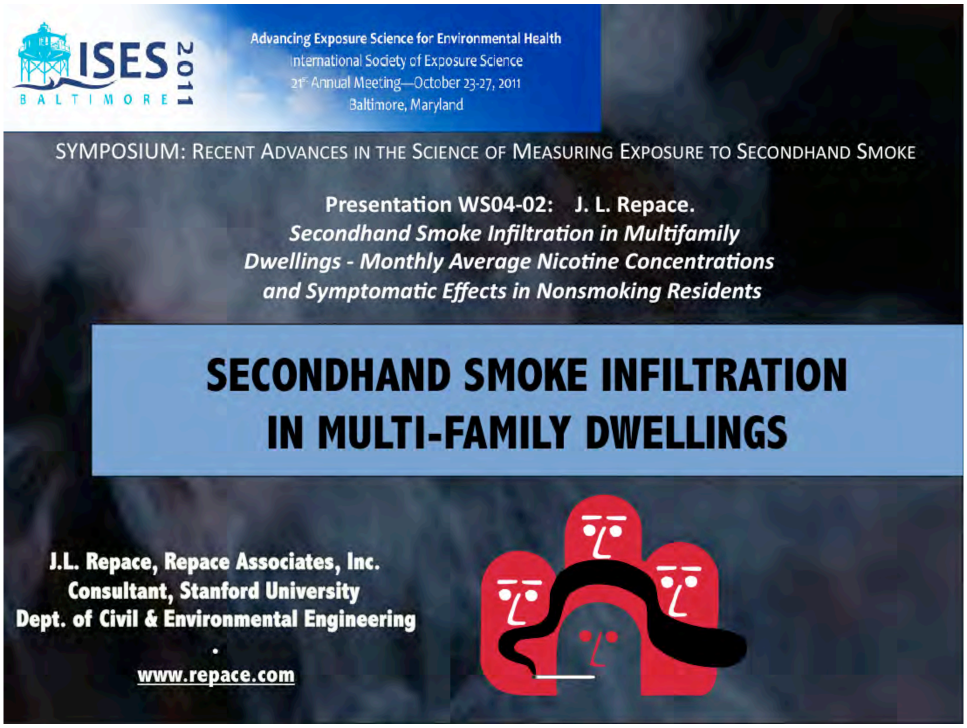

This research used passive nicotine monitors to study secondhand smoke (SHS) infiltration. To date, the monitors have been deployed in 20 multi-family dwellings (MFDs) and 3 commercial businesses. The aims of the study were: (1) to investigate the nature and commonality of the SHS complaints reported by participants, (2) to recommend goals for future research, and (3) to deliniate appropriate public health policy goals for health departments and legislators.

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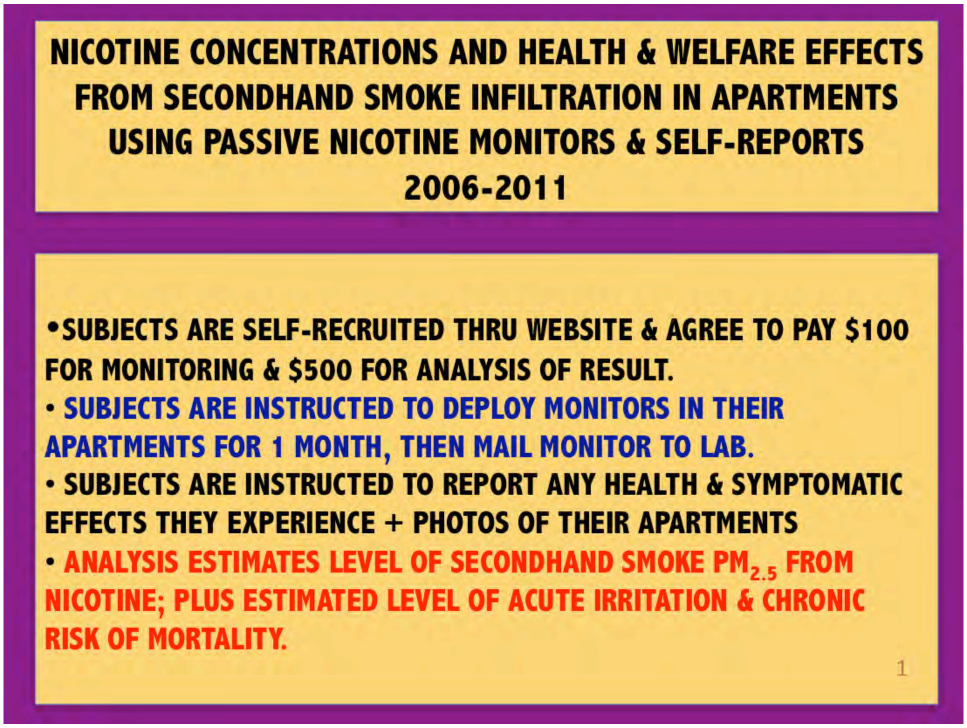
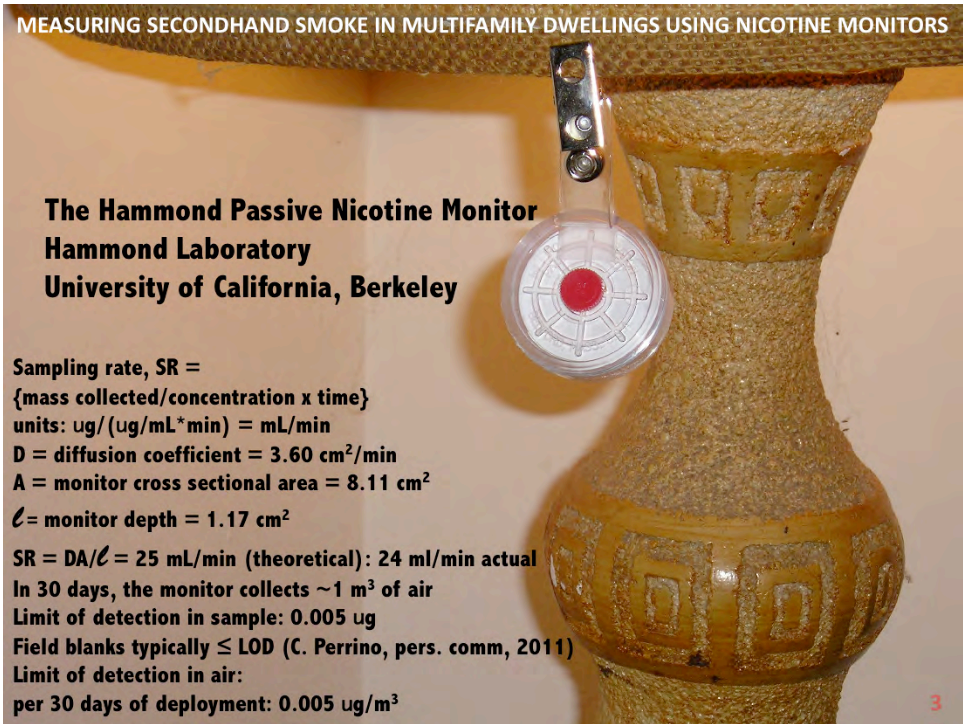


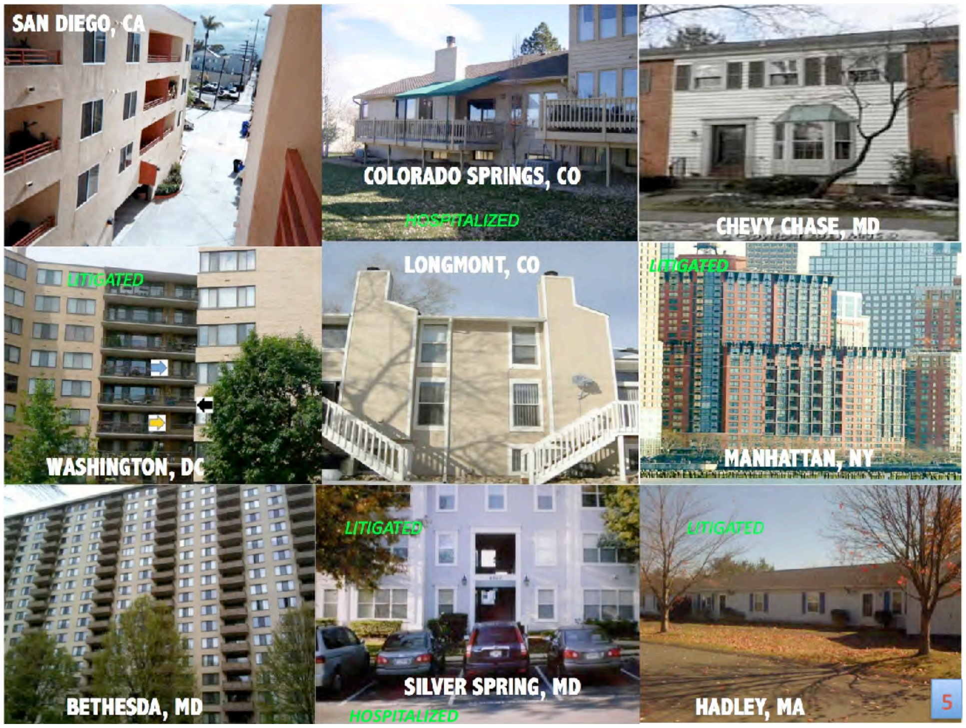
The study participants were self-selected nonsmokers who own condominiums, co-ops, and business tenants. They complained of symptomatic and health effects from SHS infiltration of their units. These persons paid to receive a passive nicotine monitor which they deployed for 1 month in their units, and provided a summary of their subjective complaints, plus photos of their buildings. In return, I provided them with a report documenting SHS intrusion, plus an estimate of the levels of irritation and health risk commensurate with that SHS exposure, which they could use in interventions and legal proceedings.

In a space where smoking occurs daily, fine particulate matter ($PM_{2.5}$) from secondhand smoke (SHS-$PM_{2.5}$) and nicotine will be present in the air in an average ratio during smoking of 10:1. The typical smoker will smoke at the rate of 2 cigarettes per hour, and spend an annualized 5 to 6 hours daily awake, yielding about 10 to 12 cigarettes smoked at home. Chainsmokers might smoke up to 3 times that rate. Stay-at-home smokers might smoke inside up to 16 hours daily.

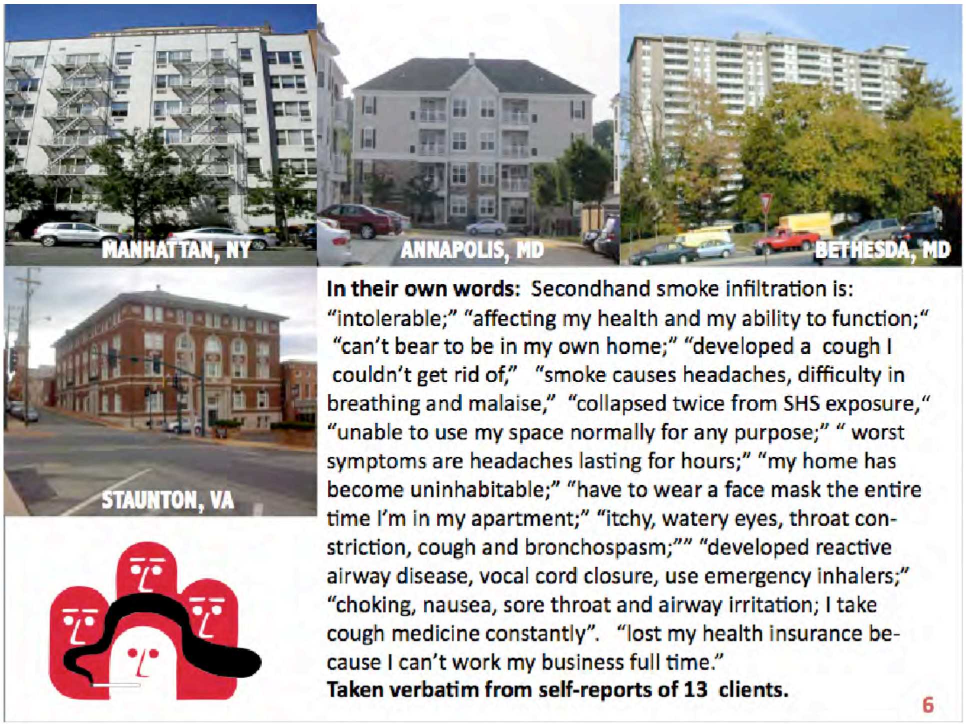


A photo of the passive nicotine monitor obtained from the Hammond laboratory at UC Berkeley. The air containing SHS nicotine vapor is sampled at the rate of 24 ml/min, or 1 m^3/month. For a 1-month deployment, the limit of detection (LOD) is 5 nanograms per cubic meter of air (ng/m^3). Since nicotine is attenuated rapidly as it progresses thru walls, ceilings, or floors, nicotine in nonsmokers' apartments may be as low as 10 ng/m^3. The 1-month sampling time also captures the smokers' regular activity patterns.

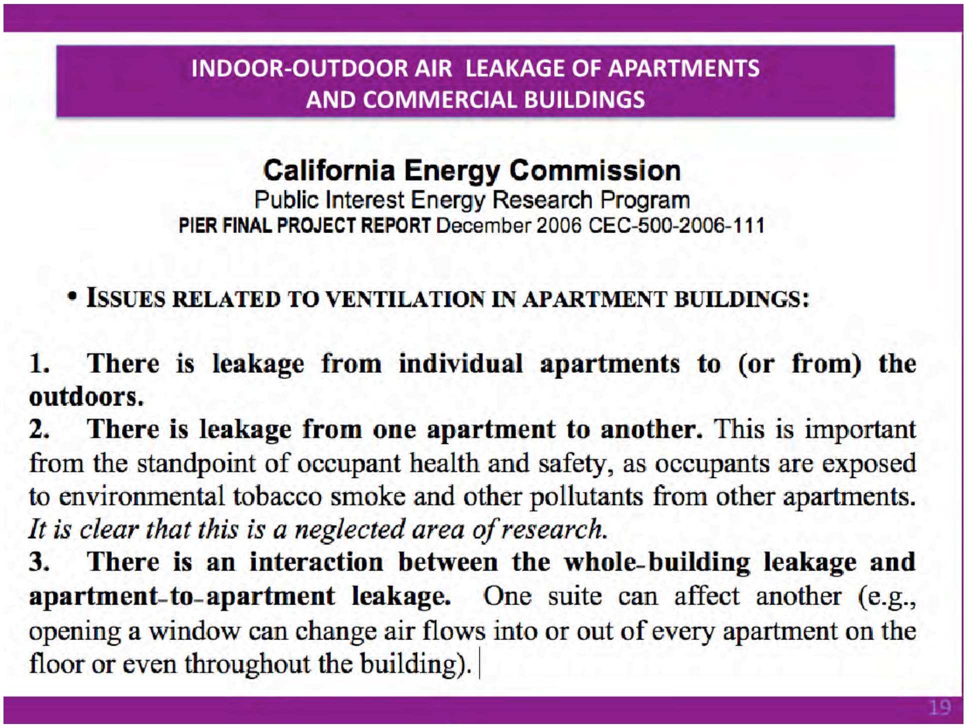
These next series of photos show the commercial and multifamily dwellings where occupants complained of SHS infiltration. These buildings are from all over the U.S., including MA, NY, NJ, MD, VA, CO, and CA. They include a wide variety of buildings, ranging from Townhomes to Garden Apts. to High Rises, and vary in age from 100 year old city buildings to 5 year old townhouses, and also include a mother-in-law apartment in a single family home.



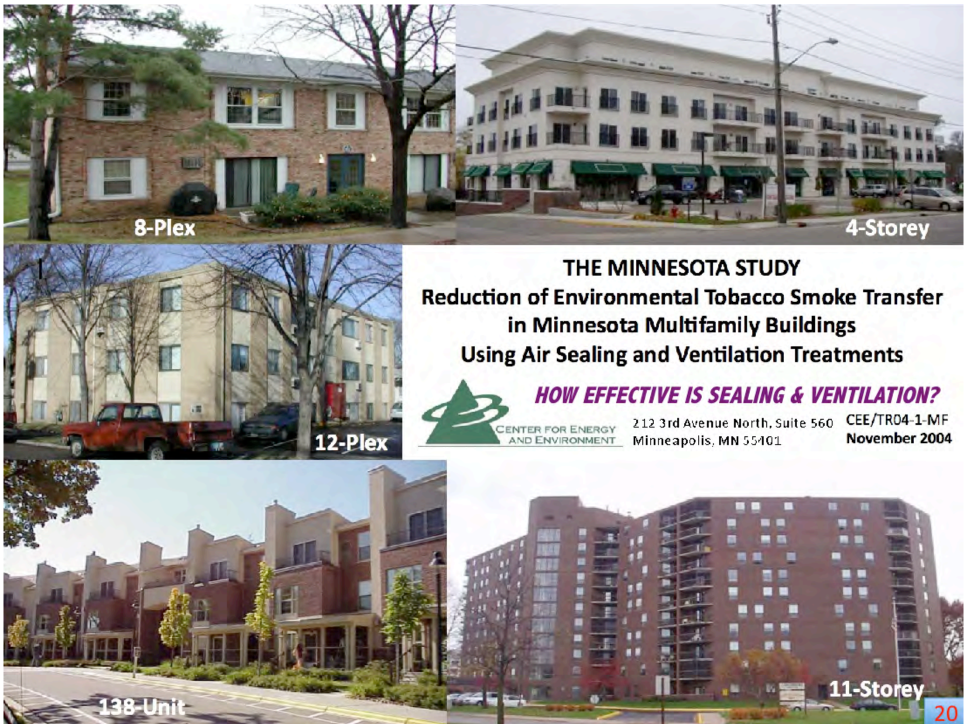
The 23 subjects in this study are 65% adult females and 35% adult males. The 20 MFD residents live in urban, suburban, and rural settings, ranging from subsidized housing for the handicapped in MA, to Luxury Penthouses in Manhattan, while the 3 business owners are from Colorado, Florida, and Virginia.



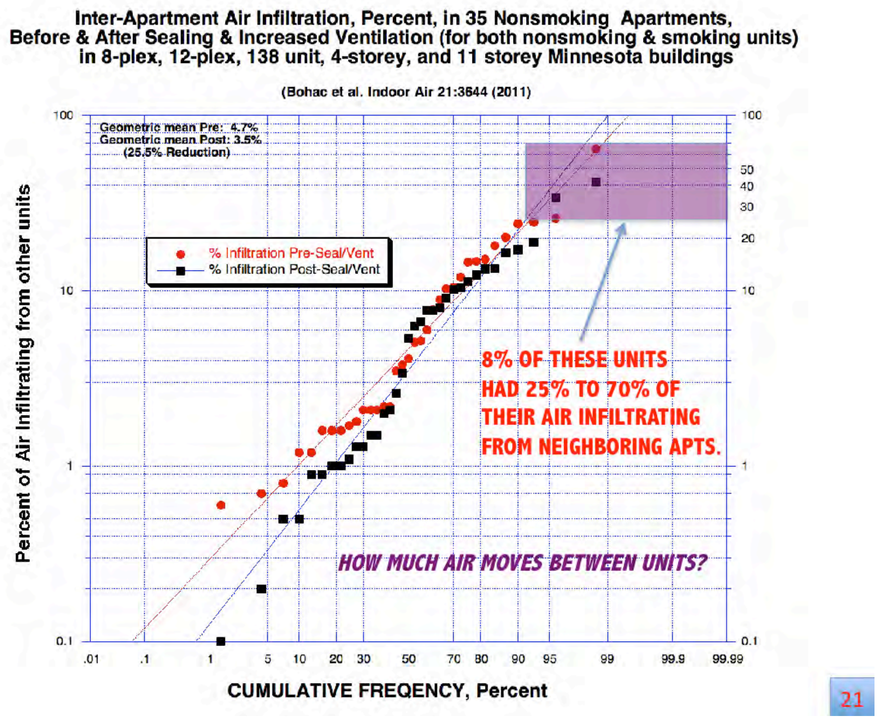
It is clear from the self-reports of many clients that their homes have become uninhabitable, and they are desperate for relief. Many of them have used the reports to establish objective proof of secondhand smoke intrusion of their homes, and use them to attempt to pursuade smokers, condominium associations, cooperative boards, to ban smoking in neighboring apartments. A number have sued the smokers, the associations, or the cooperatives.



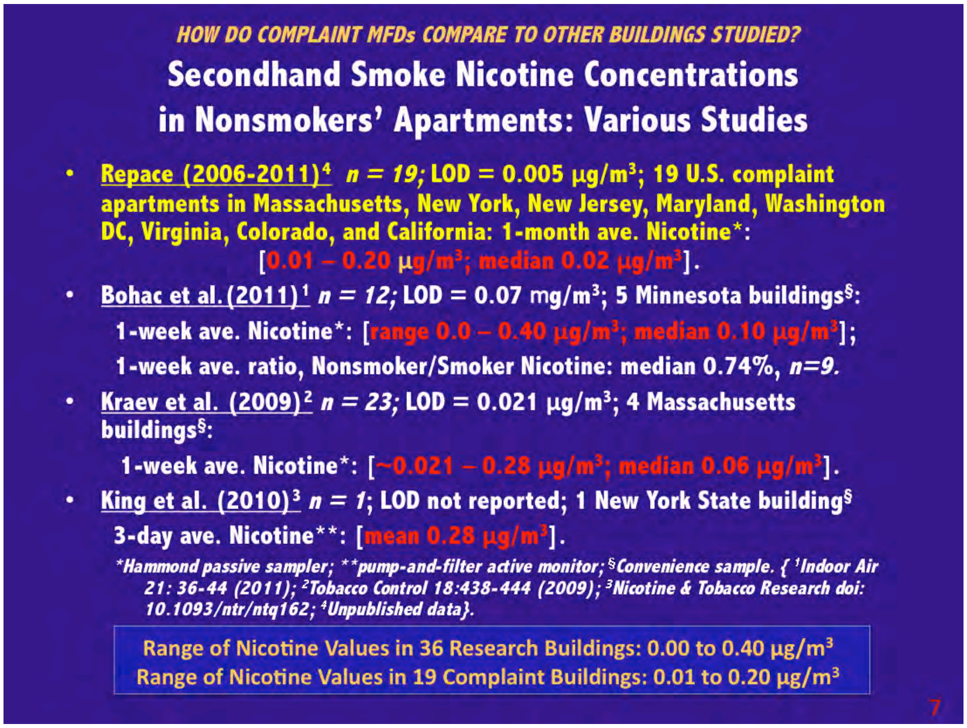
These are the conclusions of a Lawrence Berkeley Laboratory study performed for the California Energy Commission. The lesson to be learned is that the air in in apartments often comes from other apartments in the building.



This slide shows 5 buildings studied by the Center for Energy and Environment in Minnesota. They investigated how much air infiltrated between neighboring apartments, and whether sealing and additional ventilation of smokers' units could decrease or eliminate SHS intrusion into nonsmokers' units. They concluded that while these measures often – but not always -- reduced interunit airflows, they nevertheless failed to eliminate SHS infiltration.

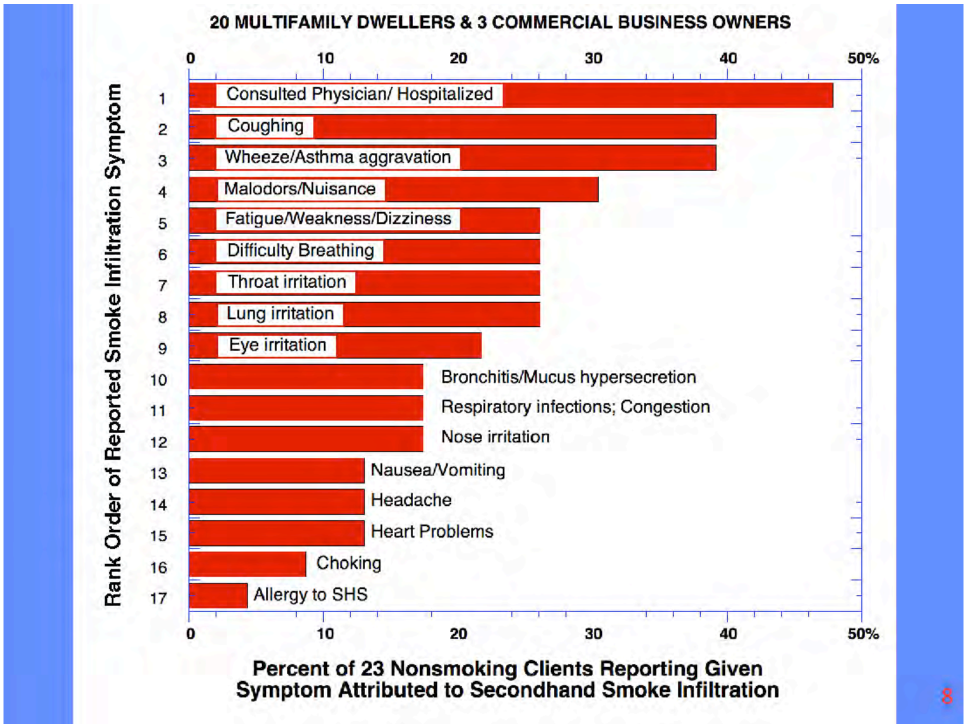


A log-probability plot of the percent of air infiltrating between units before and after sealing and increased ventilation to reduce SHS infiltration in the Minnesota study by Bohac and Hewett. The data showed that on average, 75% of the air flowing between units remained after professional sealing and ventilation measures were undertaken in 35 units studied. However several units had greater infiltration after the sealing than before. Importantly, the study disclosed that 8% of the units had 25 to 70% of their air coming from neighboring units... This graphically demonstrates why smokefree building policies rather than engineering measures, are required to eliminate SHS infltration in MFDs.

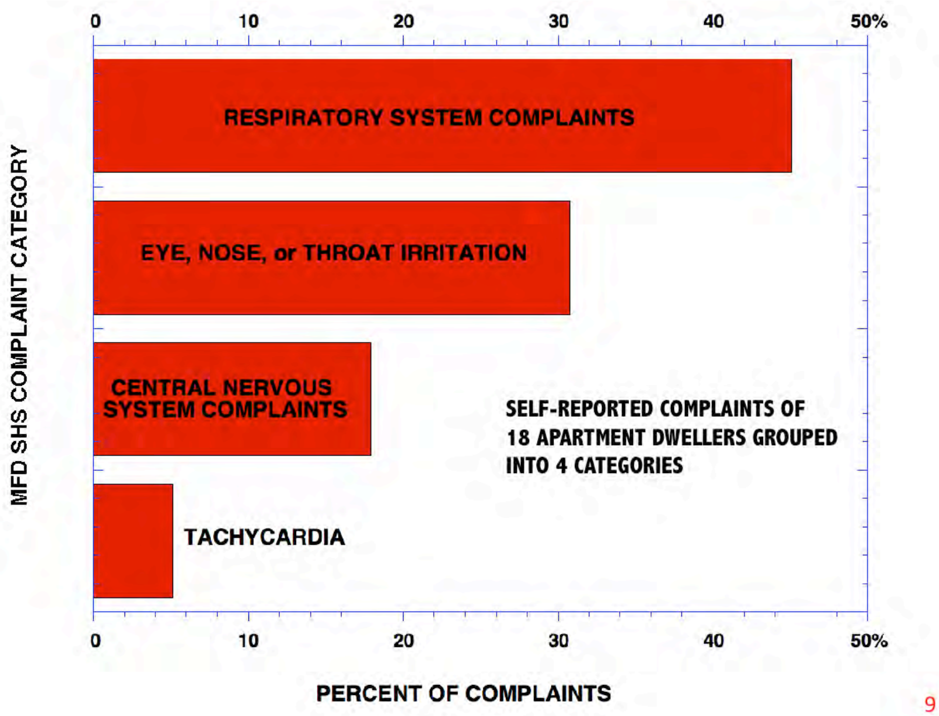


A comparison of the nicotine levels reported for all currently available studies of SHS infiltration. The monthly median nicotine level in the 19 complaint MFDs in my study was 20 ng/m^3, and ranged from 10 to 200 ng/m^3. In previous research studies in convenience-sampled buildings, Bohac et al. reported a weekly median of 100 ng/m^3, and a range of 0 to 400 ng/m^3, for 12 units in 8 MN buildings. Kraev et al. reported a weekly median of 60 ng/m^3, and a range of 21 to 280 ng/m^3 for 23 apartments in Boston public housing. King et al., reported a 3-day mean of 280 ng/m^3 for nicotine in a New York State building. Thus the range of nicotine values reported in complaint buildings does not exceed that reported for other buildings in this total set of 55 units studied.

▫



For the 23 subjects of this study, this graph rank-orders their self-reported health and symptomatic effects from SHS infiltration. Nearly half reported consulting a physician, and 17% of those reported emergency room visits or hospitalization. Their reported symptoms include headaches, dizziness, nausea, eye, nose, and throat irritation, as well as respiratory difficulty and infections.



This graph summarizes the subjects' complaints into 4 categories: 45% reported Respiratory System effects, 30% reported Sensory irritation, 18% reported Central Nervous System complaints, and 4% reported rapid heartbeats (tachycardia). This constellation of symptoms is consistent with the well-known side-effects of SHS exposure as reported in the literature (NAS, 1986).

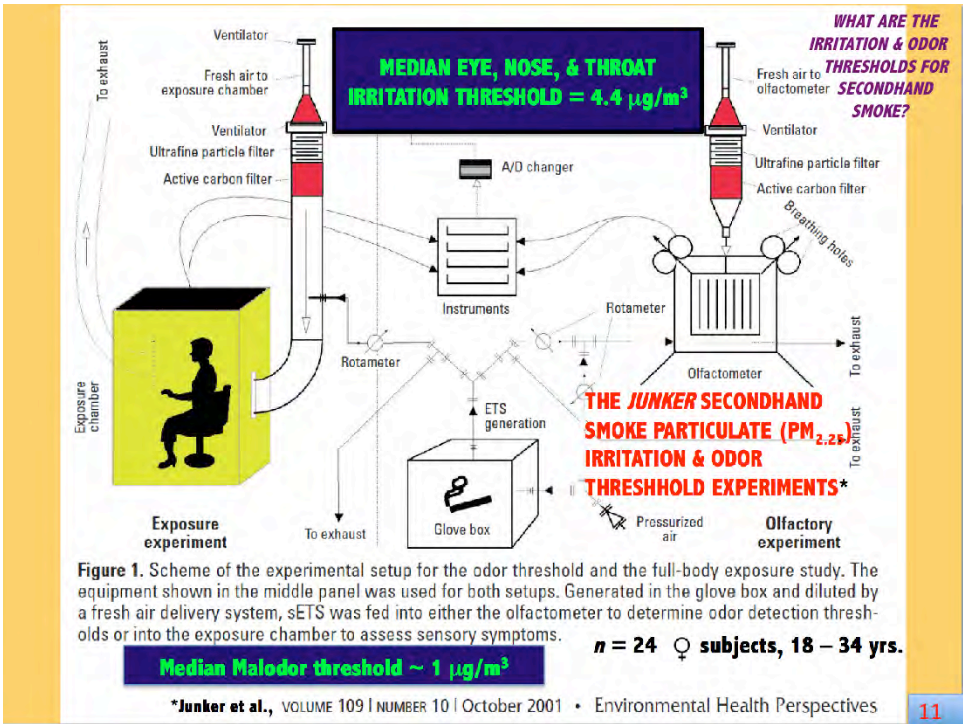
[National Academy of Sciences, National Research Council, 1986: Environmental Tobacco Smoke – Measuring Exposures and Assessing Health Effects].

Nicotine in Nonsmoker's Units Corresponds to Much Larger Levels of Secondhand Smoke $PM_{2.5}$

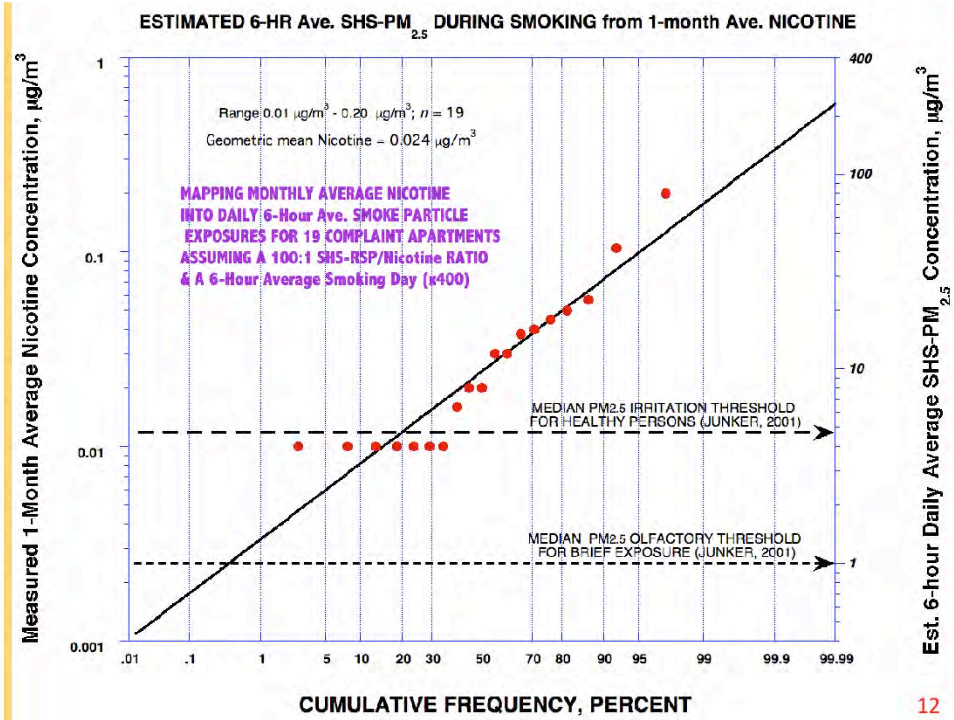
- **Bohac et al. (2004, 2011) reported that SHS- $PM_{2.5}$ penetrates through walls at up to a 25% efficiency, while nicotine penetrates through the same walls at <1%.**
- **Thus: the SHS-$PM_{2.5}$/Nicotine ratio changes from 10:1 in smokers' apartments (Repace et. al., 1993), to an estimated [(10)(25%)/(1)(1%)] = 250:1 in nonsmokers' apartments using upper limit of Bohac et al.**
- **Wagner et al. (2004) reported a SHS-$PM_{2.5}$/Nicotine ratio of ~100:1 outside a smoking lounge.**
- **Unpublished research at Stanford shows that the $PM_{2.5}$/ Nicotine ratio in virgin nonsmoking spaces ranged from 150-1000:1, most frequently 200-400:1 (P. Dacunto, pers. communication) (*n* =22) .**

BASED ON THE LIMITED DATA CURRENTLY AVAILABLE, A CONSERVATIVE ESTIMATE FOR THE $PM_{2.5}$ /NICOTINE RATIO IN NONSMOKERS' UNITS IS 100:1. 10

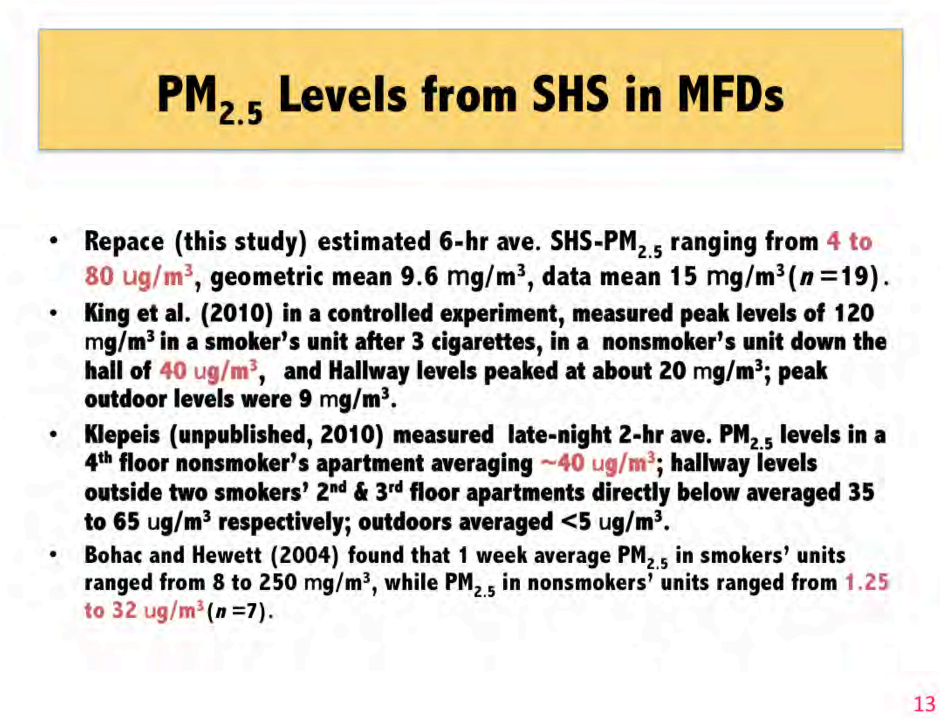
How can such apparently low levels of SHS nicotine result in such substantial acute and chronic effects? Nicotine appears to deposit on surfaces to a much greater extent than other components of SHS as they penetrate through walls, floors, and ceilings of buildings. The work of Bohac, Wagner, and Stanford colleagues suggests that the $PM_{2.5}$ to nicotine ratio increases from about 10:1 in the smokers' units by 2 to 3 orders of magnitude to 100:1 to as high as 400:1 and has been measured as high 1000:1 in places where smoking is rare. Thus, SHS $PM_{2.5}$ and toxic and irritating VOCs may be hundreds of times higher in concentration in the nonsmoking complaint units than the nicotine levels. More research is needed on the $PM_{2.5}$/ Nicotine ratio in MFD source and target apartments using controlled experiments.



Junker et al. conducted key chamber study of SHS irritation, exposing 24 healthy nonsmokers aged 18 – 34 yrs randomly to controlled concentrations, measuring their objective responses to brief 3-5 min exposures using eye-blink and startle-response tests, plus self-reports. Junker found that the median SHS-$PM_{2.5}$ level for irritation was 4.4 ug/$m^{3,}$ and for adverse odor response, 1 ug/m. Weber and Grandjean (1987) reported olfactory fatigue with increase exposure duration, but sensory irritation increased both with concentration and duration.



A log-probability plot of the nicotine distribution for the 19 multi-family complaint apartments, with monthly-ave. nicotine concentration on the left vertical axis, vs. the cumulative probability on the horizontal axis. The right axis shows the corresponding estimated daily 6-hr ave. SHS-$PM_{2.5}$ levels, with the median irritation and aversive odor levels from the Junker study indicated by the horizontal dashed lines. All 19 of the participants in my study exceeded the median adverse odor level, and all were either close to or exceed the median irritation level.



In this study, the estimated 6-hr ave. SHS-$PM_{2.5}$ levels ranged from 4 to 80 ug/m^3 with a GM of 9.5 ug/m^3 . By comparison, King (2010) measured peak $PM_{2.5}$ levels in the hallway outside a smoker's unit of 30 ug/m^3 above background, and in a nonsmoker's unit across the hall of 9 ug/m^3 above background. Klepeis (unpublished report) measured 2-hr ave. levels in the hallways outside 2 smokers' units of respectively 30 ug/m^3 and 60 ug/m^3 above background, and in a nonsmoker's unit of about 35 ug/m^3. Finally, Bohac & Hewett (2004) measured 1-week ave. $PM_{2.5}$ in nonsmokers' units ranging from about 1 to 32 ug/m^3. The predictions of the nicotine-$PM_{2.5}$ mapping model are consistent with the limited $PM_{2.5}$ measurements reported to date. Research at Stanford is underway to attempt to find real-time methods of identifying SHS-$PM_{2.5}$ using a variety of different real-time instruments.

How Big is the Risk?

- Repace et al. (1998; 1993; 1985) estimated that annual exposure to 1 ug/m^3 of SHS-PM$_{2.5}$ for an average of 6 hours daily over a period of 40 years produces 15 deaths per 100,000 persons exposed, (90% heart disease, 10% lung cancer).
- For a 100:1 SHS-PM$_{2.5}$ to Nicotine ratio in the nonsmoking unit, 1 ug/m^3 of SHS-PM$_{2.5}$ yields 0.01 ug/m^3 of SHS-Nicotine infiltrating thru walls.
- Thus, at the median odor threshold for SHS, the estimated risk is 150 deaths per million persons, or 150 times *de minimis* risk.
- At the geometric mean of 0.024 ug/m^3 nicotine for the 19 complaint buildings, the estimated risk is 3.6 deaths per 10,000, which is a *de manifestis* risk, i.e. a risk which is invariably regulated by federal environmental and occupational and food safety agencies for pollutants within their purview.

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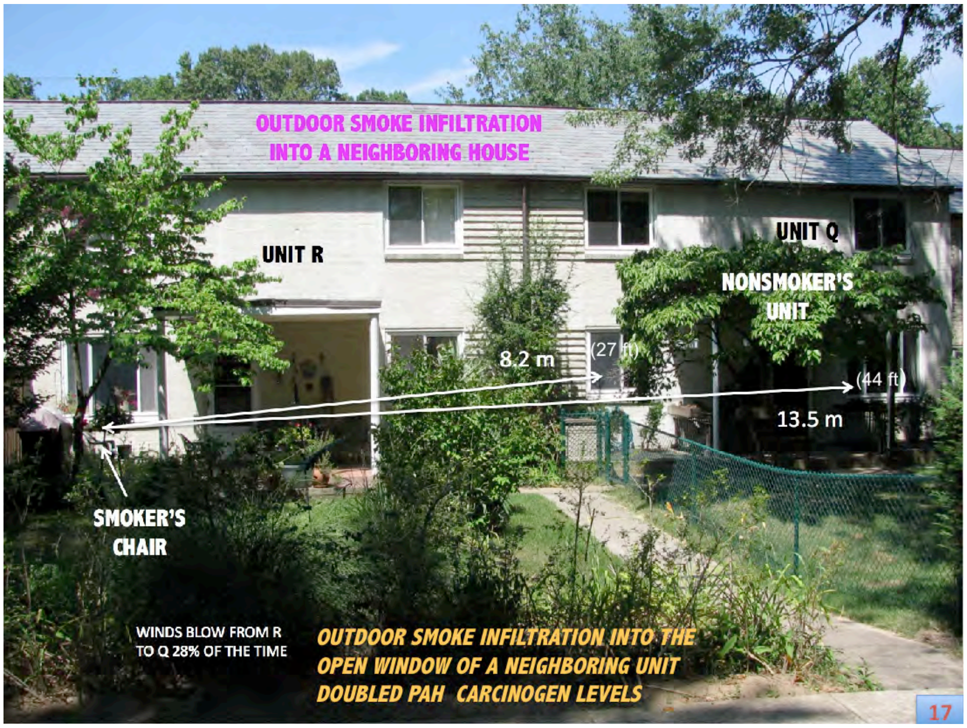
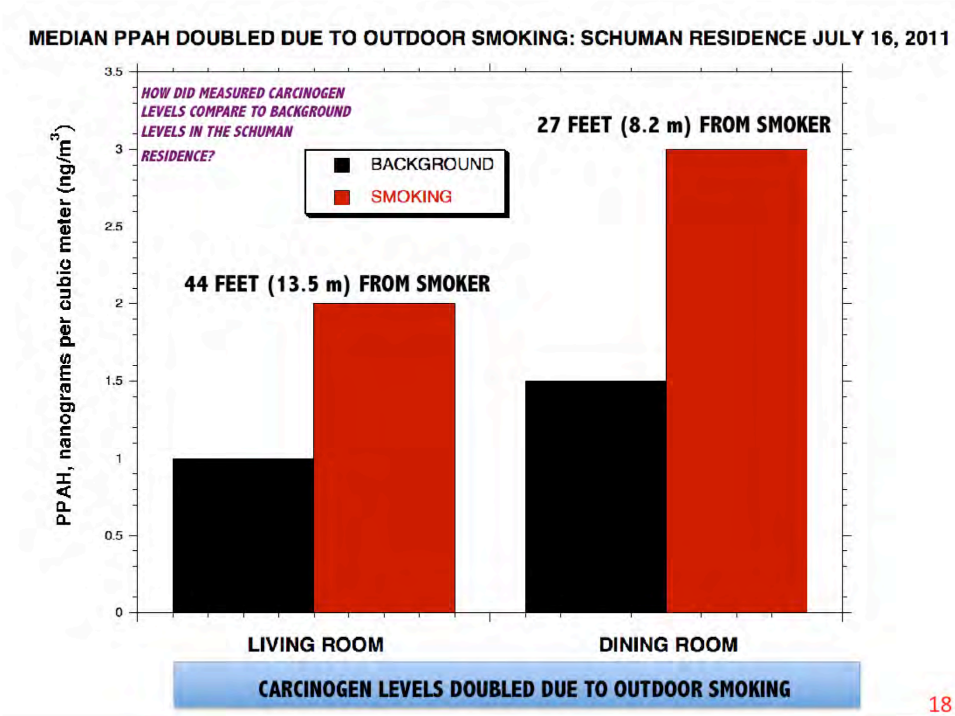
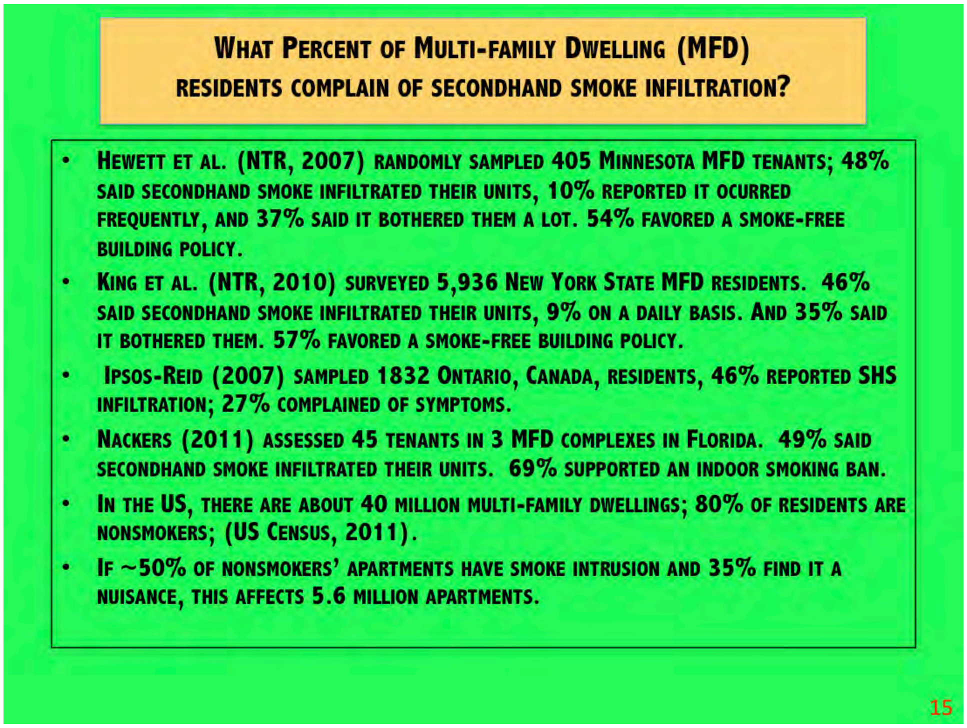
Finally,, to place the risk in perspective, I estimated the long-term risk of combined heart disease and lung cancer mortality from chronic exposure to SHS-PM$_{2.5}$ for the 19 MFD subjects in my study. I assuming the most conservative 100:1 SHS-PM$_{2.5}$/Nicotine ratio reported, and and at the measured geometric mean (GM) nicotine concentration of 24 ng/m^3, the estimated chronic mortality risk is about 3.6 deaths per 10,000 persons. Judged by Federal regulatory practices in regulating hazardous pollutants in outdoor air, drinking water, or food, this is a *de manifestis* (i.e. serious) risk.



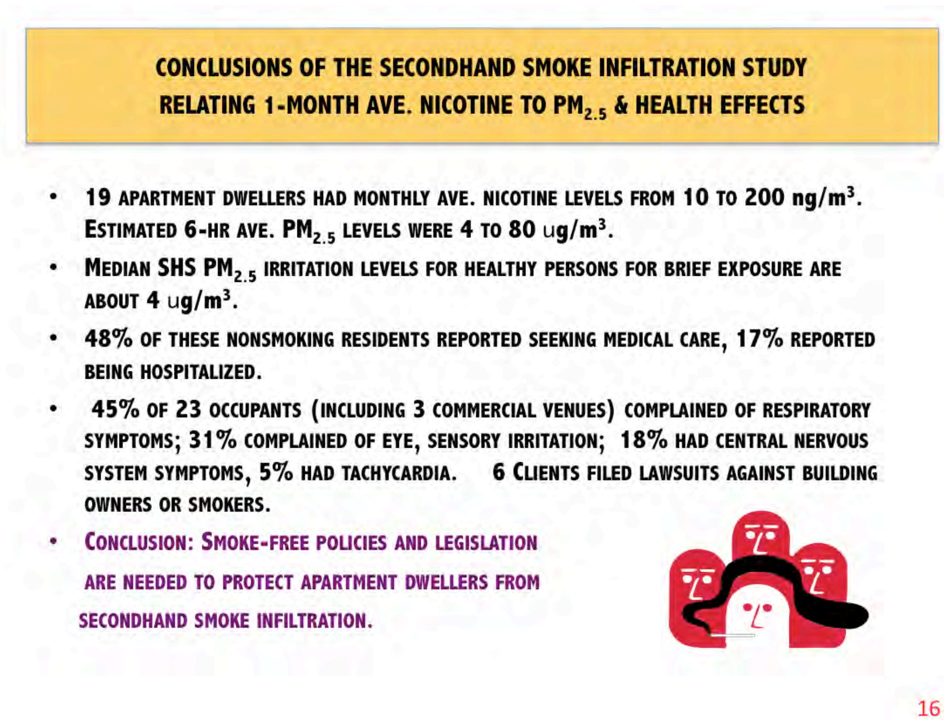
In a study of outdoor SHS penetrating thru open windows, a smoker smoked cigarettes for 20 minutes in the location denoted "smoker's chair" in the photo above. Real-time EcoChem PAS2000 CE monitors for particulate polycyclic aromatic hydrocarbons (PPAH) were located in the neighboring nonsmoker's units at 8.2(27 ft) and 13.5 meters (44 ft) distant respectively. This demonstrates that outdoor smoking at substantial distances from an open window may infiltrate into neighboring apartments.



In the situation described in the previous slide, the following results were obtained: 20-min average particulate polycyclic aromatic hydrocarbon (PPAH} carcinogen levels during outdoor smoking doubled relative to 20-min average pre-smoking background PPAH, and the air inside the nonsmoker’s unit became irritating due to SHS intrusion from outdoors, although it was not irritating during nonsmoking (background) conditions.



Surveys of 8000 residents of MN, NY, and ON, show remarkable agreement: 45 to 50% of the nonsmoking apartment residents sampled said that SHS invaded their units and 27 to 37% complained of adverse symptoms from exposure. In the US surveys, 54 to 57% favored a smoke-free building policy. Thus, it appears that as many as 5.6 million nonsmoking US apartments may be affected by SHS intrusion, indicating that secondhand smoke infiltration in multifamily dwellings is a significant public health problem.



In conclusion, while more research is required to understand the scientific issues related to inter-unit air and pollutant exchange, On the basis of the nature of the complaints, the existing data suggesting the extent to which air flows between apartments, and the widespread preference for smoke-free housing shown by several studies in MN, NY, and ON, that condominiums, coops, and rental properties should mandate smoke-free building policies. In some areas of the North America, legislative action is already occuring in both public and private MFDs.