Faroe Islands, Denmark (Repace, 2010), and submitted invited testimony on the proposed outdoor smoking ban in New York City before the New York City Council (Repace, 2010). I conducted research on outdoor air pollution from secondhand smoke on the campus of the University of Maryland, Baltimore County (UMBC) (Repace, 2005), and on 2 cruise ships in the Caribbean (Repace, 2004), where I measured PPAH and PM2.5, from outdoor smoking, and authored a paper summarizing research on the benefits of banning smoking in certain outdoor settings (Repace, 2008).

Appendix

Table A1. Data Statistics for EcoChemPAS2000ce Carcinogen Monitors Deployed in 11Q Ridge Ct. on Saturday, July 15. 2011.

Statistics	**Living Room**		**Dining Room**	
	Background	Smoking	Background	Smoking
Number of 10 sec. data Points, *n*	120	112	120	112
Units ----------->	ng/m^3	ng/m^3	ng/m^3	ng/m^3
Minimum	0	0	0	0
Maximum	6	5	9	9
Mean	1.34	2.28	1.94	3.48
Median	1	2	1.5	3
Std Deviation	1.25	1.34	2.03	2.04
Variance	1.57	1.79	4.14	4.14
Std Error	0.114	0.126	0.186	0.192
Net PPAH above background	**2.28 - 1.34 = 0.94**		**3.48 - 1.94 = 1.54**	

Calibration
The calibration of the EcoChem PAS 2000ce against cigarette smoke is described in Repace (2004). The lower limit of detection is 1 ng/m^3, and the precision is 1 ng/m^3. However, time-averaged values less than 1 ng/m^3 may be accurately quantified by time-averaging repeated measurements.