PERSONAL EXPOSURE TO ENVIRONMENTAL TOBACCO SMOKE IN EIGHT EUROPEAN CITIES

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ABSTRACT

Exposures to respirable suspended particles (RSP) and both the particulate and vapour phases of environmental tobacco smoke (ETS) were monitored in eight European cities. Over 1500 housewives and office workers participated in the studies by wearing personal monitors over a 24-h period to assess exposures in the home and workplace. Based upon median 24-h time weighted average (TWA) concentrations, the most highly exposed subjects throughout Europe were office workers living and working with smokers. The median TWA RSP, ETS particle and nicotine levels for these workers across the eight cities were 58, 12 and 1.2 $\mu g\ m^{-3}$ respectively, with highest RSP levels found in Barcelona and the lowest in Stockholm. Similarly for housewives living with smokers, the median RSP, ETS particle and nicotine levels were 52, 4.1 and 0.63 $\mu g\ m^{-3}$ respectively, with lowest RSP levels in Bremen and highest in Turin. ETS exposures were highest overall in the Mediterranean cities, Barcelona and Turin.

KEYWORDS

nicotine, solanesol, cotinine, 3-ethenylpyridine, respirable suspended particles, ETS, workplace, housewives, cigarette equivalents, personal monitoring.

INTRODUCTION

Exposures to respirable suspended particles (RSP) and environmental tobacco smoke (ETS) constituents have been reported by these authors from studies conducted in 8 major European cities: Stockholm, Barcelona, Turin, Paris, Bremen, Lisbon, Basel and Prague (see Phillips et al. 1998 for references). The studies took place between December 1994 and November 1995 and involved subjects using personal monitors over a 24-h period. ETS particles were estimated using ultraviolet absorbing particulate matter (UVPM), fluorescing particulate matter (FPM) and solanesol related particulate matter (SolPM). Vapour phase ETS was assessed by simultaneous measurement of nicotine and 3-ethenylpyridine (3-EP) concentrations. Saliva cotinine analyses were also performed, primarily to confirm the nonsmoking status of the participants.

The studies focused on assessing the exposures of housewives and office workers by obtaining accurate measurement of air concentrations. In this publication, data have been combined from all eight cities to represent the whole of Europe. This larger data set for Europe improves statistical power, particularly for the Cells where recruitment was difficult in some cities. Data normalisation has also been performed to compensate for the different limits of quantification (LOQ) and response factors, thus allowing direct comparison of exposures between both Cell and city.

METHODS

Full details of the personal monitoring procedures and analytical methodologies applied to these studies have been published elsewhere (Phillips et al. 1996). Briefly, the subjects that participated in these studies were recruited by established marketing agencies in each city, who randomly selected subjects matching the study protocol from a representative sample of the population held in their own databases. Subjects were categorised as either "housewives" or "office workers" and were further subdivided into 6 Cells based upon the smoking status of their workplaces and/or homes. A household was classified as "smoking" if a smoker of cigarettes, pipes or cigars was resident and also normally smoked within communal areas of the household. The smoking status of a workplace was defined by the absence/presence of smoking co-workers within 30 metres of the subject's workstation. These definitions were chosen for consistency and to best represent 'real world' situations across the different cities studied. Housewives wore one personal monitor (Ogden et al. 1996) and office workers two monitors (one at work and one at all other times) over a 24-h period. In addition to the above procedures, observational diaries were analysed to identify subjects who observed tobacco products being smoked whilst they were wearing their "home" and, where applicable, "work" monitoring equipment. This allowed Cell categorisations to be further refined by rejection of subjects whose diary observations did not correspond with their initial Cell assignments.

RESULTS AND DISCUSSION

As depicted in Table 1, the highest and most consistent recruitment occurred for Cell 2 (housewives from nonsmoking households) and Cell 5 (workers from nonsmoking households and smoking workplaces). The high recruitment for these Cells was probably a reflection of the European lifestyle for nonsmokers, indicating that subjects working in smoking workplaces and/or living in nonsmoking households were most prevalent. Recruitment of subjects into Cells 1, 3 and 4 proved very difficult in Stockholm due to the lack of smoking households. For Barcelona, it proved impossible to recruit the planned number subjects from nonsmoking workplaces. Subjects living with smokers and working with nonsmokers (Cell 4) proved to be the most difficult to recruit in the majority of the cities studied.

TABLE 1

Subject distribution by Cell across European cities

Cell	Stockholm	Barcelona	Turin	Paris	Bremen	Lisbon	Basel	Prague	Total
1 (SH)	9	43	36	51	21	24	26	54	264
2 (NSH)	35	42	47	44	60	56	60	39	383
3 (SH/SW)	2	25	21	45	18	28	25	64	228
4 (SH/NSW)	10	3	9	13	6	7	14	13	75
5 (NSH/SW)	53	36	51	59	49	61	43	48	400
6 (NSH/NSW)	73	5	24	10	36	21	28	20	217
Total	182	154	188	222	190	197	196	238	1567

The cumulative frequency distributions for all ETS markers, as 24-h time weighted average (TWA) concentrations, are shown in Figure 1. This depicts the expected ranking for particle measurements, at median (50%) levels, of RSP > UVPM > FPM > SolPM. The convergence of UVPM, FPM and SolPM estimates at higher levels has been commented on previously by hese authors and may be a result of ETS particles comprising an increasingly larger percentage of the total RSP as particle concentrations increase.

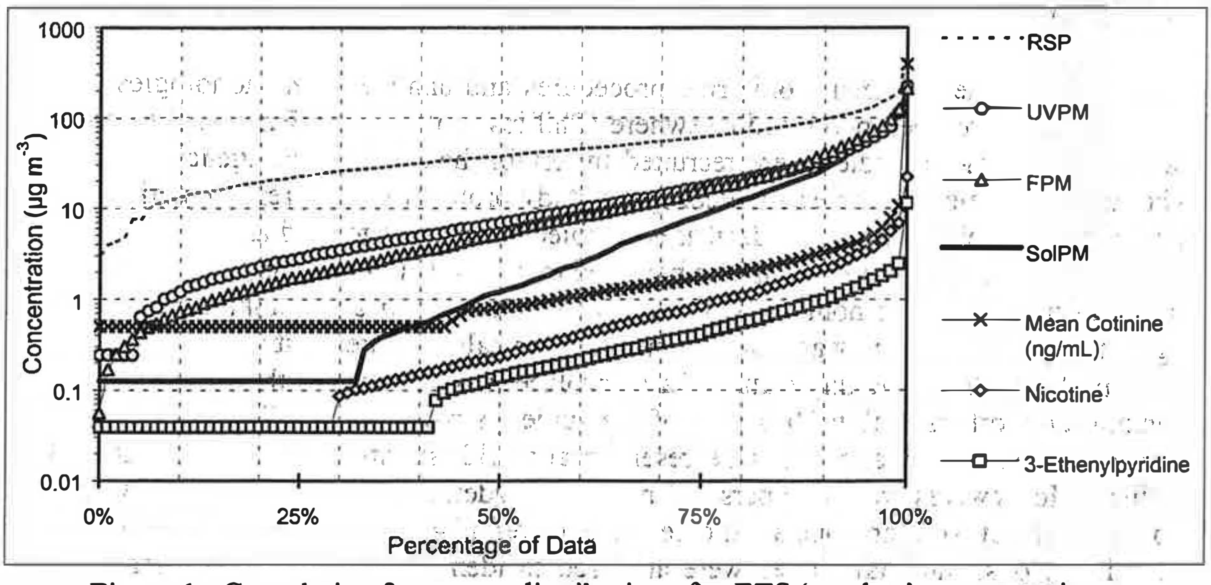

Figure 1: Cumulative frequency distributions for ETS 'marker' concentrations.

Table 2 shows that Cell 3 subjects (those living and working with smokers) experienced the highest levels of RSP and ETS. Median ETS exposure levels for these subjects were between 1.8 (nicotine) and 3.0 (SolPM) times higher than those determined for housewives living with smokers (Cell 1). The largest group of subjects, those living with nonsmokers but working with smokers (Cell 5), had ETS particle exposure levels of approximately half those found for housewives living with smokers (Cell 1). This may indicate that across Europe the home contributes more to ETS exposure than the workplace.

TABLE 2
Median 24-h TWA concentrations for all subjects by Cell

Measurement	Cell 1 (SH)	Cell 2 (NSH)	Cell 3 (SH/SW)	Cell 4 (SH/NSW)	Cell 5 (NSH/SW)	Cell 6 (NSH/NSW)
RSP (µg m^{-3})	52	34	58	38	37	25
UVPM (µg m^{-3})	12	3.4	23	13	7.7	3.5
FPM (µg m^{-3})	11	2.1	21	9.5	6.4	2.0
SolPM (µg m^{-3})	4.1	<LOQ	12	4.3	2.0	<LOQ
Nicotine (µg m^{-3})	0.63	<LOQ	1.2	0.34	0.33	<LOQ
3-EP (µg m^{-3})	0.30	<LOQ	0.61	0.25	0.18	<LOQ
Cotinine (ng mL^{-1})	1.4	<LOQ	1.9	1.5	0.83	<LOQ

The relative variations of median ETS particle levels (SolPM) from the overall European median for Cells 1, 3, 4 and 5 are plotted for each city in Figure 2. If allowance is made for Cells/cities where subject numbers were low (eg Cell 1, Stockholm), it is clear that the highest exposures to ETS particles were recorded in Barcelona and Turin. It was noticeable in these cities that smoking was particularly widespread and recruitment of subjects working in nonsmoking workplaces was very difficult. Bremen, closely followed by Basel, Stockholm and Lisbon recorded the lowest ETS particle exposures. It would appear that the highest ETS exposure levels were encountered in countries bordering the Mediterranean Sea.

Median RSP concentrations by city (Figure 3) show a similar overall pattern to that for ETS particles, with Barcelona appearing to have the highest, and Stockholm the lowest exposure concentrations. Median RSP concentrations were above 50 µg m^{-3}, the proposed European threshold for outdoor air, for a number of Cells in Barcelona, Turin, Paris and Prague. These were the only cities studied with populations in excess of 1 million, indicating that RSP concentrations might, in part, be related to city size. It will be interesting to observe in the future whether the 50 µg m^{-3} threshold can be met in some of the large industrial cities.

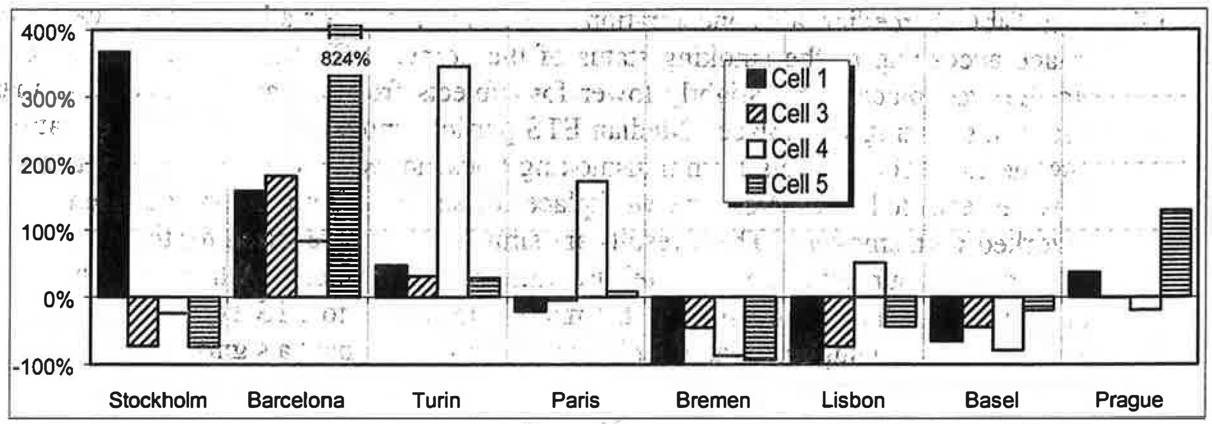

Figure 2: Relative ETS particle concentrations.

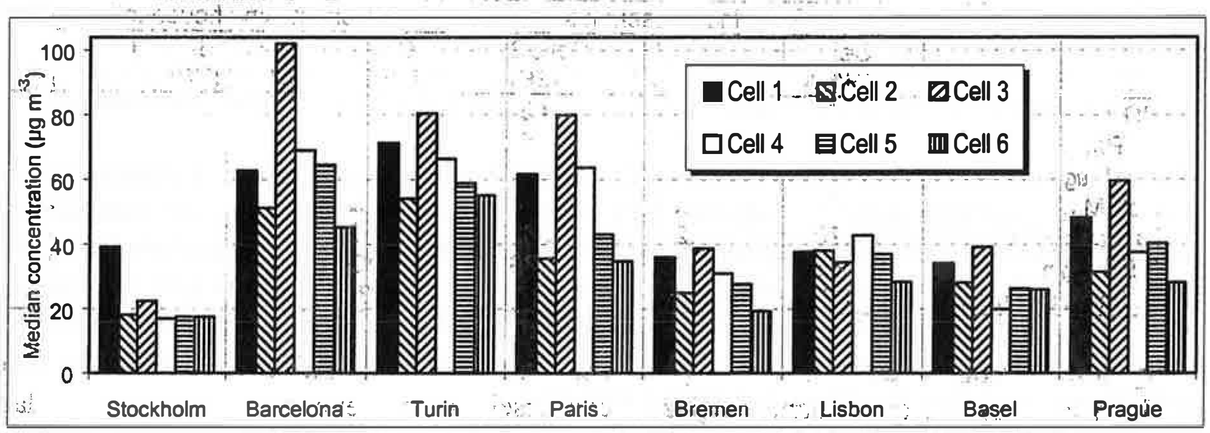

Figure 3: RSP concentrations by city.

The median concentrations calculated from the "work" monitor by individual Cell and combined according to the smoking status of the workplace are summarised in Table 3. Median levels of ETS markers were all between 2.0 and 2.7 times higher in smoking workplaces if subjects came from a smoking compared to a nonsmoking household. A similar observation was made in a recent study by these authors conducted in Australia (Phillips et al. 1998), where exposures away from either the home or workplace were higher for subjects living with smokers. In Australia, there was a suggestion that the higher exposures may have been due to subjects spending their leisure time in the presence of a smoking spouse. The lower exposure levels observed in the workplace for Europeans from nonsmoking households suggests that these subjects either modified their behaviour and avoided smoky atmospheres or they took steps to modify their environment, eg by opening nearby windows.

TABLE 3
Median ETS "marker" concentrations in the workplace

	Smoking workplaces			Nonsmoking workplaces		
Measurement	Cell 3 (SH/SW)	Cell 5 (NSH/SW)	Cells 3+5 (SW)	Cell 4 (SH/NSW)	Cell 6 (NSH/NSW)	Cells 4+6 (NSW)
RSP (μg m^{-3})	63	46	50	28	7.6	19
UVPM (μg m^{-3})	23	11	16	8.9	3.5	4.1
FPM (μg m^{-3})	19	9.1	12	4.1	1.9	2.4
SolPM (μg m^{-3})	8.4	3.1	4.5	<LOQ	<LOQ	<LOQ
Nicotine (μg m^{-3})	1.5	0.56	0.81	<LOQ	<LOQ	<LOQ
3-EP (μg m^{-3})	0.67	0.34	0.44	<LOQ	<LOQ	<LOQ
Cotinine (ng mL^{-1})	1.9	0.83	1.2	1.5	<LOQ	<LOQ

Similarly in Table 4, median air concentrations are summarised for all locations away from the workplace according to the smoking status of the home. RSP and ETS concentrations, away from the workplace, were slightly lower for subjects from a smoking household than those found in a smoking workplace. Median ETS particle and vapour phase concentrations were below the LOQ for subjects from nonsmoking households. It would appear that higher exposures were recorded away from the workplace for subjects from smoking households if they also worked with smokers. These results are similar to those reported for the workplace, and may be due to subjects spending leisure time with smokers. Although a smoking household or living with a smoker may be the major contributor to ETS exposure away from the workplace, these data suggest that other lifestyle factors may play a significant role.

TABLE 4
Median ETS "marker" concentrations away from the workplace

	Smoking households			Nonsmoking households		
Measurement	Cell 3 (SH/SW)	Cell 4 (SH/NSW)	Cells 3+4 (SH)	Cell 5 (NSH/SW)	Cell 6 (NSH/NSW)	Cells 5+6 (NSH)
RSP (μg m^{-3})	52	34	48	28	24	26
UVPM (μg m^{-3})	16	11	15	3.2	2.8	3.1
FPM (μg m^{-3})	14	9.3	13	2.5	1.8	2.3
SolPM (μg m^{-3})	5.9	3.0	5.1	<LOQ	<LOQ	<LOQ
Nicotine (μg m^{-3})	0.70	0.24	0.62	<LOQ	<LOQ	<LOQ
3-EP (μg m^{-3})	0.43	0.16	0.39	<LOQ	<LOQ	<LOQ
Cotinine (ng mL^{-1})	1.9	1.5	1.7	0.83	<LOQ	<LOQ

Diary information revealed some subjects observing smoking taking place in homes and workplaces classified as "nonsmoking" and, conversely, no evidence of smoking taking place in some "smoking" areas. Subjects falling into either category were removed from database resulting in a 32% reduction of total subject numbers. This refinement led to an average 25% increase in median concentrations for all components in the Cells where subjects were exposed to ETS (Cells 1, 3, 4 and 5). It was also noticeable that this increase in median concentrations varied considerably according to analyte, from 4.3% for saliva cotinine to 52% for SolPM. For Cells consisting of subjects not normally exposed to ETS (Cells 2 and 6), Cell refinement resulted in an overall reduction in concentrations. Median concentrations of SolPM, nicotine, 3-EP and cotinine for these Cells were below the LOQ irrespective of whether Cell refinement was undertaken.

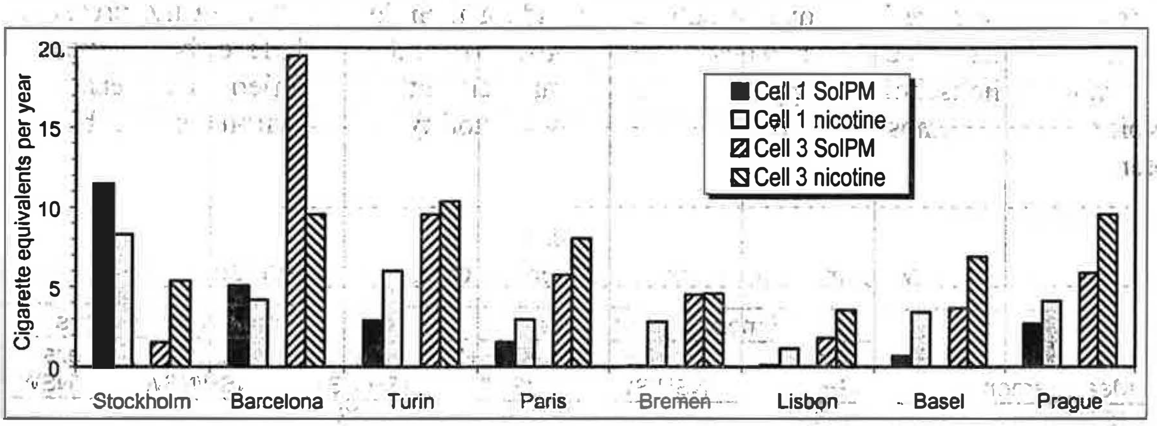

Figure 4: Median estimated annual CEs for Cell 1 and Cell 3 subjects.

In recent studies these authors have used the concept of "potential inhaled quantity" (PIQ), calculated for every individual in the study, to estimate annual exposure to ETS. In brief this model estimates PIQs using the subjects' measured exposure levels together with assumptions regarding time at work/elsewhere and gender dependent breathing rates. The normalisation procedures applied to the European data for this publication allow direct comparison of PIQs across all the cities studied. For purely conceptual comparison of PIQs between different Cells and cities, PIQs have been converted into cigarette equivalents (CE) based upon an estimated overall European mean yield of 12 mg ETS particles (tar) and 1.0 mg nicotine per cigarette. Figure 4 illustrates the median PIQs, based upon both ETS particles (SolPM) and nicotine, for Cell 1 (housewives from smoking households) and Cell 3 (workers from smoking households and workplaces). With the exception of Stockholm, where recruitment for Cell 1 was problematic, Figure 4 depicts that Cell 3 subjects would be exposed annually to more than double the PIQs estimated for Cell 1 subjects.

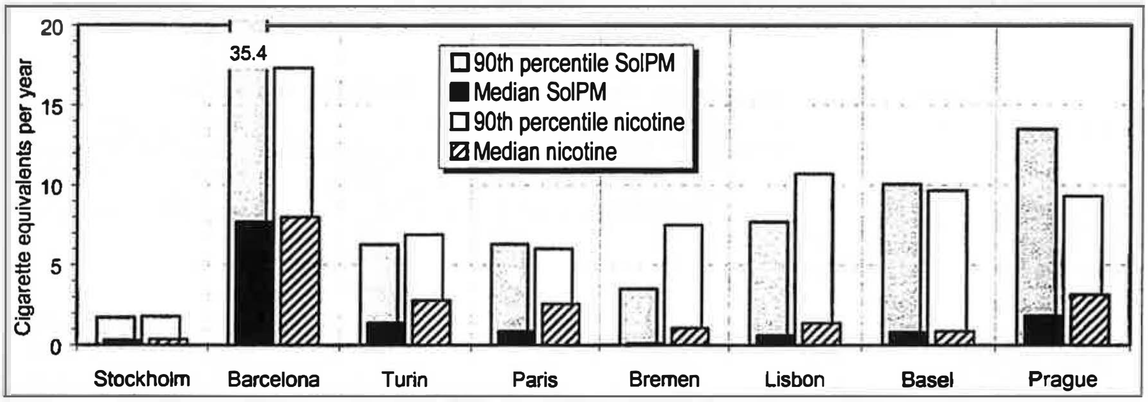

Figure 5: Estimated annual CEs for Cell 5 subjects.

A more representative comparison between the 8 cities may be obtained by examining the PIQs for Cell 5 subjects (workers from nonsmoking homes and smoking workplaces). In the majority of cities studied this was the highest populated Cell, and in all cases there were sufficient numbers to calculate both median ("typical") and 90th percentile ("highly exposed") PIQs. Figure 5 illustrates that Barcelona, again, appears to be the city with the highest exposures to ETS. A considerably different pattern is evident for Stockholm, which would appear to have the lowest estimated PIQs, with only a narrow spread between median and 90th percentile exposures.

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