PRACTICAL RESEARCH BRIEFS

Studies Reach Opposing Conclusions on Exposure to ETS

Two recent studies, one from the US Centers for Disease Control (CDC) and the other funded by a US tobacco firm, have reached disparate conclusions about how much environmental tobacco smoke (ETS) affects nonsmokers. Not surprisingly, the tobacco-funded effort finds ETS not to be a significant problem and the CDC study finds that ETS contributes greatly to nonsmoker exposure.

The CDC study involved a multiyear effort by the agency to measure the serum cotinine concentrations of over 12,000 US residents (see ***IAQU***, February 1993). In the other study, researchers performed fixed and personal exposure monitoring. Because the current "tobacco wars" are already so polarized, it's unlikely that the results from either study will lure adherents from the opposing camp.

The tobacco-funded effort, which was bankrolled by Philip Morris USA, launches a broadside against the IAQ rules proposed by the US Occupational Safety and Health Administration (OSHA), claiming that the regulation, which would have banned smoking in US workplaces, is scientifically unfounded.

This is anticlimactic for two reasons. First, the proposed rule has been languishing for months in a bureaucratic morass. In fact, some observers have already pronounced it dead. Second, most US workplaces — offices at least — already have smoking restrictions in place, and more are going smoke-free almost daily. The two studies follow.

Two-Pronged Investigation Finds Standard Ventilation Controls ETS

In the study funded by Philip Morris, Elia Sterling and colleagues measured six phase-selective ETS exposure markers, using both fixed and personal monitors. They then compared the results to determine whether there was agreement between the two measuring methods and correlated them with building HVAC parameters to determine the effect ventilation systems had on ETS exposure. Sterling reported the findings in the journal *Indoor+Built Environment* (1996; 5:112-125).

The buildings in which the study took place, Sterling told ***IAQU***, were operated by the tobacco company and had no smoking restrictions in place, representing, in Sterling's words, "a worst-case scenario." The structures were adjacent facilities in a multibuilding complex in Richmond, Virginia.

Methodology

In the personal exposure part of the research, the investigators selected nonsmoking subjects from each facility, 13 from Building 1 and 12 from Building 2. The subjects participated over a two-day period.

The researchers attached the sampling apparatus to each participant for one working day. The apparatus consisted of a standard laboratory coat, which contained the sampling equipment: two air pumps, tubing, and sampling collection media. The media were attached to the lapels of the coat in each participant's breathing zone.

Among the compounds under study in this project were four markers from the ETS particle phase — respirable suspended particulates (RSP), ultraviolet particulate matter (UVPM), fluorescent particulate matter (FPM), and solanesol. ETS markers from the vapor phase included nicotine and 3-ethenylpyridine (3-EP). Researchers also measured the concentration of total volatile organic compounds (TVOCs).

After the personal sampling period, each participant provided a saliva specimen to allow the researchers to determine salivary cotinine levels, which verified the nonsmoking status of the subjects. Subjects also kept an activity log that recorded their location in the building, work activities, and the number of cigarettes that they observed being smoked in their presence. They recorded this data for each 30-minute segment during the work day.

Fixed-Location Monitoring

In the fixed-location monitoring part of the study the researchers measured the same ETS markers, as well as TVOCs, at four locations in each building and at the outside air intake over a four-day

period. They placed the sampling devices at a height to simulate the occupants' breathing zone.

To determine the HVAC performance, researchers measured:

- Total ventilation air flow;
- The volume of ventilation air supplied to each fixed-location monitoring site; and
- Continuous monitoring of carbon dioxide (CO_2).

To determine the overall HVAC performance, the researchers included descriptive and quantitative information on the design and operational configuration of the mechanical system. This information came from a review of mechanical and engineering plans, inspection of the HVAC system components, and airflow measurements at the air handling units (AHUs).

The researcher also measured the outside air delivered to each of the fixed monitoring sites and calculated the amount of air per person to determine whether it met current ventilation standards. They also continuously measured CO_2 concentrations.

Results

Table 1 shows the summary results of personal exposure monitoring from both Building 1 and Building 2. Table 2 shows the summary results of fixed-location monitoring from both buildings.

Comparing the results from personal monitoring and fixed-location monitoring in Building 1 indicates similar mean and median values for ETS markers. Statistical analysis showed no significant difference. Mean TVOC concentrations did differ in that the fixed-monitoring stations showed higher concentrations than the personal monitoring.

Researchers hypothesized that different sampling methods may have contributed to the discrepancy. For personal monitoring they used passive sampling, and for the fixed monitoring they used active sampling. From the Building 1 results, they concluded that fixed monitoring, frequently used in this type of study, provides a close approximation to occupant exposure as determined by personal exposure monitoring.

In Building 2, the correlation between the methods was less clear. The researchers found significant differences between the concentrations of RSP, UVPM, FPM, and solanesol. However, they attributed this to the cluster of concentrations below detection limits at the fixed monitoring sites.

The researchers noted that there was no statistical difference between the concentrations of vapor phase constituents recorded by the two methods. From this they concluded that fixed monitoring can provide a close approximation

Table 1 — Summary Data from Personal Exposure Monitoring

Date	Mean/ median	Particulate fraction ($\mu g/m^3$)				Gaseous fraction ($\mu g/m^3$)			Salivary cotinine (ng/ml)	Smoking frequency (cig/h)
		RSP	UVPM	FPM	Solanesol	Nicotine	3-EP	TVOC		
Building 1										
April 13	Mean	26.4	17.1	4.1	0.13	1.8	0.9	8.4	2.3	1.4
	Median	26.7	19.4	5.1	0.14	1.5	0.8	9.2	1.3	1.5
April 14	Mean	21.2	16.8	5.0	0.17	2.2	0.9	87.2	20.2	1.4
	Median	18.8	12.2	3.1	0.10	1.6	0.9	18.2	3.3	0.5
Combined	Mean	23.6	16.9	4.6	0.15	2.0	0.9	50.3	11.2	1.4
	Median	22.8	12.9	4.3	0.11	1.6	0.9	12.8	2.1	0.9
Building 2										
April 13	Mean	30.1	25.2	14.8	0.32	1.8	1.0	76.3	1.6	1.0
	Median	32.3	24.2	14.5	0.28	1.7	0.9	23.0	<1.0	0.7
April 14	Mean	41.9	21.7	15.5	0.45	1.9	1.0	57.7	1.4	2.1
	Median	45.6	18.7	14.4	0.44	1.8	1.0	48.9	1.3	2.2
Combined	Mean	35.0	23.7	15.1	0.37	1.8	1.0	68.6	1.5	1.5
	Median	35.3	21.6	14.5	0.42	1.7	1.0	46.0	1.1	1.2

Source: Sterling et al.

Table 2 — Summary Data from Fixed-Location Monitoring

	Site	Particulate fraction (μ/g/m³)				Gaseous fraction (μ/g/m³)		
		RSP	UVPM	FPM	Solanesol	Nicotine	3-EP	TVOC
Building 1								
Means	A	24.5	14.3	4.7	0.16	2.2	0.7	79.1
	B	47.1	23.8	5.7	0.24	3.2	1.1	267.2
	C	7.5	2.4	1.8	0.05	3.1	0.8	270.2
	D	31.4	3.3	1.6	0.04	2.4	0.7	213.4
Combined Sites	Mean	29.2	11.5	3.5	0.14	2.7	0.8	207.4
	Median	22.3	6.9	2.4	0.09	2.3	0.8	192.8
Outdoor	Mean	22.5	<2.4	<0.4	<0.06	NM	NM	NM
	Median	22.4	<2.4	<0.4	<0.06	NM	NM	NM
Building 2								
Means	A	<12.5	<2.4	<0.4	<0.06	2.0	0.8	336.5
	B	21.8	4.9	5.7	0.19	2.4	1.1	106.4
	C	26.0	6.6	6.4	0.12	1.7	1.0	342.6
	D	25.8	<2.4	<0.4	<0.06	1.1	1.0	41.2
Combined Sites	Mean	18.4	2.9	3.0	0.08	1.8	1.0	206.7
	Median	20.0	<2.4	<0.4	<0.06	1.8	1.0	166.2
Outdoor	Mean	19.4	<2.4	<0.4	<0.06	NM	NM	NM
	Median	20.4	<2.4	<0.4	<0.06	NM	NM	NM
NM = Not measured								

Source: Sterling et al.

of personal exposure. Again, the researchers recorded differences in TVOC concentrations, which they attributed to the difference between active and passive sampling.

HVAC Performance

The researchers reported that the HVAC system was providing O/A at a rate above or just slightly below the rate called for in ASHRAE Standard 62-1989 — 20 cubic feet per minute per person. In fact, the data supplied by the researchers shows some O/A ventilation rates well in excess of the standard. Table 3 shows the HVAC performance data.

In assessing air delivery rates, the researchers measured the air flow at ceiling diffusers with a manometer and balometer. To assess ventilation effectiveness, they relied on smoke tubes and the professional judgment of engineers taking the measurements. From these, they estimated that Building 1 has a ventilation effectiveness of 60% and that Building 2 has a ventilation effectiveness of 80%.

Using these estimates, the O/A per person in Building 1 ranged from 19.0 cfm to 29.4 cfm at the four fixed monitoring sites. In Building 2, the rates per person, taken over two days, ranged from a low of 13.5 cfm to 56.6 cfm, well above the ASHRAE standard.

Conclusions

In addition to concluding that fixed-location monitoring is suitable as a surrogate of personal exposure, the researchers also reported that they determined 3-EP is a likely alternative to nicotine as an ETS tracer. Nicotine has proven unpredictable in determining ETS exposure levels, and the researchers felt that 3-EP may more accurately track ETS concentrations.

Table 3 — HVAC Performance in Study Buildings

Site		Total air (cfm)	Outside air (cfm)	Outside air (%)	Observed population	O/A per person
Building 1 (O/A per person based on 60% ventilation effectiveness)						
A		986.0	286.1	29.1	9	19.2
B		170.0	49.5	29.1	1	29.4
C		410.0	119.3	29.1	3	23.9
D		760.0	221.2	29.1	7	19.0
Building 2 (O/A per person based on 80% ventilation effectiveness)						
A	April 13	240.0	89.1	37.1	3	23.8
	April 14	240.0	58.3	24.3	3	15.5
B	April 13	336.0	108.2	32.2	3	28.8
	April 14	330.0	50.8	15.4	3	13.5
C	April 13	220.0	70.8	32.2	1	56.6
	April 14	305.0	47.0	15.4	1	37.6
D	April 13	365.0	117.5	32.2	3	31.4
	April 14	345.0	53.2	15.4	3	14.2

Source: Sterling et al.

The researchers also concluded that ventilation with O/A at levels consistent with current standards can deal effectively with ETS and prevent undue exposure to nonsmokers. The report ends with a criticism of the proposed OSHA regulation, claiming that the regulators have rejected "traditional engineering practice."

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CDC's Clinical Research Indicates Widespread ETS Exposure

A multiyear cross-sectional study from the US Centers for Disease Control (CDC — Atlanta, Georgia) concludes that over 91% of the US population over the age of four years have serum cotinine levels indicating significant exposure to environmental tobacco smoke (ETS). James L. Pirkle, M.D., who headed the study, told ***IAQU*** that the results indicate a dose-response relationship. However, even those who reported no home or work exposure to ETS still exhibited serum cotinine levels.

The study took part over a three-year period as part of the Third National Health and Nutrition Examination Survey (NHANES III). Pirkle and his colleagues reported their results in the *Journal of the American Medical Association* (*JAMA*, 1996, Vol. 275, No. 16, pp. 1233-1240). Researchers questioned participants about personal tobacco use, tobacco use by other residents in the home, and exposure at work. The investigators administered the questionnaires on two occasions: as part of a household interview and later in a CDC mobile examination center.

The researchers also took blood samples to determine serum cotinine levels. A level of 15 nanograms per milliliter (ng/mL) classified a participant as an active smoker and that participant was excluded from the study. Of a total of 16,919 persons initially determined eligible for the study, researchers finally selected 10,270 for whom they had both serum cotinine measurements, and complete information on tobacco use and ETS exposure.

Controlling for Diet

The researchers report that they controlled for dietary patterns that could account for elevated cotinine levels. Cotinine is a major metabolite of nicotine, with a half-life of about 16-20 hours. Some researchers have questioned the use of cotinine as a marker for ETS exposure, claiming that diet — especially eating such things as potatoes, tomatoes, eggplant, cauliflower, and green peppers — will give false readings of ETS exposure.

In this study, trained dietary interviewers collected data on eating habits. They asked participants to recall all food and drink consumed in the day preceding the study. The researchers then applied statistical analysis to the data to

Table 4 — Geometric Mean Cotinine Levels in Nonsmokers

Exposure factors		Mean cotinine level (ng/mL)	95% confidence interval
Number of smokers in home	0	0.149	0.134-0.165
	1	0.734	0.621-0.867
	>1	1.240	1.07-1.43
Number of hours exposed at work — 17 years and older	0	0.163	0.144-0.185
	1-3	0.338	0.293-0.380
	>3	0.468	0.397-0.552
Ages 4-11 years	No home ETS exposure	0.119	0.101-0.140
	Home ETS exposure	1.140	0.978-1.34
Ages 12-16 years	No home ETS exposure	0.113	0.097-0.154
	Home ETS exposure	0.808	0.622-1.04
Ages 17 and older	No home ETS exposure	0.124	0.111-0.138
	Home ETS exposure	0.700	0.586-0.835
Ages 17 and older — workers only	No home or work ETS exposure	0.132	0.118-0.149
	Work ETS exposure only	0.318	0.285-0.356
	Home ETS exposure only	0.651	0.523-0.811
	Home and work ETS exposure	0.926	0.751-1.13

Source: Pirkle et al.