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RESULTS FROM SURVEYS OF ENVIRONMENTAL TOBACCO SMOKE IN RESTAURANTS IN WINSTON-SALEM, NORTH CAROLINA

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Surveys were performed in 33 restaurants during the summer of 1986 and the winter of 1988 to assess exposures to environmental tobacco smoke (ETS) and to evaluate the variability of exposure. Portable air sampling systems (PASS's) were used to measure several ETS indicators including nicotine, respirable suspended particles (RSP), and ultraviolet particulate matter (UVPM, which provides an upper estimate of the contribution of ETS to RSP). For 1986, arithmetic mean concentrations of nicotine, RSP, and UVPM were 6.6, 192, and 100 $\mu g\ m^{-3}$, respectively; for 1988, arithmetic mean concentrations were 10.5, 107, and 65 $\mu g\ m^{-3}$, respectively. Statistically significant differences ($P < 0.05$) are shown between concentrations of nicotine, RSP, and UVPM measured during the two surveys.

INTRODUCTION

The assessment of public exposure to environmental tobacco smoke (ETS) is an important area of research in view of reports by the U. S. Department of Health and Human Services (1) and the U. S. National Research Council (2) concluding that ETS exposure represents a health risk. In response to these reports, smoking restrictions have been considered for several public environmental categories, including restaurants. Because few data are available relative to expected ETS exposures in restaurants, our research has focused, in part, on assessing exposures in this environmental category. The work we report here represents a continuation of this effort. In addition, we report our first efforts to address the question whether ETS exposures can exhibit long term (for example, seasonal) variability.

EXPERIMENTAL

Restaurant Selection For the 1986 survey, which was done from May to August, restaurants were selected so that the sample population conformed to the distribution of four restaurant categories identified by the Gallup Organization (3); these categories and the percentage of lunchtime meals they represent are: "Family Style," 36 %; "Fast Food," 34 %; "Cafeteria," 23 %; and "Adult Oriented," 7 %. Members of sampling teams obtained samples within this constraint. The 1988 survey was done from November 1988 to February 1989. The 1988 sample population was a subset of restaurants derived from the 1986 sample population. This subset reflected loss of restaurants from the 1986 sample population because of closing, remodeling, changed category, or modified operating hours. Thus, the study sample population of 33 restaurants included those restaurants common to both the 1986 and 1988 sample populations. Of these restaurants, one was sampled in triplicate, and five, in duplicate, giving a total of 41 sample sets. The distribution of these samples was: "Family Style," 39 %; Fast Food," 34 %;

Cafeteria," 10%; and "Adult Oriented," 17 %.

Sampling Locations Sampling locations within restaurants were selected according to guidelines provided by the U. S. Environmental Protection Agency (EPA) (4). These guidelines recommend that samples be collected from positions at least two feet from walls and between two and five feet above floors. Locations associated with tables near the center of rooms were given preference. Sampling devices were oriented either vertically on chairs pushed back from tables or horizontally on counter tops or ledges.

Sample Collection Samples were collected unobtrusively with the portable air sampling system (PASS) methodology (5). All samples were obtained during normal lunch hours on weekdays. For the 1986 survey, duplicate samples were obtained with two identical PASS's, each containing equipment for sampling nicotine, respirable suspended particles (RSP), and ultraviolet particulate matter (UVPM). Nicotine was collected on XAD-4 with a constant flow sampling pump operated at 1 L min^{-1} (6). RSP and UVPM were collected on Fluoropore membrane filters with constant flow sampling pumps operated at 2 L min^{-1}; particles were separated at a mass median diameter cut point of 3.5 μm with an inertial impactor. This cut point was selected so that results could be related to those provided by piezoelectric balances (7).

During the earlier part of the 1986 survey, the duration of sampling was determined by the criterion that it match the time during which sampling team members dined. This criterion was followed to characterize the time component of exposure. Later during the 1986 survey, a one-hour sampling duration was established to ensure that more particles would be collected to enhance the precision of results from analyses of RSP and UVPM.

For the 1988 survey, two types of PASS's were used to collect samples in each restaurant. One type collected nicotine by the same procedure as for the 1986 survey with the exception that the flow rate was increased from 1 L min^{-1} to 1.5 L min^{-1}. (This flow was applied to enable detection of 3-vinylpyridine, an indicator of ETS currently being evaluated by our laboratory and others.) The other type of PASS collected RSP samples in duplicate. The same procedure as for the 1986 survey was used with the exception that samples were collected at a flow rate of 3.25 L min^{-1} to separate at 2.5 μm, the cut point recommended by the EPA to define RSP (8). All samples were collected for 60 min for the 1988 survey. Samples were obtained on the same day and during the same hours as for the 1986 survey.

Analyses Collected nicotine was desorbed with ethylacetate and analyzed by gas chromatography with nitrogen selective detection (9). RSP was determined gravimetrically (10) after which the filter and collected particles were extracted by methanol and this solution analyzed spectrophotometrically at 325 nm. 2, 2', 4, 4'- tetrahydroxybenzophenone was used as a surrogate standard for the determination of UVPM (10).

RESULTS

Table I presents arithmetic means and ranges for the determinations of nicotine, RSP, and UVPM made during the 1986 and 1988 surveys. In magnitude, mean results are comparable to those reported before for surveys done in restaurants. Oldaker *et al.* (11) reported geometric mean concentrations of 5.1, 126, and 36 $\mu g\ m^{-3}$ for nicotine, RSP, and UVPM, respectively. Crouse *et al.* (12) reported respective arithmetic mean concentrations of 8.6, 81, and 34 $\mu g\ m^{-3}$ for nicotine, RSP, and UVPM. Thompson *et al.* (13) surveyed nicotine concentrations and reported arithmetic and geometric means of 5.4 and 3.5 $\mu g\ m^{-3}$, respectively.

Results of t-tests indicate that the mean nicotine concentration for 1986 is significantly less ($P < 0.05$) than the mean concentration for 1988. In contrast, mean concentrations of RSP and UVPM for 1986 are significantly greater ($P < 0.05$) than respective mean concentrations for 1988.

The table also includes arithmetic mean concentrations of ambient total suspended particles (TSP) provided by the local air pollution control authority for the times when the surveys were done. The mean level of TSP for 1986 is significantly greater ($P < 0.05$) than the mean TSP level for 1988.

Although the results of the two surveys show clearly that ETS levels exhibit significant differences, the origins of such differences are not clear. It is possible that the RSP and UVPM results are affected by ambient RSP and UVPM levels as indicated by TSP (assuming that these TSP results are representative of TSP outside of the restaurants surveyed); however, this contribution can be considered minor in view of the magnitude of differences between the TSP concentrations of the two years. Additionally, the change in the cut point for collection of RSP is expected to have but a small effect on results. Because ETS particles have mass median diameters less than 1 μm (14), changing the cut point from 3.5 to 2.5 μm will have no measurable effect on the amount of ETS RSP collected. Moreover, statistical tests indicate no difference between the amounts of observed cigarette smoking in 1986 and 1988: the smoking rates were 0.207 and 0.201 cigarettes h^{-1} in 1986 and 1989, respectively.

We hypothesize that the differences found between the levels of ETS indicators reflect the influence of two factors: (a) improved precision associated with sampling particles for 1988 relative to 1986, and (b) selective removal of nicotine by heating ventilating and air conditioning (HVAC) systems during the 1986 survey. The relatively short collection times applied for some samples collected during the 1986 survey resulted in collection of small amounts of particles thus amplifying the effect of weighing imprecision and leading, in several instances, to relatively large RSP and UVPM levels. A few data with large RSP and UVPM concentrations skew the 1986 statistics. One example is the highest RSP result, 1,374 $\mu g\ m^{-3}$, which was associated with a sampling time of 27 min in a "Fast Food" restaurant. In addition, the next highest RSP concentration, also associated with a relatively short sampling time, is 500 $\mu g\ m^{-3}$, 874 $\mu g\ m^{-3}$ lower.

Nicotine, as Thome *et al.* (15) have reported, can be removed from indoor air by cooling coils associated with HVAC systems. For the 1986 survey, sampling was done during the summer months when HVAC systems would be expected to be operating with cooling coils. By contrast, the 1988 survey was conducted during the winter months when cooling coils would not normally be used. However, we cannot test this hypothesis because we did not address the operation or performance of HVAC systems in the restaurants.

Although there are differences shown in concentrations of these indicators between the two years, extremely low exposures are indicated in terms of ETS. For example, assuming a breathing rate of 8.6 L min^{-1} (16) and a sales weighted average cigarette yielding 0.93 mg nicotine (17), an hourly exposure of 0.0058 "cigarette equivalent" can be computed (1) from the higher average nicotine concentration, 10.5 $\mu g\ m^{-3}$.

ACKNOWLEDGEMENTS

We thank Walter Morgan for help with statistical analyses, David Heavner for technical assistance, and Randall McBride for collecting and analyzing samples for the 1986 survey.

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TABLE I

SUMMARY OF RESULTS FOR DETERMINATIONS OF NICOTINE, RSP, AND UVPM

(Mean concentrations and ranges, $\mu g\ m^{-3}$)

	1986	1988
Nicotine	6.6 0.9 - 25.6	10.5* < 0.1 - 35.2
RSP	192 18 - 1374	107* < 25 - 281
UVPM	100 12 - 318	65* < 13 - 173
TSP** ambient	67 26 - 99	40* 24 - 74

* Significantly different, $P < 0.001$.
** Total suspended particles from ambient monitoring station.