CONF-950596--1

Personal Exposure to Environmental Tobacco Smoke in Workplace and Away from Work Settings: A 16 City Case Study

Jenkins, R.A.[1], **Palausky, M.A.**[1], Counts, R.W.[2], Guerin, M.R.[1], Dindal, A.B.[1], Bayne, C.K.[2]

[1]Chemical and Analytical Sciences Division and [2]Computer Science and Mathematics Division, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6120

DISCLAIMER

This Research was supported by the Center for Indoor Air Research, Linthicum, MD, under contract #ERD-88-812 with Martin Marietta Energy Systems, which manages Oak Ridge National Laboratory for the U.S. Department of Energy under contract #DE-AC05-8421400.

Personal Exposure to Environmental Tobacco Smoke in Workplace and Away from Work Settings: A 16 City Case Study

Jenkins, R.A.[1], **Palausky, M.A.**[1], Counts, R.W.[2], Guerin, M.R.[1], Dindal, A.B.[1], Bayne, C.K.[2]
[1]Chemical and Analytical Sciences Division and [2]Computer Science and Mathematics Division,
Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6120

ABSTRACT

A large study of personal exposure of non-smokers to environmental tobacco smoke (ETS) has been conducted in 16 cities in the United States. Individual participants wear two personal sampling pumps, one each at work and away-from-work. Samples of breathing zone air are collected, and subsequently analyzed for both particle phase and gas phase markers of ETS, including respirable suspended particulate matter (RSP), UV-absorbing and fluorescing particulate matter, solanesol, nicotine, 3-ethenyl pyridine, and myosmine. In addition, prior- and post-exposure saliva samples are collected, in order that smoking status may be determined using salivary cotinine.

Participants are segregated into a 2x2 factorial study design: smoking and non-smoking homes and workplaces. A comparison of the demographic distribution of the sample population with that of the United States indicates that the sample population is more female and of higher socioeconomic status. The data indicates that median 8-hour or 16-hour exposure levels are considerably lower than those which would be extrapolated from short duration area measurements. Median exposure levels of nicotine, 3-ethenyl pyridine, and RSP were 0.034, 0.029, and 13 $\mu g/m^3$, respectively in non-smoking workplaces, vs. 0.21, 0.16, and 23 $\mu g/m^3$ in workplaces where smoking was observed. Median 16-hour exposure levels for these same components away from work where subjects observed tobacco products in use were 0.36, 0.25, and 23 $\mu g/m^3$, compared with 0.024, 0.019, and 15 $\mu g/m^3$ when no tobacco products were observed.

INTRODUCTION

Environmental tobacco smoke (ETS), or second hand smoke, has become a widely discussed issue recently. The Environmental Protection Agency (EPA) has classified ETS as a human carcinogen[1] and the Occupational Safety and Health Administration is considering a ban on smoking in any working area. This study is an attempt to determine a realistic picture of the amount of ETS individuals are exposed to during an average day. Over the course of the study, approximately 1500 individuals across the United States collected air samples over the course of one 24-hour period. These samples were analyzed for 7 constituents of ETS, and the results were compared with participant's recorded information regarding observations of tobacco product use around them. Participants were categorized into one of four cells, determined by smoking / nonsmoking environments in their home and workplace:

Cell 1	Smoking Home Smoking Workplace	Cell 2	Smoking Home Non-Smoking Workplace
Cell 3	Non-Smoking Home Smoking Workplace	Cell 4	Non-Smoking Home Non-Smoking Workplace

While an ideal population for the study would consist of equal numbers of participants in each of the cells, realistically it proved to be difficult to recruit a large number of individuals living and working in environments where unrestricted smoking is allowed.

Three institutions had responsibility for activities in the study. Oak Ridge National Laboratory (ORNL) was responsible for overall study design, independent surveillance of sampling and laboratory analyses, observation of and assistance with field operations, and data integration, interpretation, and reporting. Bellomy Research, Inc. was responsible for initial questionnaire design, recruitment of subjects (through subcontracted local market research agencies), assistance with field operations, and coding of subjects written responses into a computer database. R.J. Reynolds Tobacco Co., Inc. research and development personnel were responsible for management of field sampling operations, sample management, and analysis of all samples collected during the study.

EXPERIMENTAL METHODS

Sample Collection

Participant Recruiting. Over the course of a year, approximately 100 people were recruited in each of 16 cities throughout the United States to take part in the study. Local marketing research agencies in each of the cities recruited participants through random telephone calling. In order to take part in the study, individuals had to be at least 18 years of age, currently working at least 35 hours a week outside the home on a "traditional" shift (approximately 8:00 A.M. to 5:00 P.M.), and be a non-smoker for the previous six months. Demographic information gathered during recruiting included: age, gender, household members' use of tobacco products, smoking restrictions in their workplace, and smoking behavior of co-workers. Potential participants were also asked about affiliation with organizations that might indicate a personal interest in the outcome of the study - for example, they were asked if they worked for a tobacco manufacturer or distributor, or were members of the American Lung Association.

Approximately 20 - 30 participants were scheduled to be at a local test facility on each of four nights. A video explaining how to collect air samples and fill out the paperwork for the study was shown to each group. During and following the video, participants collected a saliva sample and completed a First Visit Survey including details about their household and working environments. Study personnel verified that the subjects could turn the air sampling equipment on and off, and each was given a bag containing equipment to collect two air samples. Beginning the next morning, subjects collected air samples for 24 hours, filling out diaries on at least an hourly basis. These diaries are essentially a list of possible indoor airborne pollutants, and a table in which to make tick marks during the time frame in which a pollutant is observed. The away from work ("Home") diary also included a table in which to indicate locations where time was spent while wearing the pump - inside the home, outdoors, etc. In addition to the diaries, the take-home paper work included "Work" and "Home" Pump Surveys. These are questionnaires asking detailed questions about the specific day during which the samples were collected. Both surveys ask questions regarding sample collection, e.g., if the sampler head was ever covered or turned upside down, and if anything happened during sample collection that might "exaggerate the reading of the air." On the second day after their initial visit, subjects returned to the test facility, completed a Last Visit Survey, and collected a second saliva sample. When each subject's paperwork had been reviewed to assure that all materials were accounted for, they received a gratuity and their participation in the study was complete.

Sampling Equipment. The sampling equipment used by the participants in the study was designed to be rugged, quiet, compact, and easy to use. Each set of sampling equipment consisted of two sound insulated sampling pumps (the "Home" pump outfitted with a larger battery pack in order to run the pump for a minimum of 18 hours), each attached to a clip-on sampling head. The pumps were in plastic cases approximately 8.5" long x 6.5" wide x 4.25" high with adjustable shoulder straps attached. Participants were instructed to wear them with the strap over the right shoulder and the pump resting on the left hip. The sampling head contained both particle and vapor phase ETS marker collection devices and was designed to be worn in a person's "breathing zone," i.e., clipped onto a shirt collar or lapel.

Particle phase ETS markers were collected on Fluoropore membrane filters (37 mm diameter, 1 μm pore size, Millipore Corp., Bedford, MA) at a flow rate of approximately 1.7 liters per minute (L/min). A cyclone vortex assembly (Sensidyne Inc., Clearwater FL) was incorporated into the particle phase collection device in order to collect particles smaller than 3.5 μm on the filter. Particle phase markers determined as part of this study were: respirable suspended particulate matter (RSP, ≤3.5 μm); ultraviolet absorbing particulate matter (UVPM); fluorescing particulate matter (FPM); and solanesol. Vapor phase ETS markers were collected on XAD-4 resin cartridges (SKC Inc., Eighty-Four, PA) at a flow rate of approximately 0.5 - 0.7 L/min. Vapor phase markers determined as part of this study were: 3-ethenylpyridine, nicotine, and myosmine.

Air and Saliva Sample Collection. Each individual collected two air samples, a "Work" sample and an away from work ("Home") sample. Particle and gas phase components of ETS were collected in each sample. Participants collected work samples by turning on the first pump on arrival at work on the morning of the first day and wearing it throughout the day. At the end of the day, while still at work, participants turned off the first pump and turned on the second pump (with the larger battery pack.) Participants wore the second pump for the rest of the 24-hr period, including time spent inside their home, running errands, eating in restaurants, etc. At times when participants were bathing or sleeping, they hung the pump on a doorknob or chair nearby. The next morning on arrival at work, the second pump was turned off. Participants returned to the local test facility that night and turned in their sampling equipment and samples. During visits to the test facility, each participant collected two saliva samples by chewing on cotton dental dams. These saliva samples were assayed for cotinine, a metabolite of nicotine, and were used assess the current smoking status of each participant.

Before pumps were sent out with participants, the flow rate through the Fluoropore filter was set to between 1.70 and 1.74 L/min and recorded; the residual flow through the XAD-4 tube was recorded, and was generally between 0.5 and 0.7 L/min. Flow rates were measured and recorded again when participants returned the sampling equipment, along with the number of hours the pumps had been run and the participant's ID number. Saliva samples collected by participants were immediately stored in a freezer or in coolers over dry ice; particle and gas phase samples were stored in the same manner at the end of each evening. At the conclusion of sample collection, all of the samples from each city were shipped over dry ice to the analytical laboratory for next day delivery.

Sample Analysis

Particle Phase Analytes. The weight of RSP in a participant's sample was determined gravimetrically, as the difference between the filter weight before and after sample collection[2]. After the RSP assay was complete, each filter was extracted with methanol, and the amount of UVPM and FPM in a participant's sample were determined by liquid chromatography (LC), using ultraviolet and fluorescence detectors[2]. An aliquot of the same extract was assayed for solanesol, also by LC using an ultraviolet detector[3].

Gas Phase Analytes. After desorption of the XAD-4 resin into ethyl acetate containing 0.01% triethylamine, the vapor phase markers 3-ethenylpyridine, nicotine, and mysomine were determined by gas chromatography (GC) with a thermionic specific (nitrogen selective) detector[4].

Cotinine. Saliva samples collected by participants were centrifuged to separate the saliva from the cotton dental dam and the amount of cotinine present was determined by radioimmunoassay[5].

Quality Control and Surveillance of Laboratory Analyses. When samples were received at the analytical laboratory, they were logged in and stored in freezers until analyses could be performed. As a routine part of all analyses, samples were bracketed by standards covering the expected concentration range for the samples. If any sample result fell outside the concentration range of the standards, it was diluted to within the range of the standards and re-run. For the gas phase analytes, quality control samples (six per city) were inserted into the sample stream by field personnel. These quality control samples were XAD-4 resin tubes spiked at two levels with 4-vinylpyridine (a commercially available

isomer of 3-ethenylpyridine), nicotine, and myosmine. These samples were labeled with participant ID numbers spaced throughout the range of samples so that they would be "blind" QC samples for the analyst performing the assay. "Flow blank" XAD-4 resin tubes and Fluoropore filters were used to calculate the "background" levels of the analytes. Flow blanks and spiked QC samples were treated identically to participant samples.

ORNL provided samples to the analytical laboratory for each analyte determined in this study as part of routine surveillance activities. These samples were "known" samples sent directly to the lab, and blind samples placed into the analysis stream along with participant samples.

Standard weights (platinum wires) were used as surveillance samples for the RSP assay. They were weighed at ORNL and sent to the laboratory in sets of two, matched so that the difference in their weights was in the upper range of the weight difference expected for a participant filter sample. The wires were weighed during weeks in which filters were being weighed for the study. The weights were entered as initial and final weights in the results reported to ORNL. Cotinine surveillance samples were saliva samples collected from several active smokers and non-smokers at ORNL, frozen immediately after collection at ORNL and shipped to the laboratory over dry ice. The goal was simply to ensure that smokers could be distinguished from non-smokers.

Solutions of 2,2',4,4'-tetrahydroxybenzophenone (THBP, a UVPM surrogate), scopoletin (an FPM surrogate), and solanesol were prepared and assayed at ORNL and shipped to the laboratory over dry ice. These solutions were assayed along with participant's particle phase samples. Results were supplied to ORNL as part of the data package for each city.

Solutions containing nicotine and 4-vinylpyridine were prepared and assayed at ORNL, shipped to RJR, and assayed along with participant gas phase samples from cities 2 - 7 and 13 - 16. Results were supplied to ORNL as part of the data packages for each city. Further surveillance samples for the gas phase analytes were prepared using XAD-4 resin tubes and assayed along with participant gas phase samples from cities 4 - 16. These samples consisted of spiked tubes and actual ETS air samples. The spiked tubes were prepared using solutions of known concentrations of nicotine and 4-vinylpyridine in methanol. The ETS air samples used were collected in uniform atmospheres of sidestream tobacco smoke generated in an environmental chamber (Bruischat Environmental, Inc., Holland, MI). Samples drawn from these environments were analyzed, and the results were reported to ORNL in μg per sample. These numbers were converted to $\mu g/m^3$ and compared to in-house results. Results for all of the XAD-4 tubes were reported along with the data packages for the cities.

Spiked and smoke-exposed XAD-4 tubes were used in the "surreptitious exchange" of ORNL samples for real participant samples conducted during field operations. XAD-4 tubes with known concentrations of nicotine and 3-ethenylpyridine or 4-vinylpyridine (smoke-exposed or spiked tubes) were carried to 9 of the 16 cities in the study by ORNL personnel and used to replaced tubes in a set of pumps not assigned to a participant. The ORNL samples were turned in with participant samples from that group and entered the sample stream identically to participant samples.

RESULTS

A total of 1564 participants completed sample collection for the study. The cell breakdown of the study population was: Cell 1, 11%; Cell 2, 16%; Cell 3, 19%; and Cell 4, 55%. Demographic data indicates that the study population is older, more female and more educated, and has a higher income than the U.S. population as a whole.

Surveillance activities indicated good performance on the part of the analytical laboratory. The results for the standard weights used in surveillance of the RSP assay were 98.5% to 128.5% of the results obtained at ORNL (mean = 107.2%). For particle phase analytes, determined concentrations for THBP solutions ranged from 94.7% - 104.2% of theoretical; for scopoletin, from 89.9% - 105.4%; and for solanesol, from 93.2% - 98.6%. Mean results for THBP, scopoletin, and solanesol were 100.0%, 94.4%, and 95.3%, respectively. For solutions of gas phase analytes, determined concentrations for

3. Ogden, M.W., Maiolo, K.C. *LC-GC* 1992 10 459-462.

4. Ogden, M.W.; *Capillary Chromatography - The Applications*, 1st ed.; W.G. Jennings and J.G. Nikelly, Eds.; Hüthig, Heidelberg, Germany, 1991; Chapter 5.

5. Davis, R.A., Stiles, M.F. "Determination of Nicotine and Cotinine: Comparison of GC and Radioimmunoassay Methods," at the 47th Tobacco Chemists Research Conference, 1993.

Table 1. Median 24-hour Time Averaged Airborne Concentrations of ETS Markers By Cell

		Median 24-hour Time Averaged Airborne Concentrations of ETS Markers, $\mu g/m^3$						
Cell	# of Subjects	3-EP	Nicotine	Myosmine	RSP	UVPM	FPM	Solanesol
1	157	0.80	1.47	0.16	33.6	11.2	7.47	0.11
2	234	0.33	0.47	0.06	23.3	5.41	3.34	0.03
3	281	0.09	0.11	0.02	20.5	2.30	1.33	0.003†
4	808	0.03	0.03	0.01	15.2	1.10	0.57	0.003†

†Actual value was non-detectable; one half of the limit of detection in μg, an average flow rate, and a 24-hour time were used.

Table 2. Median 8- or 16-hour Time Averaged Airborne Concentrations of ETS Markers By Venue

			Median 8- or 16-hour Time Averaged Airborne Concentrations of ETS Markers, $\mu g/m^3$						
Venue	Environment	# of Subjects	3-EP	Nicotine	Myosmine	RSP	UVPM	FPM	Solanesol
Home	Smoking	548	0.25	0.36	0.05	22.7	4.38	2.76	0.01
	Non-Smoking	948	0.02	0.02	0.003†	15.2	1.04	0.53	0.002†
Work	Smoking	520	0.16	0.21	0.03	23.0	3.43	2.21	0.004†
	Non-Smoking	962	0.03	0.03	0.007†	13.1	0.93	0.41	0.004†

†Actual value was non-detectable; one half of the limit of detection in μg, an average flow rate, and an 8 or 16 hour time were used.

Table 3. Median 8-hour Time Averaged Airborne Concentrations of ETS Markers at Workplaces Segregated by Type of Smoking Restriction

		Median 8-hour Time Averaged Airborne Concentrations of ETS Markers, $\mu g/m^3$						
Type of Smoking Restriction	# of Subjects	3-EP	Nicotine	Myosmine	RSP	UVPM	FPM	Solanesol
Unrestricted	168	0.36	0.58	0.08	35.4	6.90	4.15	0.02
Designated Areas Only	365	0.08	0.09	0.02	15.7	1.88	1.04	0.004†
No smoking Indoors	823	0.03	0.03	0.007†	13.1	0.87	0.38	0.004†

†Actual value was non-detectable; one half of the limit of detection in μg, an average flow rate, and an 8 hour time were used.

KEYWORDS

Environmental tobacco smoke, passive smoking, indoor air pollutant measurement