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Environmental Tobacco Smoke in Finnish Restaurants and Bars Before and After Smoking Restrictions were Introduced

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Objectives: The Finnish Tobacco Act was amended on 1 March 2000 to include restrictions on smoking in restaurants and bars. To evaluate the effectiveness of the restrictions, environmental tobacco smoke (ETS) concentrations in restaurants and bars were measured prior and after the amended Act entered into force. The Act was enforced in stages so that all stages were effective on 1 July 2003. According to the Act, smoking is prohibited in all Finnish restaurants and bars with certain exceptions. Smoking may be allowed in establishments where the service area is not larger than 50 m^2 if the exposure of employees working there to ETS can be prevented. On premises with larger service area, smoking may be allowed on 50% of the service area, provided tobacco smoke does not spread into the area where smoking is prohibited. At bar counters or gambling tables smoking is not allowed, if the spreading of tobacco smoke cannot be restricted to the employee side of the counter. Therefore, according to the Act all areas where smoking is prohibited are to be smoke-free. Methods: Establishments with a serving area larger than 100 m^2 were selected for the present study. The evaluation both before and after the enforcement of the Act included the following: The ventilation rate was first measured in each establishment. Then 3–5 area samplers, depending on the layout, were placed in locations that best described the establishment and the working areas of the personnel. The measurements were performed twice at each establishment, during peak hours. The sample collection time was 4 h during which the guests and the cigarettes smoked were counted. The air samples were analysed for nicotine, 3-ethenylpyridine (3-EP) and total volatile organic compounds (TVOC) by thermodesorption–gas chromatography–mass spectrometry. Results: Altogether 20 restaurants and bars situated in three Finnish cities participated in the study out of which 16 participated during all four measurement periods. None of the establishments had introduced a total ban on smoking and they all had reserved only the smallest area allowed by the Finnish Tobacco Act as the smoke-free area. The measured geometric mean (GM) nicotine concentration in all participating establishments was 7.1 $\mu g\ m^{-3}$ before the amended act was in force and 7.3 $\mu g\ m^{-3}$ after all stages of the Act had been enforced. The GM concentration of nicotine in food and dining restaurants was 0.7 $\mu g\ m^{-3}$ before and 0.6 $\mu g\ m^{-3}$ after the enforcement of the Act, in bars and taverns the concentrations were 10.6 and 12.7 $\mu g\ m^{-3}$, and in discos and night-clubs 15.2 and 8.1 $\mu g\ m^{-3}$, respectively. The GM nicotine concentrations measured in the smoke-free sections varied between 2.9 and 3 $\mu g\ m^{-3}$. 3-EP concentrations measured correlated well with the nicotine concentrations and were approximately one-fifth of the nicotine concentrations. The measurements showed higher TVOC values in the smoking sections than in the smoke-free sections, but because there are many other sources of TVOC compounds in restaurants and bars TVOC cannot be regarded as a marker for ETS. Conclusions: The overall air nicotine concentration decreased in 10 out of the 18 establishments that participated in the study both before and after all stages of the amended Act had been in force. Structural changes or changes to the ventilation systems had been carried out in nine of these establishments, i.e. the smoke-free sections were actually non-smoking and were mainly separated from other sections by signs and very little was done to keep the smoke

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from spreading into the smoke-free sections. In four establishments, the highest air nicotine concentration was measured in the smoke-free section. In 10 establishments, the air nicotine concentration at bar counters had dropped after the Act. Exposure of the workers and the public to ETS was, therefore, not reduced as intended by the Finnish legislature. Thus, it seems obvious from the present study that improving ventilation will not be a solution to restricting tobacco smoke from reaching smoke-free areas and physical barriers separating smoking from smoke-free areas are required.

Keywords: environmental tobacco smoke; nicotine; restaurants and bars; smoking restrictions; Tobacco Act

INTRODUCTION

In the hospitality industry workers are exposed to environmental tobacco smoke (ETS) at higher concentrations and for longer periods of time than other worker groups typically (Siegel, 1993). It has been estimated that the mortality due to ETS exposure at work in Finland was 0.9% of the total mortality of the Finnish population in the relevant disease and age categories in the year 1996. Approximately 8% of the workforce were passive smokers in 1998–2000 (Nurminen and Jaakkola, 2001). In a recent paper Jamrozik (2005) estimated that 617 employed people in the UK die owing to passive smoking each year, including 54 worker deaths in the hospitality industry each year.

In Finland smoking restrictions concerning other workplaces than restaurants and bars were introduced into the Tobacco Control Act in 1995 and have proven effective (Heloma *et al.*, 2000). The Finnish Tobacco Control Act originally from 1977 was amended to include restaurants and bars in the year 2000, and now classify tobacco smoke as a carcinogen. Smoking is now prohibited in restaurants, bars, gambling premises and corresponding establishments unless the exposure of employees working there to ETS can be prevented otherwise. The Act was enforced gradually so that on the 1st of March 2000, 70% of the serving area could be reserved for smokers in establishments larger than 100 m^3, provided the tobacco smoke does not spread into the smoke-free sections. 'Smoke-free' is used throughout this paper to describe the non-smoking areas of the clientele area as well as the employee areas e.g. bar counters and gambling tables of the establishments studied. Starting 1 July 2001, establishments with a client area larger than 50 m^2 could reserve a maximum of 50% of the serving area for smokers, again provided the smoke does not spread to smoke-free sections. Bar counters and gambling premises in all establishments have to be free of tobacco smoke. If simple structural or ventilation measures are not enough to control the spread of tobacco smoke to the smoke-free sections, other more extensive alterations could be made until 1 July 2003.

This study was launched to assess the impact of the amended Tobacco Control Act on ETS concentration in restaurants and bars. ETS concentration in the target restaurants and bars was measured by determining nicotine, 3-ethenylpyridine (3-EP), and total volatile organic compounds (TVOC) in air at fixed locations in ~20 establishments during each study period. The survey consisted of four measurement periods. One prior to the passage of legislation restricting smoking, the second when at least 30% of the service area had to be reserved for non-smoking customers, the third when at least 50% of the service area had to be reserved for non-smoking customers and the fourth after the more extensive alterations had to be completed on the 1st of July 2003.

MATERIALS AND METHODS

The first study period was carried out from September 1999 to December 1999, the second from October 2000 to March 2001, the third from October 2001 to April 2002 and the fourth from October 2003 to March 2004. All measurement periods occurred during the wintertime in Finland, which enables comparison of results, because the ventilation was dependent solely on mechanical ventilation present in all establishments. Establishments with a service area larger than 100 m^2 were selected for the study by contacting the owners directly during summer and autumn 1999. Additional selection criteria included: the mechanical ventilation systems of the premises could be measured, smoking was allowed in the premises, and the different compartments of an establishment were not completely separated from other areas by physical barriers, i.e. one-room establishments were preferred.

Depending on the clientele, the frequency and degree of smoking differs. Therefore, establishments of three different types were selected. One type denoted, as pubs in this paper include typical pubs, bars and taverns. Another group of establishments was nightclubs, which also include discos. The third group was the dining restaurants where food was the main attraction. To get a broader view of the situation in Finland the establishments were selected from three Finnish cities: Helsinki, Lappeenranta and Jyväskylä. The selection process of the chosen establishments was not truly random and the study locations selected reflect the views of a hospitality

management professional with local knowledge of the cities studied.

The survey periods consisted of three phases: (i) the selection and inspection phase explained above; (ii) ventilation measurement phase; and (iii) monitoring phase. The second phase was conducted during the same week as the monitoring phase and included: measurement of the amount of air leaving and/or entering the establishment, and measurement of the area and volume of the premises. The total amount of air leaving or entering the premises was measured by either balometers or rotating vane anemometers and was performed by a ventilation engineer. In addition, the locations of the air-sampling monitors were decided upon during phase two. Three to five locations per establishment were selected. Criteria for the sampling locations were the following: Describes the entire space as well as possible, at least one at the bar counter(s), at least one in the smoke-free and one in the smoking sections (not applicable before legislation was passed). The sampling devices were placed at a height of 1.4–1.7 m above the floor, approximately at the breathing zone level of employees and customers. During the second survey period, after the legislation restricting smoking had been enforced, the same locations for the area monitoring were used if possible and additional locations were added to meet the criteria for at least one sampling location in the smoke-free and the smoking sections. The monitoring phase included air sampling for a 4 h period during peak hours. Once during the week and once during the weekend (Friday or Saturday evenings). During the monitoring period the customers were counted every hour and the cigarette butts were collected to estimate the amount of cigarettes smoked during the sampling time. The air monitor consisted of a sampling pump SKC Model 222 (SKC Inc, Eighty Four, PA, USA) collecting air at 100 cm^3 min^{-1} through a stainless steel tube (Part no. L4270123, Perkin Elmer, Norwalk, CT, USA) packed with 150 mg Tenax TA 35/60 mesh (Art 706216, Macherey-Nagel GmbH & Co. KG, Düeren, Germany). The sample analysis has been described in a previous publication (Rothberg *et al.*, 1998). Briefly, the samples were desorbed at 300°C and analysed for nicotine and 3-EP by thermodesorption–gas chromatography–mass spectrometry. The measured TVOC, nicotine and 3-EP concentration represent the average concentration during the 4 h period. For samples with nicotine and 3-EP concentrations below the limit of quantitation (0.05 μg m^{-3}) we used 0.025 μg m^{-3} for calculations. Theoretical average nicotine concentrations in air were calculated based on the air exchange rate and cigarettes smoked (Daisey, 1999; Ott, 1999; Repace, 2005).

$$\overline{c(T)} = \frac{n_{ave} g_{cig}}{V \Phi T} - \frac{\Delta c}{\Phi T} \quad (1)$$

where $\overline{c(T)}$ = average concentration (μg m^{-3}); n_{ave} = burned cigarettes during averaging time; g_{cig} = cigarette emission [1800 μg nicotine per cigarette (Repace *et al.*, 1998)]; Δc = change of concentration over the averaging time; Φ = air exchange rate (1 h^{-1}); V = Volume of establishment (m^3); and T = averaging time (4 h).

Because the measurements were performed during peak hours it was assumed that the initial and final air nicotine concentrations in the establishments were the same ($\Delta c = 0$) and thereby the latter term in formula (1) disappears. The formula assumes complete mixing and that adsorption equals desorption at surfaces and, therefore, the calculated average concentration is only suggestive. The theoretical average nicotine concentrations were calculated to evaluate the placement of air sampling locations and to evaluate the quality of the ventilation measurements. SAS-software version 8.2 was used for statistical analyses.

RESULTS AND DISCUSSION

Twenty establishments were evaluated during the first survey period before the Act and 17–18 establishments after the enforcement of the Act (Table 1). Of these establishments, 14 were the same during all measurement periods (Table 2). All establishments participating in the survey had mixed ventilation, i.e. dilution ventilation and none had displacement ventilation. Displacement ventilation is an air distribution system in which incoming air originates at floor level and rises to exhaust outlets at the ceiling as opposed to mixed ventilation where inlets and outlets may be placed side by side and the contaminants in the air are first diluted by the incoming fresh air before removal through the exhaust outlets. The air change rate in the study establishments varied between 3.3 and 15.3 times per hour (Table 2). Smoking was allowed in all establishments during all the study periods and all establishments had reserved smoke-free areas that were approximately equal to the minimum area allowed by the Finnish Tobacco Act. Nightclubs E and F had in 2004 only reserved the areas around the bar counters as the smoke-free area and it was difficult to judge whether the areas counted for 50% of the service area. The service-area of establishment Q was <100 m^2 (80 m^2), but they had, nonetheless, reserved 30% of the service-area for non-smoking customers in the year 2000.

As expected, establishments focused on serving food (dining) showed lower geometric mean (GM) air nicotine and 3-EP concentrations than bars and taverns (pubs) or nightclubs and discos (nightclubs). No significant difference in the aforementioned concentrations can be seen between establishments of the type pubs and nightclubs. The amount of ETS, found at the different types of establishments, followed the

Table 1. ETS levels measured in restaurants and bars before and after an amended tobacco act restricting smoking was introduced (Measurements at 3–5 stationary points at each participating establishment. Values in μg m^{-3})

	All types[a]			Pubs[b]			Nightclubs[c]			Dining[d]			Bar counter[e]			Non-smoking[e]			Smoking[e]		
	Nic.	3-EP	TVOC	Nic.	3-EP	TVOC	Nic.	3-EP	TVOC	Nic.	3-EP	TVOC	Nic.	3-EP	TVOC	Nic.	3-EP	TVOC	Nic.	3-EP	TVOC
2004[f]																					
GM	7.3	1.7	210	12.7	3.3	210	8.1	1.9	300	0.6	0.1	80	6.7	1.6	200	2.9	0.8	150	11.0	2.4	240
GSD	5.8	4.6	2	3.6	2.4	2	5.0	3.2	2	5.2	5.1	1	5.5	4.4	2	5.7	5.5	2	4.9	3.7	2
1st quartile[g]	2.6	0.9	120	6.4	2.0	130	3.2	1.0	180	0.2	<0.05	70	1.9	0.8	110	0.7	0.4	90	5.1	1.6	150
3rd quartile[h]	26.1	5.3	360	29.5	6.2	300	26.3	3.7	470	2.2	0.2	100	25.8	5.0	310	11.0	2.5	210	30.7	6.0	380
N[i]	18	/	159	10	/	78	6	/	61	2	/	20	18	/	69	18	/	54	18	/	110
2002[f]																					
GM	6.9	2.1	300	12.9	3.6	340	7.8	2.6	330	0.7	0.3	180	5.8	1.9	280	3.0	1.1	260	11.6	3.1	330
GSD	4.7	3.6	2	3.5	2.3	2	3.2	2.1	2	5.0	4.5	1	4.8	3.6	2	5.2	4.6	2	3.4	2.4	2
1st quartile[g]	3.3	1.4	210	6.8	2.3	230	3.5	1.8	250	0.2	0.09	160	1.9	1.1	210	1.1	0.5	200	6.0	1.8	220
3rd quartile[h]	24.1	4.8	440	35.7	6.9	540	18.1	4.0	450	2.1	0.9	210	20.8	4.8	420	11.4	3.2	340	31.4	6.1	520
N[i]	17	/	167	9	/	72	6	/	64	2	/	20	17	/	73	17	/	52	17	/	103
2000[f]																					
GM	6.2	1.8	230	12.4	3.4	220	7.3	2.4	290	1.1	0.3	170	5.4	1.7	220	2.9	0.9	210	9.2	2.5	240
GSD	5.8	4.8	2	3.3	2.6	2	4.1	3.0	2	10.5	8.0	1	5.7	4.7	2	8.6	7.4	2	3.8	3.1	2
1st quartile[g]	2.8	0.9	140	6.6	2.0	140	2.8	1.3	170	0.2	<0.05	120	1.4	0.7	130	1.0	0.4	130	4.6	1.5	160
3rd quartile[h]	21.6	4.6	370	30.2	6.6	370	21.5	4.8	510	11.1	2.3	220	20.0	4.7	330	16.1	3.4	310	25.2	4.9	370
N[i]	17	/	167	8	/	57	6	/	68	3	/	30	17	/	79	17	/	56	17	/	109
1999[f]																					
GM	7.1	1.2	250	10.6	1.7	220	15.2	3.0	410	0.7	0.1	140	6.1	1.0	240	NA	NA	NA	7.1	1.2	250
GSD	7.9	7.9	2	6.0	6.4	2	4.0	4.3	2	7.7	5.6	2	8.7	9.2	2	NA	NA	NA	7.9	7.9	2
1st quartile[g]	2.1	0.4	150	4.8	0.9	140	7.0	1.7	280	0.2	<0.05	110	1.4	0.2	150	NA	NA	NA	2.1	0.4	150
3rd quartile[h]	31.0	6.0	440	31.9	6.1	400	40.0	7.6	680	2.8	0.4	240	34.0	6.3	440	NA	NA	NA	31.0	6.0	440
N[i]	20	/	160	10	/	71	6	/	57	4	/	32	20	/	82	NA	/	NA	20	/	160

NA, Not available; Nic., Nicotine; 3-EP, 3-ethenylpyridine; TVOC, total volatile organic compounds.
[a]Includes pubs, nightclubs and dining establishments.
[b]Establishments where customers gather mainly to socialise.
[c]Includes discos and nightclubs.
[d]Includes establishments specialising in serving lunch and dinner.
[e]Stationary measurement points at the bar counters, in the non-smoking sections and in the smoking sections, respectively.
[f]Measurements half a year before (1999), half a year after the enforcement of the amended Tobacco Act on 1 March 2000, measurements when 50% of clientele area should be smoke-free 2002 and measurements when the entire Act was in force 2004.
[g]25th percentile.
[h]75th percentile.
[i]Number of participating establishments/number of samples analysed.

Table 2. Characteristics and measurements evaluated both before and after the amended Tobacco Act was introduced

Establishment[a]	Customer (no.)[b]	Cigarettes smoked (no.)[c]	Service area (m^2)	Volume (m^3)	Air change rate ($1\ h^{-1}$)[d]	Ave. Nic.[e] ($\mu g\ m^{-3}$)	Bar counter Nic.[f] ($\mu g\ m^{-3}$)	Non-smoking Nic.[f] ($\mu g\ m^{-3}$)	Smoking Nic.[f] ($\mu g\ m^{-3}$)	Theoretical Nic.[f] ($\mu g\ m^{-3}$)[g]	Ave.[h] TVOC[i] ($\mu g\ m^{-3}$)	Bar counter TVOC[i] ($\mu g\ m^{-3}$)	Non-smoking TVOC[i] ($\mu g\ m^{-3}$)	Smoking TVOC[i] ($\mu g\ m^{-3}$)	3-EP[j] ($\mu g\ m^{-3}$)	Bar counter 3-EP[j] ($\mu g\ m^{-3}$)	Non-smoking 3-EP[j] ($\mu g\ m^{-3}$)	Smoking 3-EP[j] ($\mu g\ m^{-3}$)
In pubs and taverns																		
A99	140	310	270	730	9.4	28.5	50.0			20	310	400			4.8	8.1		
A00	90	360	270	730	6.7	23.9	33.8	4.5	28.7	33	350	420	130	400	7.8	10.6	2.6	9.1
A02	70	300	270	730	6.9	19.4	27.8	2.3	23.7	27	410	500	270	440	5.2	7.2	1.2	6.2
A04	110	180	270	730	7.9	13.4	20.3	8.8	20.1	14	160	210	140	200	3.5	5.9	2.5	5.0
B99	70	370	400	1200	4.2	15.7	11.0			33	340	280			2.4	1.4		
B00	80	370	400	1200	3.3	25.1	40.8	4.5	30.2	41	270	370	150	300	4.4	5.4	1.3	5.1
B02	100	500	400	1200	4.2	25.8	21.5	2.3	31.6	45	420	390	220	470	5.2	4.6	1.5	6.1
B04	60	270	400	1200	4.5	17.7	41.0	10.5	22.5	22	200	290	150	220	2.9	4.5	2.3	3.3
G99	100	410	158	680	6.9	27.7	25.5			39	330	310			4.7	4.3		
G00	60	280	158	680	6.9	12.7	12.2	16.2	13.2	27	190	180	280	190	1.9	1.8	2.3	2.0
G02	90	470	158	680	6.9	22.6	11.7	9.1	25.9	45	470	390	400	490	5.3	3.9	3.9	5.6
G04	60	290	158	680	6.8	14.3	9.2	8.1	15.9	28	280	240	250	280	3.5	2.7	2.6	3.7
I99	50	340	315	882	5.3	17.0	22.0			32	240	260			3.4	3.3		
I00	40	380	315	882	5.3	29.5	29.6	29.6	29.3	36	320	360	360	290	8.1	8.7	8.7	7.3
I02	80	710	315	882	7.8	19.2	14.8	14.8	23.4	47	280	260	260	310	5.8	5.1	5.1	6.5
I04	70	750	315	882	5.8	24.2	18.8		24.2	66	450	460		450	5.9	5.6		5.9
K99	30	120	40	152	5.7	38.9	39.1			62	420	430			6.9	7.4		
K04	40	270	110	308	7.0	9.6	1.9		9.6	57	290	220		290	3.0	1.4		3.0
N99	30	250	300	750	9.0	19.3	16.7			17	300	220			3.3	2.8		
N00	20	110	300	750	9.0	10.1	11.7	6.6	13.5	7	160	170	140	190	2.5	2.6	1.8	3.3
N02	30	220	367	750	9.0	20.4	20.9	3.2	26.1	15	270	290	210	290	3.5	3.7	1.8	4.0
N04	70	450	367	750	9.6	23.4	23.4	16.6	27.8	28	150	170	120	170	6.9	7.5	5.3	7.9
OP00	120	360	300	810	14.5	7.3	11.5	1.0	11.5	14	200	230	150	230	2.2	3.4	0.5	3.4
OP02	130	350	300	810	14.5	25.3	27.8	0.4	31.4	14	390	430	160	450	3.9	4.3	0.2	4.8
OP04	100	360	300	810	13.3	66.5	62.0	1.1	82.9	15	680	740	250	790	5.9	5.8	0.6	7.2
Q99	30	170	80	200	8.1	91.8	75.9			48	510	500			8.8	7.3		
Q00	30	200	80	200	8.1	46.1	49.0	73.9	32.2	56	520	590	900	330	13.7	15.4	23.5	8.8
Q02	40	170	80	200	8.1	35.6	26.8	16.2	45.3	48	580	490	400	670	8.6	6.8	5.1	10.3
Q04	40	180	80	200	18.9	17.2	14.3	0.7	22.7	21	190	160	70	230	4.7	3.6	0.4	6.2

Table 2. *Continued*

Establishment[a]	Customer (no.)[b]	Cigarettes smoked (no.)[c]	Service area (m^2)	Volume (m^3)	Air change rate ($1\ h^{-1}$)[d]	Ave.[e] Nic.[f] ($\mu g\ m^{-3}$)	Bar counter Nic.[f] ($\mu g\ m^{-3}$)	Non-smoking Nic.[f] ($\mu g\ m^{-3}$)	Smoking Nic.[f] ($\mu g\ m^{-3}$)	Theoretical Nic.[f] ($\mu g\ m^{-3}$)[g]	Ave.[h] TVOC[i] ($\mu g\ m^{-3}$)	Bar counter TVOC[i] ($\mu g\ m^{-3}$)	Non-smoking TVOC[i] ($\mu g\ m^{-3}$)	Smoking TVOC[i] ($\mu g\ m^{-3}$)	3-EP[j] ($\mu g\ m^{-3}$)	Bar counter 3-EP[j] ($\mu g\ m^{-3}$)	Non-smoking 3-EP[j] ($\mu g\ m^{-3}$)	Smoking 3-EP[j] ($\mu g\ m^{-3}$)
R99	70	490	130	351	10.3	43.3	19.0			61	590	300			9.7	5.0		
R00	30	200	130	351	10.3	12.5	15.7	5.7	15.9	25	270	330	130	340	3.2	3.6	1.4	4.1
R02	50	220	130	351	10.3	23.7	16.1	3.4	33.8	27	500	510	330	590	5.1	4.3	2.0	6.7
R04	40	230	130	351	4.1	33.7	26.0	10.0	45.5	72	270	250	160	330	6.4	5.5	3.0	8.0
T99	20	210	221	641	7.3	4.3	0.5			20	60	40			1.2	<0.05		
T00	30	140	221	641	7.3	1.4	0.8	1.0	1.6	13	70	60	70	70	1.1	0.7	0.8	1.2
T02	40	190	221	641	7.3	5.6	5.3	2.6	6.5	18	150	140	120	160	1.6	1.5	1.0	1.8
T04	100	200	221	641	7.3	11.1	7.1	7.6	12.2	19	90	80	80	100	2.2	1.8	2.2	2.2
In nightclubs and discos																		
C99	280	770	500	1800	4.0	40.5	29.4			48	880	570			9.5	7.8		
C00	170	450	500	1800	8.4	18.3	12.9	12.9	25.2	13	790	420	420	1030	4.5	3.6	3.6	5.9
C02	140	590	458	1800	6.8	25.1	15.1	9.4	29.0	21	430	350	490	410	3.9	2.9	2.6	4.3
C04	180	470	500	1800	5.0	30.0	15.8	5.7	40.6	24	360	230	710	320	3.3	2.1	1.4	4.2
E99	300	430	550	1700	5.9	26.1	30.3			19	490	520			3.7	4.2		
E00	340	590	550	1700	5.9	12.3	9.7	24.1	6.3	26	250	220	330	200	3.4	2.8	6.7	1.8
E02	400	1210	550	1700	5.9	13.2	10.6	15.1	6.1	54	330	290	330	290	3.1	2.4	3.4	1.7
E04	180	370	260	1040	3.9	18.0	9.2		18.0	40	230	220		230	3.7	1.4		3.6
F99	100	200	260	800	4.5	21.7	11.0			24	660	500			4.0	1.6		
F00	160	490	260	800	9.9	22.6	7.9	28.9	16.9	28	820	260	470	1030	5.2	1.7	6.8	3.7
F02	50	190	260	800	9.9	10.0	2.4	6.6	12.2	11	340	200	280	390	2.3	1.0	2.0	2.4
F04	200	420	240	720	7.5	29.2	15.3		33.7	35	630	220		630	5.6	2.4		6.4
H99	430	1210	529	1517	8.5	55.4	59.3			42	770	800			12.6	14.1		
H00	250	820	529	1517	8.5	7.7	9.3	1.9	11.5	28	290	320	260	340	4.1	4.8	1.6	5.7
H02	340	1050	529	1517	8.5	3.1	3.0	1.6	4.4	36	300	280	230	330	2.9	2.8	1.9	3.7
H04	160	860	529	1517	4.9	12.2	7.9	1.9	20.9	52	480	440	350	610	4.0	3.4	1.7	5.7
J99	210	710	484	1355	9.3	14.0	16.6			25	270	240			2.8	3.1		
J00	170	720	484	1355	9.3	5.0	4.0	2.7	5.5	26	80	80	80	90	1.8	1.7	1.4	1.9
J02	260	810	484	1355	9.3	10.6	11.5	6.7	11.5	29	240	200	210	250	3.8	3.8	3.1	3.9
J04	140	480	484	1355	9.5	1.6	1.8	1.7	1.5	17	160	170	170	160	1.1	1.2	1.5	1.0

S99	70	190	500	1350	9.1	5.4	5.4			7	130	130			0.9	0.9		
S00	190	530	500	1350	9.1	17.1	18.1	14.5	18.4	19	390	400	570	300	3.3	3.4	3.1	3.4
S02	270	250	500	1350	9.1	17.9	18.6	19.2	20.4	9	450	450	430	500	3.2	3.4	3.3	3.7
S04	70	270	500	1350	10.4	23.5	27.3	6.4	34.8	8	360	380	240	440	2.6	3.1	1.0	3.7
In restaurants																		
D99	30	30	272	890	6.2	2.2	1.6			2	250	260			0.4	0.2		
D00	30	30	272	890	5.2	4.3	2.8	0.2	8.3	3	180	200	190	160	0.9	0.8	0.1	1.8
D02	40	40	272	890	8.5	3.8	1.6	0.2	7.2	2	170	150	140	200	0.9	0.4	0.1	1.7
D04	20	20	272	890	6.6	2.9	2.1	1.2	4.6	1	100	100	90	110	0.8	0.4	0.1	1.4
L99	60	60	179	448	15.3	3.6	1.0			4	130	140			0.7	0.1		
L00	50	90	179	448	15.3	5.0	0.4	0.3	9.6	6	160	130	130	190	0.9	0.2	0.1	1.7
L02	20	100	179	448	15.3	1.2	0.4	0.3	2.0	7	210	220	200	230	0.4	0.2	0.1	0.7
M99	50	100	138	373	8.3	4.7	3.4			14	170	190			0.7	0.5		
M04	20	30	519	1453	8.0	0.2	0.1	0.1	0.2	1	80	60	60	130	<0.05	<0.05	<0.05	0.1
OP99	50	170	300	810	14.5	3.0	2.0			12	170	170			0.6	0.4		

Each number represents the average of two measurements.
[a]Establishments A–F in Helsinki, G–L in Lappeenranta and N–T in Jyväskylä, numbers after the letter denotes measurement year.
[b]Average customer count during 4 h measurement.
[c]Cigarette butts counted during 4 h measurement.
[d]Airflow in volume units per hour divided by the building space volume in identical volume units.
[e]Arithmetic average concentration of all measurement points (3–5).
[f]Nicotine.
[g]Theoretical average nicotine concentration calculated based on formula (1).
[i]Total volatile organic compounds.
[j]3-ethenylpyridine; non-smoking areas only present after introduction of the amended Act; establishment OP changed its business concept to a pub after the first measurement period in 1999.

same pattern for measurements performed before and after the introduction of the Act. The GM nicotine and 3-EP concentrations at bar counters did not differ from the measured GM concentrations in other parts of the establishments. This was true even though smoking was prohibited at bar counters during the measurements performed after the modified Act had been introduced. In the smoke-free sections, the GM nicotine and 3-EP concentrations were lower than in the smoking sections. Smoke-free sections were not present before the introduction of the Act (Table 1).

Combining all measurements in all types of establishments the measured GM nicotine and 3-EP concentration did not differ statistically between the different study periods. This result is not surprising, as there are no studies reporting drastic changes in the smoking habits in Finland during the time period of this study (Table 3). In Table 3, the statistical analysis used was the Friedman's two-way analysis of variance for the difference between the four measurement periods. Furthermore, to make sure the differences seen are not just due to a change in customer number or smoking frequency during the measurements adjusted values for nicotine and 3-EP were also used in the analysis. The measurement performed before the Act was in force (year 1999) showed a significant difference ($P < 0.05$) for the measured nicotine concentration adjusted by the number of smoked cigarettes in the arithmetic average of all measurement points in an establishment and at the bar counters when compared with the same measurements performed in 2002 after the Act was in force. Because the same statistically significant difference was not seen for the unadjusted nicotine concentration and the nicotine concentration adjusted by the customer number and because no statistically significant difference was found when 3-EP was used as the ETS marker, it may be concluded that no significant change in ETS-concentration took place after the Act was enforced at bar counters or in the overall ETS-concentration calculated from all measurement points. This difference found in the statistical analysis between the results for nicotine and 3-EP as a marker for ETS may be due to the smaller absolute concentration value of 3-EP compared with nicotine (nicotine ~4–5 * 3-EP). When comparing the nicotine and 3-EP concentrations in the smoke-free sections with the arithmetic mean of all measurement points from the measurement period before the Act was introduced, the difference is statistically significant using both unadjusted and adjusted values for nicotine and 3-EP concentrations (Table 3, $P \leq 0.004$). This result indicates that customers visiting the smoke-free areas of these restaurants and bars are less exposed to ETS than before the Tobacco Act was in force, but when viewing the measured GM concentrations of nicotine and 3-EP in the smoke-free sections (Table 1) it is clear that exposure to ETS cannot be avoided in the establishments studied, perhaps with the exception of dining restaurants (Table 2). Furthermore, in five establishments the measured nicotine and 3-EP concentrations in the smoke-free section were higher than in the smoking section during the measurements in year 2000 (E, F, G, I and Q in Table 2). All except establishment E and J were able to keep the ETS concentrations in the smoke-free sections below that in the smoking sections during the measurement periods in the years 2002 and 2004.

Structural changes or changes to the ventilation systems had been carried out in nine of the establishments (A, C, D, E, G, H, J, N and Q). The changes made were mainly changes in the distribution of air, i.e. changes in the amount of air entering bar counters and into smoke-free areas. The changes were not successful in preventing ETS from entering these areas (Table 2).

The Pearson correlation coefficient between all measured air nicotine and 3-EP-concentrations was 0.82 ($P < 0.0001$) and the Pearson correlation coefficient between the measured and the calculated

Table 3. Friedman's two-way analysis of variance was conducted for the difference between the four measurement periods using nicotine (Nic.) and 3-ethenylpyridine (3-EP) concentration as marker for environmental tobacco smoke (ETS) in all the establishments studied

	Nic.*	3-EP*	Nic./cig.**	3-EP/cig.**	Nic./cust.***	3-EP/cust.***
All measurement points	0.386	0.618	0.012[a]	0.147	0.592	0.083
At bar counters	0.636	0.272	0.026[b]	0.155	0.243	0.280
In the smoking section	0.629	0.737	0.198	0.750	0.941	0.655
In the non-smoking section	<0.001[c]	0.004[c]	<0.001[c]	<0.001[c]	<0.001[c]	<0.001[c]

Measurements performed in years 1999, 2000, 2002 and 2004 at three to five stationary points at each participating establishment. The arithmetic mean of the measurement points were calculated in $\mu g\ m^{-3}$*, $\mu g\ m^{-3}$ per smoked cigarettes** and $\mu g\ m^{-3}$ per average customer count*** and used to compare the situation between each measurement period. Values represent the *p*-values from the Friedman's two-way analysis of variance. If the value is <0.05 then at least one measurement period differs from on of the other periods.

[a]Measurements before the act was in force (1999) is significantly different from measurement periods in 2000 and 2002.
[b]Measurements before the act was in force (1999) is significantly different from measurement periods in 2002.
[c]Measurements before the act was in force (1999) is significantly different from all other measurement periods.

theoretical nicotine concentration was 0.55 ($P < 0.0001$). The correlation coefficient for nicotine and 3-EP support the fact that either one or both may be used as ETS markers. The correlation coefficient between the measured average nicotine concentration and the calculated nicotine concentration show that it is possible to estimate nicotine concentration in an establishment by counting smoked cigarettes, using the nicotine emission rate from the literature and measuring the air exchange rate. This calculated nicotine concentration may not be as exact as the measured, but on the other hand, the selection of sampling locations and the number of samples taken greatly affects any calculations on, e.g. average nicotine concentrations in an establishment (Fig. 1). The GM concentrations of the calculated theoretical nicotine concentrations were in 1999, 17.3 μg m^{-3}, in 2000, 17.8 μg m^{-3}, in 2002, 19.9 μg m^{-3} and in 2004, 18.3 μg m^{-3}, which may be compared to the results presented in Table 1. The calculated theoretical nicotine concentrations indicate that the selection of sampling locations, collection of cigarette butts and measurements of ventilation rates were reasonably successful. The discrepancy between the calculated and measured average nicotine concentration in establishments E, H and J was probably caused by too few samples for this size of establishments (five measurement locations in 484–550 m^2) and the discrepancy in establishments L, OP and T was due to too few sampling points in the smoking sections. Nevertheless, these results suggest that by estimating the number of smoked cigarettes, and if the air-exchange rate in an establishment is known, a reasonable estimate of the amount of ETS present can be calculated.

The Pearson correlation coefficient was 0.7 ($P < 0.0001$) between the measured TVOC concentration and the measured nicotine or 3-EP concentration. TVOC values may be used as an indicator for indoor air quality, but TVOC is not always a suitable marker for ETS (Fig. 1). Figure 1 presents on a logarithmic scale the relationship between the measured ETS-markers and TVOC and fresh airflow rate expressed in dm^3 s^{-1} per smoked cigarettes in the smoke-free sections of the establishments of this study. Throughout the text dm^3 denotes litres . The figure may be used to give an idea of the ventilation rate, which would be needed to gain a reasonable ETS-marker concentration in the smoke-free area, e.g. a nicotine concentration in the smoke-free area of 0.5 μg m^{-3}

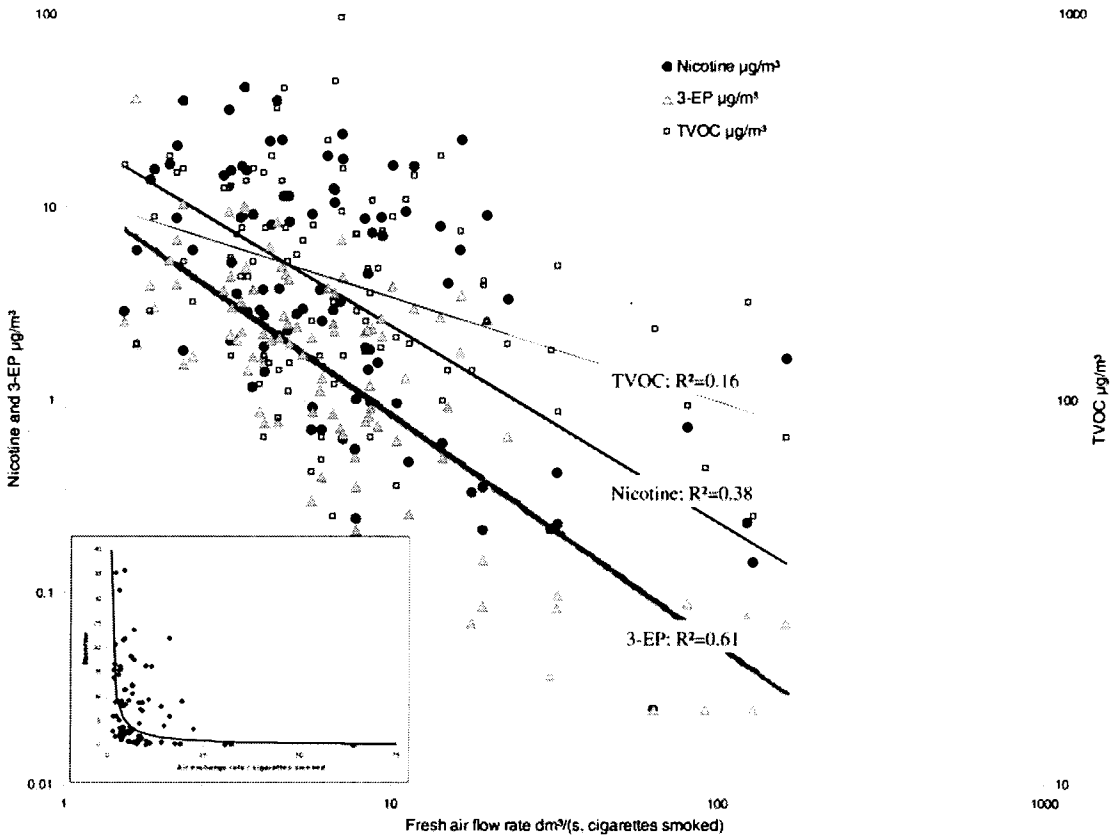

Fig. 1. Concentration of nicotine, 3-ethenylpyridine (3-EP) and total volatile organic compounds in air as a function of fresh airflow rate adjusted by smoked cigarettes in the smoke-free areas of Finnish restaurants and bars (the small figure in the lower left corner represent the measured air nicotine concentration plotted as a function of airflow rate on a normal scale).

may be obtained with a fresh airflow rate of ~50 $dm^3\ s^{-1}$ per smoked cigarette. Such flow rates are not feasible in restaurants or bars. The ventilation was probably not planned in an optimal way in the study establishments, and, as seen from the coefficient of determination for nicotine $R^2 = 0.38$, there is a lot of uncertainty in the calculations from these real world measurements. Nonetheless, the fresh airflow rates needed to prevent ETS from entering the smoke-free sections are going to be very high in this type of settings where 50% of the service area in a restaurant or bar is to be made smoke-free.

Generally, these results suggest that partial smoking restrictions reduce ETS concentrations in smoke-free areas but they far from eliminate workers exposure to ETS. In restaurants serving food partial smoking restrictions seem to work, provided the ventilation system meets the minimum requirements of the Finnish building code (10 $dm^3\ s^{-1}$ per person) effective during the measurement periods. The ventilation rates were, in all but two establishments, below the target value, average 6.5 $dm^3\ s^{-1}$ per person or m^2. Smoking in bars and nightclubs is intense, as proven by the fact that the ETS concentration was nearly 10 times higher in these establishments than in food restaurants. Clearly, a simple separation of smokers from non-smokers is not enough when assigning smoke-free sections in bars and nightclubs. If the smoke-free area is selected without paying attention to the air distribution system, it may cause the ETS concentration to be even higher in the smoke-free area than in the smoking section.

CONCLUSIONS

In conclusion, the difference in the ETS concentration in smoking and smoke-free sections was small and at bar counters the ETS concentration was similar to the average concentration in the establishments. The requirement set by the amended Tobacco Act in Finland that tobacco smoke has to be prevented from spreading to smoke-free sections was not met in any of the investigated establishments. Neither could a reduction in the ETS concentration at bar counters be observed. It follows that the exposure of workers as well as the public to ETS in the studied establishments had not been reduced as intended by the Finnish legislative body. The selection process for the study establishments left out suburban restaurants and bars, and because only establishments with a serving area larger than 100 m^2 were chosen many small pubs were also left out. These aforementioned types of establishments are typically regarded as very smoky environments. In addition, there are many lunch restaurants in workplaces in Finland where smoking has been prohibited since the last modification of the Tobacco Act in 1995 and even before that time. Even though, the authors believe that the effects of the modified Tobacco Act on the ETS-levels in Finnish restaurants and bars presented in this paper can be generalized to the situation in Finland.

To improve working conditions, spreading of ETS to smoke-free sections should be prevented and the working areas (bar counters etc.) should be placed in the smoke-free section. The present study and other studies (Brauer and 't Mannetje, 1998; Moschandreas and Vuilleumier, 1999; Spengler, 1999; Maskarinec *et al.*, 2000; Repace, 2000; Jenkins *et al.*, 2001; Cenko *et al.*, 2004) indicate that mixed ventilation without physical barriers will not yield truly smoke-free sections. Other possible solutions to reduce ETS exposure of hospitality workers and patrons include total smoking ban, physical barriers between sections combined with a sufficient airflow from smoke-free to smoking sections, local ventilation solutions at workstations combined with sufficient areal smoking restrictions (Hyvärinen *et al.*, 1997; Yamato *et al.*, 2004; Jacobs and Gids, 2005). Such solutions are not yet common in Finnish restaurants and bars and are, therefore, the subject of forthcoming studies.

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