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Environmental Tobacco Smoke in the Nonsmoking Section of a Restaurant: A Case Study

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This study tested the concentrations of environmental tobacco smoke (ETS) components in a small restaurant/pub with smoking and nonsmoking areas—a facility outfitted with a heat-recovery ventilation system and directional airflow. The ETS levels in the nonsmoking area were compared with those in other similar restaurants/pubs where indoor smoking is altogether prohibited. The results indicate that ETS component concentrations in the nonsmoking section of the facility in question were not statistically different ($P < 0.05$) from those measured in similar facilities where smoking is prohibited. The regulatory implications of these findings are that ventilation techniques for restaurants/pubs with separate smoking and nonsmoking areas are capable of achieving nonsmoking area ETS concentrations that are comparable to those of similar facilities that prohibit smoking outright. © 2001 Elsevier Science

INTRODUCTION

Several studies have examined environmental tobacco smoke (ETS) concentrations and/or personal exposure in a variety of public restaurants and drinking establishments ("hospitality facilities"). Earlier studies tended to focus on either short duration area measurements or personal monitoring measurements on surrogate "customers" (Brunnemann *et al.*, 1992; Thompson *et al.*, 1989; Oldaker *et al.*, 1990; Turner *et al.*, 1992; Collett *et al.*, 1992; Lambert *et al.*, 1993). More recent investigations have focused on the personal exposure to ETS of night-club musicians (Bergman *et al.*, 1996), casino workers (Trout *et al.*, 1998), or wait staff and bartenders (Maskarinec *et al.*, 2000). With the strict segregation of smoking and nonsmoking areas in those hospitality facilities that still permit smoking, the use of directional airflow and heat-recovery ventilation systems has become increasingly popular. However, little data have been reported with which to assess the effectiveness of such systems in securing adequate air quality in the nonsmoking areas of such facilities. The intuitive benchmark for such a comparison is the air quality level in hospitality facilities where indoor smoking is prohibited. In most instances, such facilities will not be absolutely free of ETS, since smoking is often permitted immediately outside the establishments and traces of ETS components could be introduced from human and material traffic and other sources extraneous to smoking. The purpose of this study was to test a directional-flow heat-recovery ventilation and filtration system in a pub that segregates smoking and nonsmoking areas and its effectiveness in providing nonsmoking areas ETS concentrations comparable to the ETS concentrations in similar facilities where indoor smoking is prohibited.

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METHODS

Two organizations were involved in the conduct of the study. The Chemical and Analytical Sciences Division of Oak Ridge National Laboratory (Oak Ridge, TN) was responsible for overall protocol development, preparation of the ETS sampling media and analysis of the collected samples, interpretation of the data, and overall reporting. Finn Projects (Toronto, Ontario, Canada) was responsible for the system conceptual design and modifications, field sampling, and real-time field measurements.

Facilities Surveyed

The facility to be studied, the Black Dog Pub, is located in Scarborough, Ontario, Canada, a suburb of Toronto. Prior to the selection of the Black Dog Pub as the test site, a number of restaurants were reviewed and inspected. The Black Dog was selected as the owner had already shown commitment to improving air quality, having previously invested in heat-recovery ventilation technology, and was willing to cooperate in retrofitting the ventilation system. Also, it was believed that the test facility should have a very high average occupancy and a high percentage of smokers, so that it could represent a wide spectrum of bars and restaurants.

The Black Dog Pub has a designated smoking area of approximately 110 m^2, with a seating capacity of 45 individuals. Patrons may order drinks from a bar in this area (15 seats at the bar) and/or food from several (8) tables located around the bar. A nonsmoking eating area, approximately 70 m^2 in area, with a seating capacity of 99, is located adjacent to the smoking bar/eating area. It is separated from the smoking area by a wall with two pass-through windows and by two open doorways. Patrons may order drinks or food in this area from one of 20 tables. Note that there are no physical barriers in the pass-through and doorways, in order to ensure the free flow of air from the nonsmoking to the smoking section.

Ventilation for the Black Dog Pub is provided by a 3100 ft^3/min (cfm) energy/heat recovery ventilation system (ERV or HRV), with a desiccant wheel that was retrofitted in 1999. The HRV is tied into two existing rooftop heating, ventilation, and air conditioning (HVAC) units, with a capacity of 5 tons each. The new system creates directional flow of air (west to east of the facility in Fig. 1) from the nonsmoking area to the smoking area where it is exhausted, while energy (heating and cooling) is recovered by the HRV desiccant wheel on the exhaust side. The ventilation system was redesigned such that 1600 cfm of fresh air was introduced from the west side into the nonsmoking area and 1500 cfm was introduced at the borderline between the smoking and nonsmoking areas through three new ceiling diffusers. Also, the design included two new exhausts on the opposite (east) side of the bar, near the entrance doorway, with an exhaust volume of 1550 cfm each.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE 62-99) for food and beverage service facilities prescribes a rate of 20 cfm/occupant fresh-air input for dining room areas and 30 cfm/occupant for bars and cocktail lounges. Thus, based on an occupancy of 90 in the dining room and 45 in the bar/lounge, 3150 cfm of outdoor air is required to meet this standard for the Black Dog Pub. No make-up air is provided to the pub; only 100% fresh outdoor air is provided.

The rooftop intake hood of the HVAC unit is fitted with an aluminum mesh prefilter and a secondary bank of disposable filters to remove pollen, dust, etc. The filters are replaced ever 3 months. Since 100% fresh air is used, the filtration system only needs to reduce outdoor contaminants and does not have to address ETS, cooking fumes, or other indoor contaminants. The net result is that the air flows from the nonsmoking area into the smoking area, where it is exhausted, while the energy (heat/cool) is transferred to the incoming fresh air. It is estimated that 78% of the energy is recovered by the HRV unit.

Smoke tests were carried out to ensure that the directional airflow prevented intrusion from the smoking to nonsmoking areas of the Black Dog Pub. The tests were primarily concentrated at the interface of the two sections, i.e., at the open doorway and pass-through in the walls that separate the areas (Fig. 1). Smoke tests

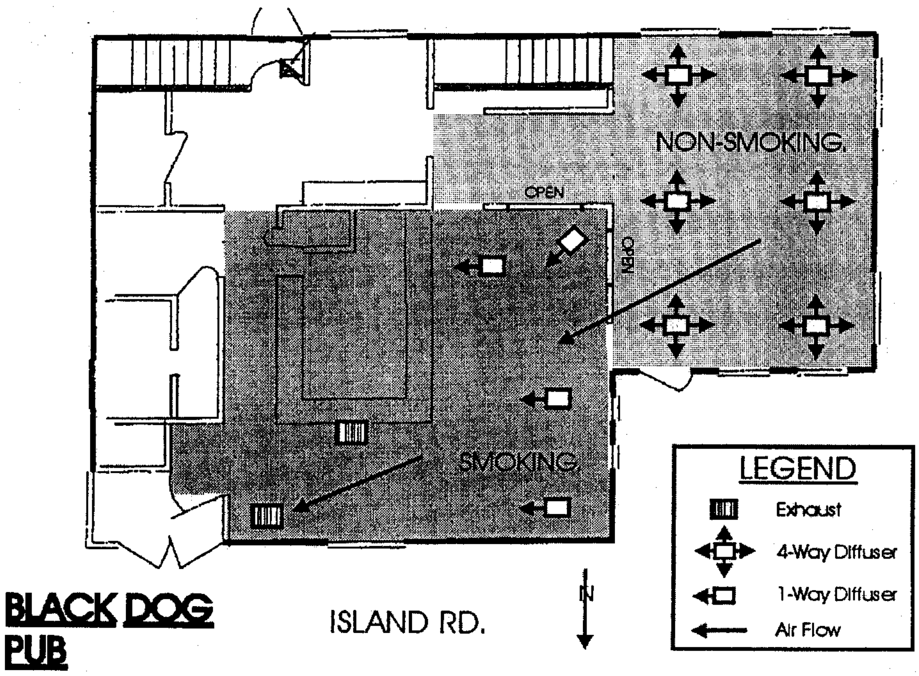

FIG. 1. Schematic diagram of layout of Black Dog Pub.

were also carried out in the smoking section to ensure effective removal of the ETS in that section as well.

Following initial sampling of the Black Dog Pub in December 2000, a purge unit was added to the HRV unit, to correct a potential carry over of the exhausted air into the fresh air stream from 4% to a much reduced 0.4%. At the same time an additional bank of filters was added downstream of the HRV to capture any nicotine/particles that might be carried over to the fresh air supply.

Control Facilities

Three "control" facilities were regulated by local ordinance as nonsmoking hospitality establishments and were used for comparative purposes. No smoking was observed in any of the facilities during the test periods.

The Eaton Centre North Food Court is located in the north end of the Eaton Centre Building in downtown Toronto. An atrium extends from the third level below grade to the second floor above grade. Three levels of escalators lead down to the food court after entering the complex from the Yonge & Dundas street level entrance, and access is also provided by elevators. The building in which the food court is contained is a regulated nonsmoking establishment. The only areas where smoking is allowed in this facility are in the restaurants located on the ground level and second floor above grade, a significant distance from the North Food Court and separated by several levels of escalators.

Facility M is located approximately 15 km southeast of Kitchener, Ontario, Canada. The building in which the facility is located is an indoor sports complex including indoor climbing walls, batting cages, a video arcade, etc. On one side of Facility M is the bar, with seating at the bar and at tables for approximately 70 people. The bar has an exit to the patio where staff and customers can smoke. On the other side of the facility is the restaurant area with seating at tables for approximately 150. The entrance to the kitchen is located in the restaurant area. In between the bar and the restaurant area is the host/hostess station at the entrance to the facility.

Facility B is located on the second and third floors of an historic hotel in downtown Waterloo, Ontario, Canada. The hotel consists of three bars, one of which is Facility B. A pool hall is located on the second floor, and a restaurant occupies the basement. One entrance to Facility B is from the stairwell at the entrance of the hotel; Facility B can also be accessed through an entrance from the pool hall. Facility B has seating for approximately 75 people on its first level and another 60 people on its second level. The entrance to the kitchen and the washrooms are located on the first level. Also on the first level is an exit to an outdoor patio with additional seating. The patio is often used as a smoking area year-round.

Details of the ventilation systems in the control facilities were not sought, for they had been installed in accordance with local building codes.

Real-Time Measurements

Respirable suspended particulate concentrations were determined in real time, using a DustTrak 8520 aerosol monitor (TSI, Minneapolis, MN). The DustTrak operates on the principle of nephelometry (light scattering by particles) and employs a 90° light-scattering laser photometer. The instrument had been recently factory calibrated using the respirable fraction of standard ISO 12103-1 for A1 test dust (Arizona Test Dust). Although data were measured continuously (once per second), data were reported as 1-min averages. For these studies, the calibration factor was maintained at 1.00. Average particle concentrations were determined by calculating the mean concentration reported from 1-min averages over the duration of the measurement interval. In each facility, the single DustTrak was colocated with an ETS component sampler in the facilities in question. In the Black Dog Pub, this was at the cashier/wait station in the nonsmoking section of the facility. In two of the other facilities, the DustTrak was located behind the bar. In the food court, the DustTrak was located in the middle of the seating section.

The carbon dioxide (CO_2), humidity, and temperature monitor used was the YES-206LH Falcon (Young Environmental Systems, Richmond, British Columbia, Canada), acquiring data at a 2-min interval. In all cases except the food court, the CO_2 (a nondispersive infrared-based sensor) and humidity/temperature sensor was colocated with the DustTrak. In the food court, the sensors were placed in the southwestern corner of the seating area. The data were measured continuously and reported as 2-min time-weighted averages.

Sampling Durations and Schedules

All facilities were sampled during a traditionally very busy time at Toronto/Waterloo/Kitchener restaurants: the week between Christmas and New Years 2000. The Black Dog Pub was sampled on two evenings, whereas the others were sampled for one evening each. Following a minor modification in the ventilation system, the nonsmoking areas of the Black Dog Pub also were resampled on two evenings in early January 2001. All facilities were sampled during what was perceived to be their busiest time of day. For the taverns, this was typically in the time period of 5:30 PM until 11:30 PM. For the food court, sampling was conducted between 10:20 AM and 3:40 PM. Sampling periods are summarized in Table 1. The number of patrons present in the facility was counted on an hourly basis and averaged over the course of the sampling period. Those data are presented in Table 1 as well.

TABLE 1
Dates and Times of Indoor Air Quality Sampling

Facility	Date	Sampling time	Average hourly patron count
Black Dog Pub			
Night 1	December 29	6:10 PM–11:30 PM	79
Night 2	December 30	5:30 PM–10:20 PM	58
Night 3	January 9	5:20 PM–11:10 PM	29
Night 4	January 10	5:10 PM–10:35 PM	25
Nonsmoking Facility M	December 27	6:20 PM–11:25 PM	123
Nonsmoking Facility B	December 28	6:20 PM–11:25 PM	34
Mall food court	December 28	10:20 AM–3:40 PM	216

Sampling Locations at the Designated Facilities

The initial sampling at the Black Dog Pub included simultaneously collecting two ETS marker samples from the smoking section and three from the nonsmoking section. The sampling locations in the nonsmoking area were located at the cashier station (immediately adjacent to the smoking station), on a fireplace (across from the opening to the smoking section), and on a window sill (south wall of the nonsmoking section) (see Fig. 1). In the second sampling at the Black Dog Pub, samples were collected only in the nonsmoking section. For the mall food court, three ETS marker samples were collected: one in the northwest corner of the food court, one in the southwest corner, and one on the east side of the court. In Facility M, five ETS marker samples were collected, one each from the following locations: left of the fireplace in the restaurant area, one at the condiment station at the kitchen entrance in the restaurant, one at the hostess station, one near the entrance to the outdoor patio/smoking area in the bar, and one behind the circular bar. In Facility B, five samples were also collected, one each in the northwest and northeast corners of the bar, one behind the bar, one near the entrance to the outside patio and smoking area, and one near the wait station.

ETS Constituent Sampling System

The sampling equipment for ETS markers and particle phase species was similar to that described by Ogden *et al.* (1996) and is now commercially available as the Double Take sampler, manufactured by SKC, Inc. (Eighty-Four, PA). Two sound-insulated constant-flow pumps are built into a single unit and were used to collect the vapor phase and particulate phase samples. Vapor phase samples were collected using XAD-4 cartridges (Cat. No. S2-0361, SKC, Inc.) at a rate of approximately 1.1 L/min. Particulate phase samples were collected using 37-mm Fluoropore filters at a flow rate of 2.2–2.3 L/min, through a BGI-4 (BGI, Waltham, MA) cyclone separator. The cyclone vortex provided a 50% cutoff of particles of 4-μm diameter. Primary differences between the sampling system described by Ogden *et al.* (1996) and the units used in this study were the use of two pumps in a single unit, an opaque conductive plastic sampling train for the particles, and a modified cyclone vortex. Particle phase markers determined as part of this study were ultraviolet-absorbing particulate matter (UVPM), fluorescing particulate matter (FPM), and solanesol. The filter cassette was fabricated from opaque conductive plastic. A cyclone vortex assembly preceded the filter cassette, such that the material collected on the filter was all of respirable (50% cutoff at 4 μm mass median aerodynamic diameter) size. The sampling systems were assembled in a nonsmoking office area in a building geographically removed from the establishments to be sampled, using the following procedure. Filters were placed in cassettes identified by unique labels that were, in turn, affixed in the sampling head. Vapor phase samples were collected on XAD-4 cartridges located in a secondary airflow path and analyzed for nicotine and 3-ethenyl pyridine. XAD-4 cartridges were labeled, and the glass tips were broken off and installed in the sampling head. Using two mass flow meters, the particulate phase flow was adjusted to 2.2–2.3 L/min, vapor phase flow was adjusted to 1.0–1.1 L/min, and both were recorded. When the sampling systems were returned to the nonsmoking office area at the end of the sampling period, sample durations and flow rates were recorded again. Average flow rates (mean of start and ending) and sampling duration were used to calculate the volume sampled and thus the ETS marker concentrations. Following sample collection, samples were stored at 4°C and shipped while being maintained at this same temperature to Oak Ridge National Laboratory for analysis. Field blanks were collected for each facility sampled.

Analysis of Indoor Air and ETS Components

Analytical chemical procedures used in this study were identical to those used in our previous studies (Jenkins *et al.*, 1996; Maskarinec *et al.*, 2000). Vapor phase samples were analyzed for nicotine and 3-ethenyl pyridine, according to the method of Ogden (1991). The XAD-4 cartridges were extracted using 1.5 ml ethyl acetate containing 0.5% (v/v) triethylamine and 8.2 μg/ml quinoline (internal standard). The analysis was performed using a Hewlett–Packard Model 5890A gas chromatograph equipped with a Model 7673 autosampler, a 30-m DB-5MS fused silica capillary column (0.32 mm i.d., 1 mm film thickness) (Part No. 123-5533, J & W Scientific, Folsom, CA), and a nitrogen/phosphorus detector.

Methods used for the determination of particulate phase ETS markers have been described in detail elsewhere (Ogden *et al.*, 1990; Conner *et al.*., 1990 Ogden and Maiolo, 1992). UVPM, FPM, and solanesol were

TABLE 2
Environmental Conditions in Surveyed Establishments

Facility	Temperature,°C			Relative humidity, %			Carbon dioxide concentration, ppm			DustTrak particle concentration,[b] μg/m³		
	Average[a]	Minimum	Maximum	Average[a]	Minimum	Maximum	Average[a]	Minimum	Maximum	Average[a]	Minimum	Maximum
Black Dog Pub												
Night 1	20.6	15.9	21.6	20.8	13.5	31.4	701	468	1216	24	11	49
Night 2	21.7	15.5	22.4	23.4	20.5	36.5	578	471	691	21	4	162
Night 3	21.9	14.0	23.1	18.7	16.8	27.4	504	446	630	NA	NA	NA
Night 4	21.4	15.3	22.0	23.2	21.7	34.0	587	535	723	49	34	132
Nonsmoking Facility M	23.6	12.9	24.5	25.0	20.9	49.6	1083	769	1277	16	0	61
Nonsmoking Facility B	19.4	15.4	20.1	27.9	24.0	36.9	1156	674	1734	36	27	57
Mall food court	21.2	16.7	22.8	19.0	17.5	28.9	841	557	1270	127	45	269

[a] Average responses were determined by taking the mean response of 1-min averages over the duration (see Table 1) of the measurements.
[b] Note that DustTrak reading may over- or underrepresent actual gravimetric respirable suspended particulate values in these venues.

determined after extraction of the filter with 1.5 ml methanol. UVPM and FPM were determined simultaneously using a Hewlett–Packard Model 1090 HPLC equipped with an autosampler, a short section of 0.2-mm tubing (to replace the column), and sequential diode array and fluorescence detectors. 2,2′,4,4′-tetrahydroxybenzophenone was used as a surrogate standard for the UVPM measurement, while scopoletin was used for the determination of FPM. Solanesol was determined using a Hewlett–Packard Model 1090 HPLC equipped with an autosampler, a Deltabond ODS column, 250 × 3 mm, 5 μm particle diameter (Part No. 255-204-3, Keystone Scientific, Inc., Bellefonte, PA), and a diode array detector operated at 205 nm. The mobile phase was acetonitrile/methanol (95/5 v/v), operated at 0.5 ml/min.

All values were measured in micrograms per sample and converted to micrograms per cubic meter using the flow rate and duration data. Conversion factors (to convert the response to the standard to a particulate matter equivalent) were taken from those reported by Nelson *et al.* (1997) for a sales-weighted average for Canadian cigarettes. Actual conversion factors used were as follows: FPM, 41; UVPM, 7.3; Sol-PM, 68. Limits of detection for an individual sample depends on the sample volume, which in turn is dependent on the sampling flow rate and duration. Assuming a 5-h sample collection period, estimated limits of detection (typically 3× the signal background) for UVPM, FPM, Sol-PM, nicotine, and 3-EP were 0.9, 0.8, 9.4, 0.09, and 0.11 μg/m³, respectively. This assumes a total volume sampled for the particle phase and vapor phase constituents of 0.66 and 0.33 m³, respectively.

RESULTS AND DISCUSSION

The environmental conditions, CO_2, and optical particle concentrations measured in the facilities are reported in Table 2. Average temperatures ranged from ca. 19 to 24°C. Since this study was conducted in the winter, outside air was especially dry, and thus, as expected, the relative humidity (RH) inside these facilities was relatively low. Average RHs ranged from ca. 19 to 28%. The effect of the improved heat recovery ventilation in the Black Dog Pub is evident in the CO_2 concentrations. Average CO_2 concentrations ranged from 500 to 700 ppm, compared with average concentrations of ca. 840–1150 ppm in the other facilities. In general, the maximum observed concentrations were also lower in the Black Dog Pub, compared with the wholly nonsmoking facilities. Differences in overall ventilation is likely to contribute to some of these differences. Interestingly, the highest maximum CO_2 concentration was observed in the facility with one of the lower mean patron counts, Facility B.

The optical particle concentrations, as measured by the DustTrak (only in nonsmoking areas) were, on the whole, quite low. The highest observed average concentrations were in the food court facility, where the mean level was 127 μg/m³. It should be noted that using a calibration factor of 1.00, when measuring ETS, the DustTrak will tend to overestimate the actual respirable suspended particulate matter (RSP) levels considerably. For example, in some as-yet-unpublished studies in hospitality venues in the United States conducted by our laboratory, the mean ratio of the time-averaged DustTrak reading to gravimetric RSP was 3.01 ± 0.92 for 56 instances in which a DustTrak was colocated with a gravimetric RSP sampler. Some preliminary measurements in our laboratory suggest that the instrument may underreport gravimetric particle concentrations that are composed predominantly of cooking oil aerosol. Given that this represents a relatively limited data set, probably the most useful information to be gleaned from the optical particle measurements is relative airborne

TABLE 3

Concentrations of Environmental Tobacco Smoke Constituents Nonsmoking Areas in Black Dog Pub vs Comparative Nonsmoking Facilities

	Concentrations, μg/m³				
	UVPM	FPM	Sol-PM	Nicotine	3-EP
Black Dog Pub nonsmoking areas, $N = 12$					
Median	3.4	5.4	0.0	0.00	0.18
Mean	3.5	5.8	2.5	0.44	0.23
SD	1.8	2.5	3.7	0.76	0.28
80th percentile	4.9	7.6	7.0	0.77	0.48
95th percentile	6.4	9.6	8.1	1.75	0.70
Nonsmoking tavern/food court data, $N = 13$					
Median	5.2	8.6	1.5	0.00	0.00
Mean	4.6	7.2	2.6	0.21	0.07
SD	2.3	4.0	3.0	0.28	0.10
80th percentile	6.3	10.7	5.5	0.49	0.16
95th percentile	7.9	12.1	7.1	0.64	0.23

particle concentrations, rather than absolute quantitative measures.

Based on the data collected in this study and reported in Table 3, mean ETS component concentrations in the nonsmoking section of the Black Dog Pub were not statistically different (at the 95% confidence level, i.e., $P < 0.05$, for all measured constituents) from those determined in the control nonsmoking facilities. (Note that the number of measurements in each category is not large, so that while medians and percentiles are reported to provide a sense of the data distribution, absolute values for anything other than means should be used with caution.) In the Black Dog Pub nonsmoking section, mean concentrations of UVPM, FPM, and ETS particles as Sol-PM, nicotine, and 3-EP were 3.5, 5.8, 2.5, 0.44, and 0.23 μg/m³, respectively. This compared with levels of 4.6, 7.2, 2.6, 0.21, and 0.07, respectively, for the control facilities. Maximum levels of constituents observed in the Black Dog Pub nonsmoking section were 6.7, 9.8, 9.1, 2.54, and 0.82, μg/m³, respectively.

Note that for the combustion-derived particles (UVPM and FPM) the FPM levels were determined to be somewhat higher than those of UVPM. At these low particle concentrations, the differences may be due to minor compositional differences in the atmospheres. The ETS-specific components were present in many of the samples in measurable concentrations. While initially counterintuitive for nonsmoking facilities, it is not unexpected to find low but measurable levels of ETS components in nonsmoking establishments. Virtually all of these facilities permit outdoor smoking immediately outside their establishments, and thus it is not unexpected that, depending on the location of air intakes for the facilities (including entryway doors), some ETS would be entrained into incoming air. Moreover, certain ETS components are generated from sources other than tobacco smoking. Field or analysis blanks did not contribute to the apparent level of ETS components in the comparative facilities. All blanks contained no detectable levels of the measured components. Note that the nonsmoking area levels are lower that those determined for the limited number of studies that have examined such in similar venues. For example, Lambert *et al.* (1993) reported mean nicotine levels in the nonsmoking sections of seven restaurants to be 1 μg/m³, with a range of 0.2–2.8 μg/m³, compared with a mean level of 0.44 μg/m³ (and a median of 0.00) for this study. In a previous study (Jenkins and Counts, 1999), we reported that subjects in workplaces where smoking was banned or banned but smoking was observed (which did not include hospitality venues) experienced 8-h time-weighted average mean nicotine concentrations of 0.086 and 0.122 μg/m³, respectively.

In Table 4, the smoking area concentrations observed in this study are compared with those determined from a subset of establishments (single room bars) most similar to the layout existing at the Black Dog Pub in a study of area and personal exposure samples in the hospitality industry reported previously (Maskarinec *et al.*, 2000; Jenkins and Counts, 1999). With the exception of 3-EP concentrations, there are no statistically significant differences ($P < 0.05$) between the levels of

TABLE 4

Comparison of ETS Component Concentrations in Smoking Areas Black Dog Pub vs Single-Room Bars

	Concentrations, μg/m³, mean ± SD				
	UVPM	FPM	Sol-PM	Nicotine	3-EP
Black Dog Pub ($N = 8$)	95 ± 32	153 ± 32	165 ± 49	12.2 ± 19.3	1.7 ± 2.7
Knoxville single-room bars ($N = 26$)[a]	146 ± 107	133 ± 104	123 ± 113	21.9 ± 17.1	5.2 ± 3.3

[a] From Maskarinec *et al.* (2000) (these data are a subset of those facilities which resemble most closely those described in this study.)

measured ETS components in the Black Dog Pub and those determined in similar facilities in the comparative establishments. Mean 3-EP levels were about one-third those found in the comparative establishments. This suggests that the smoking levels in the smoking areas of the Black Dog Pub were not inordinately low, even though somewhat lower readings could be expected on account of the superior ventilation system installed. Thus, even though expected concentrations of ETS markers were observed in the smoking section of the Black Dog Pub, those of the same constituents in its nonsmoking areas were both low and comparable to those measured in similar nonsmoking establishments.

REGULATORY AND POLICY IMPLICATIONS

Since the publication of the 1992 EPA report entitled *Respiratory Health Effects of Passive Smoking: Lung Cancer and Other Disorders*, wherefrom the agency classified ETS as a Group A carcinogen (US EPA, 1992), in the United States and Canada, and to a lesser extent in other industrialized countries, smoking is increasingly proscribed in enclosed public spaces. Despite unresolved ambiguities and controversies about the interpretation of epidemiologic data, the regulatory process to prohibit smoking in enclosed public areas has continued to gain momentum. This process has raised significant issues for the hospitality industry where many of the industry's restaurant and bar patrons wish to smoke. Some hospitality facilities have prohibited smoking, but many other facilities have sought to provide segregated smoking and nonsmoking areas, in an attempt to accommodate the preferences of all their customers. This, in turn, has led to a renewed concern on the part of both regulators and nonsmokers, about whether mechanical filtration and air handling systems are capable of ensuring adequate air quality standards in nonsmoking areas contiguous to smoking areas.

Here, the intuitive air quality benchmark is the average levels of ETS constituents that prevail in hospitality facilities where smoking is prohibited, since no stricter standard could be fairly imposed. ETS levels in nonsmoking facilities cannot be zero, for many ETS constituents are generated from sources other than tobacco or can be introduced in nonsmoking facilities from outdoor-air ETS residues, from material exchanges, from human traffic, and from sources other than tobacco smoking.

This small study provides important evidence to the regulator, the hospitality industry and the nonsmoking public that there are cost-effective alternatives to a prohibition of smoking in hospitality establishments, alternatives that can satisfy the concerns and interests of both nonsmoking and smoking customers. A system such as installed at the Black Dog Pub would cost the owner $329 per month on a 5-year lease, including installation and maintenance costs. ERV units use enthalpy wheel heat exchangers that reduce cooling loads in the summer and heating/humidification loads in the winter. HRV units use flat-plate heat exchangers and can be used in reducing heating loads in the winter. Directional airflow can be easily retrofitted at most facilities by creating sufficient positive pressure in the nonsmoking section with the introduction of a forced air supply. The air then flows toward the negative pressure area of the smoking section, where the exhausts are located. Supply air grills must also be positioned and conformed to direct the air toward the exhaust in the most unidirectional way.

Although limited in size, this study clearly shows that a suitably designed ventilation system installed in a restaurant/bar with both smoking and nonsmoking sections can produce ETS levels in the nonsmoking section that are not statistically different from those found in venues where smoking is prohibited. This alternative would avoid the contentious debate about "safe" ETS exposure limits by taking the level of ETS found in nonsmoking hospitality establishments as the baseline standard. If the hospitality venue that provides both smoking and nonsmoking areas can assure its nonsmoking customers that the ETS level in their area is comparable to that which they would find in a completely nonsmoking facility, then there would seem to be no rational reason for a prohibition of smoking in the controlled areas. As a word of caution, it should be noted that this study addresses only the issue of nonsmoking patron exposure to ETS, and it does not examine the issue of employee exposure.

CONCLUSIONS

This small study focuses on a restaurant/pub in which the smoking and nonsmoking sections were segregated and a heat-recovery ventilation system was installed, combined with directional airflow. Although additional studies are desirable, the data indicate that it is possible to reduce ETS in the nonsmoking section to levels that are comparable to those encountered in similar facilities in which smoking is prohibited altogether. The findings suggests that effective segregation of smoking and nonsmoking areas in hospitality facilities is both achievable and economically viable if sufficient attention is given to overall system design, robust air exchange rates, directional airflow, and the use of appropriate heat-recovery systems.

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REFERENCES

Bergman, T. A., Johnson, D. L., Boatright, D. T., Smallwood, K. G., and Rando, R. J. (1996). Occupational exposure of nonsmoking nightclub musicians to environmental tobacco smoke. *Am. Ind. Hyg. Assoc. J.* **57,** 746–752.

Brunnemann, K. D., Cox, J. E., and Hoffmann, D. (1992). Analysis of tobacco-specific N-nitrosamines in indoor air. *Carcinogenesis* **13,** 2415–2418.

Collett, C. W., Ross, J. A., and Levine, K. B. (1992). Nicotine, RSP, and CO_2 levels in bars and nightclubs, *Environ. int.* **18,** 347–352.

Conner, J. M., Oldaker, G. B. III, and Murphy, J. J. (1990). Method for assessing the contribution of environmental tobacco smoke to respirable suspended particles in indoor environments. *Environ. Technol.* **11,** 189–196.

Jenkins, R. A., and Counts, R. W. (1999). Occupational exposer to environmental tobacco smoke: Results of two personal exposure studies. *Environ. Health Perspect.* **107**(Suppl. 2), 341–348.

Jenkins, R. A., Palausky, A., Counts, R. W., Bayne, C. K., Dindal, A. B., and Guerin, M. R. (1996). Exposure to environmental tobacco smoke in sixteen cities in the United States as determined by personal breathing zone sampling. *J. Exposure Analysis Environ. Epidemiol.* **6**(4), 473–502.

Lambert, W. E., Sammet, J. M., and Spengler, J. D. (1993). Environmental tobacco smoke concentrations in no-smoking and smoking sections of restaurants. *Am. J. Pub. Health* **83**(9), 1339–1341.

Maskarinec, M. P., Jenkins, R. A., Counts, R. W., and Dindal, A. B. (2000). Determination of exposure to environmental tobacco smoke in restaurant and tavern workers in one US city. *J. Exposure Analysis Environ. Epidemiol.* **10,** 36–49.

Nelson, P. R., Conrad, F. W., Kelly, S. P., Maiolo, K. C., Richardson, J. D., and Ogden, M. W. (1997). Composition of environmental tobacco smoke (ETS) from international cigarettes. II. Nine country follow-up. *Environ. Int.* **24,** 251–257.

Oldaker, G. B., Perfetti, P. F., Conrad, F. C., Jr., Conner, J. M., and Mcbride, R. L. (1990). Results of surveys of environmental tobacco smoke in offices and restaurants. In *International Archives of Occupational and Environmental Health Supplement: Indoor Air Quality* (H. Kasuga, Ed.), pp. 99–104. Springer-Verlag, Berlin, Germany.

Thompson, C. V., Jenkins, R. A., and Higgins, C. E. (1989). A thermal desorption method for the determination of nicotine in indoor environments. *Environ. Sci. Technol.* **23,** 429–435.

Trout, D., Decker, J., Mueller, C., Bernert, J. T., and Pirkle, J. (1998). Exposure of casino enployees to environmental tobacco smoke. *J. Occup. Environ. Med.* **40**(3), 270–276.

Turner, S., Cyr, L., and Gross, A. J., (1992). The measurement of environmental tobacco smoke in 585 office environments. *Environ. Int.* **18,** 19–28.

U.S. Environmental Protection Agency (US EPA) (1992). *Respiratory Health Effects of Passive Smoking: Lung Cancer and other Disorders*, EPAa/60/6-90/006F. US EPA, Washington DC.