



Fact Sheet on Secondhand Smoke (*cont.*)

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Technical Appendices A and B

Appendix A.

Why Secondhand Smoke Cannot Be Controlled By Ventilation

This is illustrated by Figure A-1 below. The vertical axis refers to air pollution levels measured in restaurants, bars, and other establishments in the Washington DC metropolitan area; the horizontal axis refers to the smoker density. The dashed lines refer to the calculated air exchange rates, which span the range from 1/2 air change per hour in a naturally ventilated bingo game (data point T), to a maximally-ventilated cocktail lounge (data point F) at 7 air changes per hour. Generally, the best ventilated spaces have the highest smoker densities. The number of burning cigarettes per hundred cubic meters multiplied by 3 gives the estimated density of smokers (Repape and Lowrey, 1980, 1982). This means that 1 burning cigarette per hundred cubic meters is equivalent to 3 smokers per hundred cubic meters, assuming the smokers smoke at the U.S. average rate of 2 cigarettes per hour. 1/2 to 7 air changes per hour is the practical range of ventilation in most buildings. The figure illustrates that under all conditions of typical smoking and ventilation, the annual average level of the U.S. National Ambient Air Quality Standard (NAAQS) for fine particles (PM_{2.5}), which defines clean air, is violated. The NAAQS is designed to protect against air-pollution-induced morbidity and mortality.

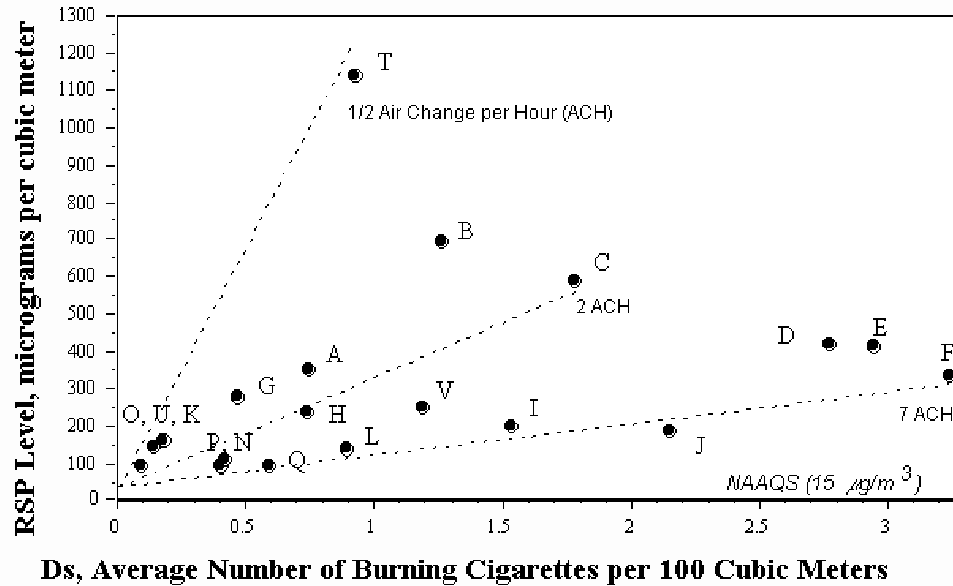
Modeling Nicotine Concentrations

The major reports on SHS have paid scant attention to the fact that SHS concentrations can be accurately calculated by means of mathematical models. With the $\sim 40 \mu\text{g}/\text{m}^3$ background subtracted, the above respirable particle concentrations can be used to estimate nicotine concentrations by dividing by 10 (Hammond, et al., 1987; Repape and Lowrey, 1993; Repape et al., 1998). Repape et al (1998) and Repape and Lowrey (1993) have shown the following expression describes the nicotine concentration as a function of the habitual smoker density and the air exchange rate. The habitual smoker density D_{hs} is three times the active smoker density (i.e., number of burning cigarettes averaged over the observation interval),

and assumes that the smokers smoke at the U.S. national average rate of 2 cigarettes per hour per smoker (Repace, 1987).

Figure A-1.

Repace and Lowrey (1980; 1982)



Smoking indoors leads to highly polluted air. Repace and Lowrey (1980;1982) measured fine particle air pollution, i.e., particulate matter 3.5 microns in diameter or less ($\text{PM}_{3.5}$) in a variety of establishments (Repace, 1993). Data points E, H, K, L, and N are typical restaurants, B and V are reception halls, J is a hospital waiting room, I is a bowling alley, D, G, and T are bingo games, while O is a sports arena, C and Q are bars, F is a nightclub, U is a dinner theatre, and A is a private home during a party.) All of these establishments are in the Washington, DC metropolitan area. The dashed lines show the estimated air exchange rates. D_s , the number of burning cigarettes per hundred cubic meters, is equal to 1/3 the density of habitual smokers D_{hs} , so that a D_{hs} value of 3 is equal to a D_s value of 1. The U.S. Annual National Ambient Air Quality Standard (NAAQS) for Respirable Particulate Matter 2.5 microns or less ($\text{PM}_{2.5}$) is shown for comparison ($15 \mu\text{g}/\text{m}^3$). Thus, under typical conditions of smoking and ventilation, indoor air becomes massively polluted with fine particle air pollution, jeopardizing human health.

As an example of the use of mathematical models to calculate the nicotine and RSP concentration from secondhand smoke, consider a typical office workplace with $D_{hs} = 0.71$ habitual smokers per hundred cubic meters (This corresponds to a value of $D_s = 0.24$ in the figure above). Typical engineering practice recommends a ventilation rate equivalent to $C_v = 0.84$ air changes per hour (Repace et al., 1998) using the nicotine equation below yields an estimated steady-state nicotine concentration of $N = 22 D_{hs} / C_v = (22)(0.71)/0.84 = 19$ micrograms per cubic meter ($\mu\text{g}/\text{m}^3$). Assuming the workers are not present during lunch hour, and allowing for growth and decay of tobacco smoke reduces the time-averaged concentration for an 8 hour workday to 81% of steady state (Repace et al., 1998), or $15 \mu\text{g}/\text{m}^3$. By comparison, Hammond et

al. (observed an 8 hour time-weighted average nicotine concentration for 9 open office workplaces of $16 \mu\text{g}/\text{m}^3$).

Nicotine Concentration Equation

(Repace et al., Risk Analysis 18: 71-83, 1998)

$$N = 22 D_{\text{hs}} / C_v$$

(where D_{hs} = smoker density in habitual smokers per 100 m^3 , C_v = air exchange rate in air changes per hour, and N is the equilibrium nicotine concentration in $\mu\text{g}/\text{m}^3$)

As the nicotine concentration equation shows, the concentration will be high whenever the smoker density is high and the air exchange rate is low, irrespective of whether exposure occurs in homes, workplaces, or social settings, contrary to tobacco industry arguments, which assert that workplaces are much less polluted than homes. The relationship between exposure and dose is discussed below.

Appendix B.

Dosimetry of Secondhand Smoke

The major reports on SHS have also paid little attention to the fact that SHS doses in blood, urine, and saliva can be accurately predicted using mathematical models. The model below shows the factors involved in determining dose of the nicotine metabolite cotinine in blood plasma (i.e., serum). What are the factors determining dose, and what do the clinical epidemiological studies of biomarkers show? What is the range of dose? What are the best methods of assessing dose?

Steady-State Plasma Cotinine Model

[Repace and Lowrey, Risk Analysis 13: 463-475 (1993)]

$$P = (\phi\alpha\rho/\tau\delta) H N_{(\text{ng/ml})}$$

ϕ = fraction of nicotine converted to cotinine (0.78)

α = fraction of nicotine absorbed (0.71)

ρ = respiration rate (1 m³/hr)

δ = plasma clearance rate (64 ml/min)

τ = # minutes/day (1440)

H = exposure duration (hr/day)

N = daily average nicotine concentration (μg/m³)

x 1000 ng/μg

The above equation shows that plasma cotinine is linear with nicotine concentration. While there may be individual metabolic variability (as there is for all drugs and chemicals) in large numbers of individuals, group doses will reflect group exposures (Benowitz, 1996).

As an example of the use of mathematical models to calculate body-fluid cotinine dose, Repace and Lowrey (1993) estimated that the average U.S. nonsmoker in the 1980's had an average daily nicotine dose from secondhand smoke of 143 μg, averaged over work and home exposure. Assuming a reasonable 7 hr daily exposure, and a respiration rate of 1 m³/hour, this is equivalent to an estimated nicotine concentration of N = 20 μg/m³. In the above plasma cotinine equation, P = [(0.78) (0.71) (1) / (1440)(64)] {7} {20} {1000} = 0.84 ng/ml. By comparison, the U.S. Centers for Disease Control conducted a national probability survey of serum cotinine in the late 1980's and early 1990's; for all nonsmokers with cotinines less than 20 ng/ml, the arithmetic mean serum cotinine was 0.54 ng/ml (D. Mannino, CDC, personal communication). The expected range of serum cotinine from passive smoking appears to be about 0 to 15 ng/ml in nonsmokers (Repace and Lowrey, 1993). Both gas chromatography and radioimmunoassay have been used in measuring body-fluid cotinine (Benowitz, 1996).

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