June 6, 1980

CONSIDERATIONS RELATED TO ENVIRONMENTAL TOBACCO SMOKE

I have reviewed a number of articles in the literature as background to the Repace and Lowery article, Science 208: 464, 1980. Hinds and First, New England Journal of Medicine 292: No. 16, p. 844 (1975), report nicotine concentrations between 1 and 10.3 µg per m^3 in a variety of public places including trains, buses, public waiting rooms, restaurants, and cocktail lounges. The average concentration that they report is 4.8 µg per m^3.

Badre, Guillerm, et al, Annals Pharmaceutiques Francais 36: No. 9-10, 443 (1978), seriously criticize the Hinds and First work and demonstrate that the collection technique employeed by Hinds and First is inefficient and only collects about 13% of the nicotine present. These authors also report nicotine concentrations in a variety of public places from trains, train stations, hospital lobbies, automobiles, and restaurants. With the exception of the automobile and a sealed room, nicotine concentrations range from 25 to 52 µg per m^3 with an average concentration of 38 µg per m^3.

Holzer and Oro, Journal of Chromatography 126: 771 (1976), report the concentration of nicotine as 40 µg per m^3 in a room of undefined dimensions and smoking an unreported number of cigarettes.

Valentin, Bost, and Wawra, Praeventive Medicin 167: 5/6, 405 (1978), provide a review of experimental data published on passive smoking in the workplace from 1970-1977. They indicate nicotine levels in the air in the vicinity of smokers can be expected to be as high as 100 µg per m^3.

It may be estimated that the concentration of nicotine in sidestream smoke is about 10% and that a large portion of the smoke in the room environment is generated from the sidestream rather than by exhalation of mainstream smoke by the smoker. This allows the estimation of the total particulates in the room when the nicotine concentration is known. The Hinds and First publication would yield an estimate of 48 µg of particulate per m^3, whereas the other articles yield estimates of 380, 400, and up to 1,000 µg per m^3, respectively. It appears that the Hinds and First article is unusual with respect to the literature and must be seriously questioned with respect to validity. We also conclude from the literature that the expected total particulate level in public places would be in the range of about 400 µg per m^3 with some occurrences of higher levels in poorly ventilated, small areas containing a large number of smokers.

However, nicotine does appear to have some limitations as a tracer for tobacco smoke. Badre, et al, show the disappearance of nicotine from the environment is exponential, whereas the particluate aerosol itself disappears at a more linear rate. We presume that the nicotine actually evaporates from the aerosol with time and undergoes a vapor state oxidation in the presence of ultraviolet radiation. This means that nicotine can be reliably used as a tracer on relatively fresh smoke (about 20 minutes after generation). Application of the nicotine tracer to smoke older than 20 minutes would lead to progressively increasing underestimates of the aerosol concentration.

The significance of a level of exposure in the range of 400 µg per m^3 can be estimated by comparison to the dose obtained by the smoker. If we assume that man has a tidal volume of about .5 liters for inspiration and respires at the rate of 12 per minute, .36 m^3 of air will be inhaled per hour. If we futher assume that all of the inhaled material is retained, .14 mg of particulates will be inhaled and retained from an atmosphere containing 400 µg per m^3. If we further compare this to the average yield of an American cigarette of about 15 mg, this would correspond to about 1% of a cigarette per hour of exposure or for a 10-hour workday, about 10% of one cigarette or approximately one puff. The extreme value discussed above of about 1.0 mg per m^3 would correspond to about 2-1/2 puffs in a 10-hour period. A direct confirmation of these extimates can be made by determination of serum and urinary nicotine levels among smokers and non-smokers in rooms contaminated with cigarette smoke. Serum and urinary cotinine levels can also be used for this purpose. Harke, Muensch. Med. Wochschr. 112:1(1970), reported urinary cotinine and nicotine levels in non-smokers exposed in a smoke-filled room. They reported values for the non-smoker between 1.2% and 3.8% of the smoker.

Horning, et al, Life Sciences 13:1331(1973), report that non-smokers in the smoking environment had about 5% of the urinary nicotine level of the smoker. Russell and Feyerabend, The Lancet 1: 1979 (1975) report blood and urinary nicotine in non-smokers exposed for 78 minutes in a smoky room. The serum nicotine level of the non-smoker group was .9 ng per ml. which compares with an average smoker value of 24.5 ng per ml. or the non-smoker is about 3.7% of the smoker. However, the serum nicotine increase in the non-smoker exposed for 78 minutes was only .2 µg ml. or less than 1% of the average smoker value. The urinary concentration of the non-smoker after exposure to the smoky room was about 6% of the value of the smoker.

These differences in nicotine and cotinine levels between smokers and non-smokers can be taken at face value to indicate that the non-smoker absorbs qualitatively much less nicotine

than the smoker. However, the quantitative assessment must consider the build-up and disappearance of nicotine from serum in the smoker and non-smoker. Similarly, rates of metabolism of nicotine to cotinine must also be considered when interpreting levels of exposure based on this metabolite. Figure 1 is derived from the literature data on the disappearance of nicotine from human serum, illustrating that the metabolic half-life of nicotine is about 40 minutes. The result of this fast clearance rate in the smoker is little build-up of serum nicotine levels with smoking at one hour intervals. If smoking is more rapid than this, some build-up does occur as shown by Russell and Feyerabend, Drug Metabolism Reviews 8:45 (1978), Figure 2. Thus, concentrations of serum nicotine do not afford a direct assessment of the total exposure, but more nearly reflect the amount of nicotine absorbed during the smoking of the last cigarette unless a high frequency of smoking occurs. In the case of the non-smoker, the exposure in a smoke-filled room would be continuous and the nicotine concentration in serum would rise to some equilibrium value where the input and disappearance per unit time were equal. Thus it would appear to be impossible to relate serum nicotine levels in the population of large to daily dose. The amount of nicotine excreted in urine is small relative to the total intake and the amount found in the urine is further compounded by pH of the urine, (Feyerabend & Russell Br. J. Clin. Pharma. 5, 293 (1978). It, therefore, appears that nicotine excreted in the urine of the population at large would not be a useful measurement to describe dose.

Cotinine (the major metabolite of nicotine) has a much greater half-life in body fluids (30 hrs.) than nicotine (Zerdenberg, Jaffe, et al, Comprehensive Psychiatry 18(1), 93 (1977)) and therefore appears to have potential use as a measure of tobacco smoke.

CONCLUSIONS

The concentration of nicotine in the environmental air of poorly ventilated rooms with smokers is in the order of 40 µg per m^3 according to the majority of the reports found in the literature. Assuming sidestream smoke contains 10% nicotine, 400 µg per m^3 of particulates is estimated to occur in these poorly ventilated areas. These estimates are in the range of values reported by Repace and Lowery; Sci. 208:464 (1980). Simple calculations indicate that the dose of smoke received by the non-smoker in such air environment is very small even after a ten hour period. Direct measurement of nicotine and cotinine in non-smoker's serum and urine indicates that detectable amounts are present; however, quantitative relationships between exposure and concentration in body fluid has not been established.

It may be possible to use cotinine excreted in urine as an indicator of daily exposure in both the smoker and non-smoker. Hill and Marquardt In press recently reported the relationship between serum cotinine concentration and amount excreted in the urine. Figure (3).

If such a relationship can be established, it appears possible to obtain urine samples over suitable time periods from representative individuals in work places and other environments to establish representative exposure levels of non-smokers. Such data should be useful in establishing the insignificant level of exposure of non-smokers compared to smokers.

FIGURE 1

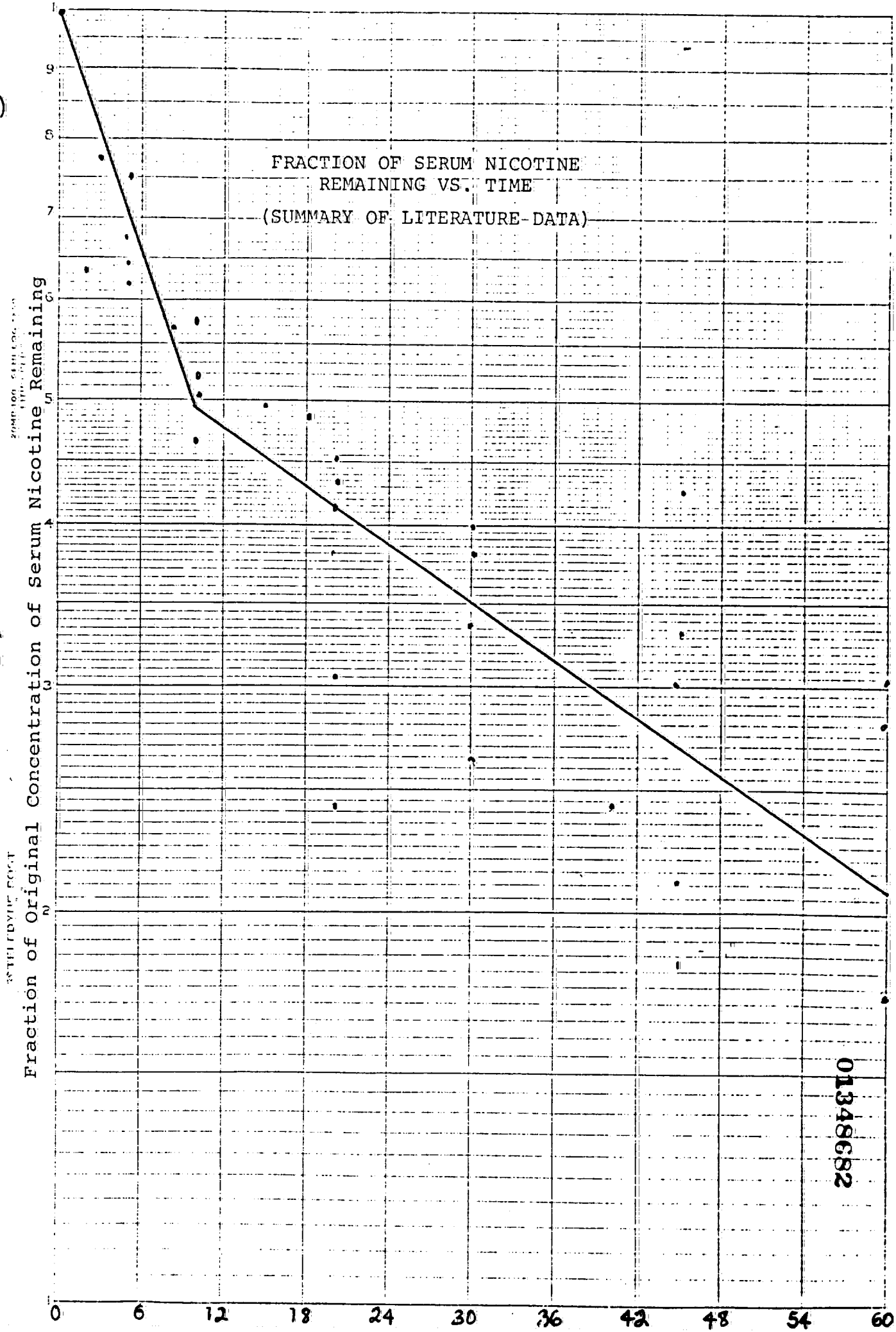

FIGURE 3

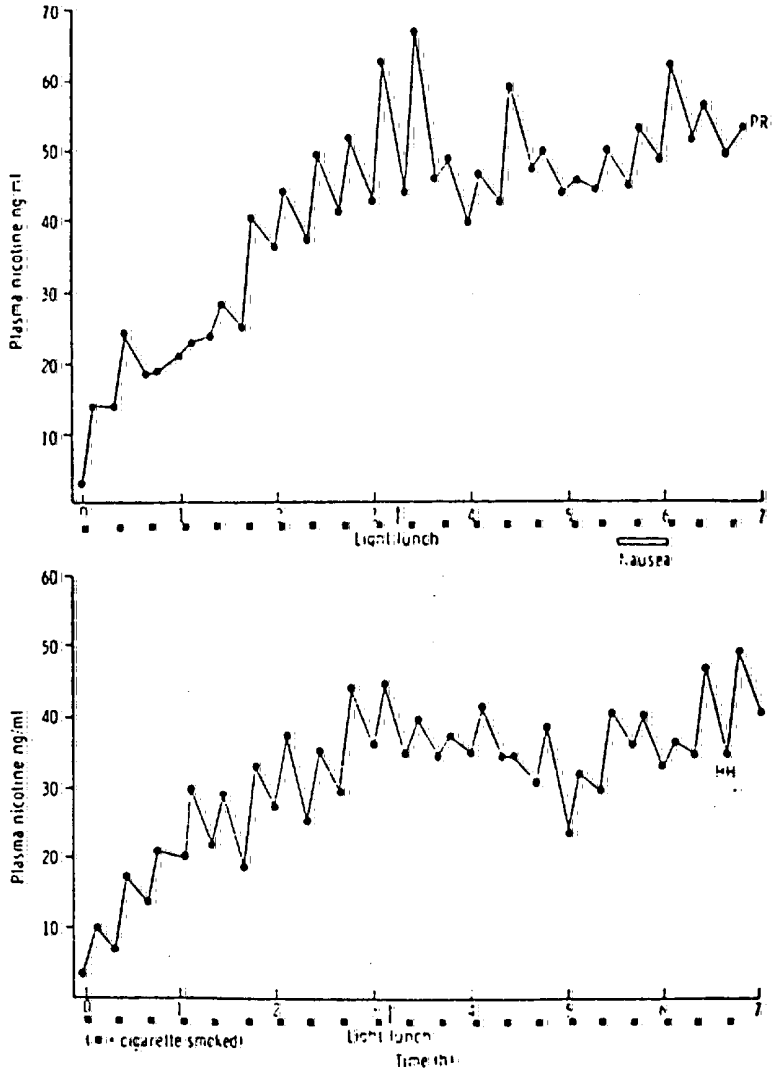

FIG. 7. Plasma nicotine levels during forced prolonged heavy smoking at a rate of three cigarettes per hour for 7 hr. Each cigarette was smoked over precisely 5 min, and blood samples were taken just before and 2 min after each cigarette. Both subjects were regular smokers whose usual smoking frequency was just over 20/day. Nicotine yields of the cigarettes were 1.3 for P.R. and 1.4 mg for H.H. Urinary pH was uncontrolled.

Source: Russell and Feyerabend, Drug Metabolism Reviews, 8, 45 (1978).

FIGURE III

Plasma and urinary cotinine levels in five smokers smoking three brands of cigarettes containing different amounts of nicotine. Values obtained after smoking cigarettes for nine days ($r = 0.95$, $P \leq 0.01$).