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Outdoor, indoor and personal distribution of BTEX in pregnant women from two areas in Spain – Preliminary results from the INMA project

Sabrina Llop [1,2,3], Ferran Ballester [2,3,4], Inma Aguilera [3,5,6], Marisa Estarlich [2,3], Rosalia Fernandez-Patier [1], Jordi Sunyer [3,5,6,7], Ana Esplugues [2,3,4], Carmen Iniguez [2,3]

[1] *Instituto de Salud Carlos III, Ctra. Majadahonda a Pozuelo km 2, 28220 Majadahonda, Madrid, Spain*
[2] *Centro Superior de Investigación en Salud Pública (CSISP), Avd. Catalunya 21, 46020, Valencia, Spain*
[3] *CIBER en Epidemiología y Salud Pública, Spain*
[4] *School of Nursing. University of Valencia, C/ Jaume Roig, s/n 46010, Valencia, Spain*
[5] *Municipal Institute of Medical Research, Doctor Aiguader 88, 08003, Barcelona, Spain*
[6] *Centre for Research in Environmental Epidemiology, Doctor Aiguader 88, 08003, Barcelona, Spain*
[7] *Universitat Pompeu Fabra (UPF), Plaça de la Mercè, 10-12, 08002 Barcelona, Spain*

ABSTRACT

Volatile organic compounds (VOCs), which are habitually found in both outdoor and indoor environments, may represent a significant health risk. In this context, pregnancy is a critical period since foetuses are more vulnerable than adults to exposure to toxic compounds. The objective of this study is to present the preliminary results of a series of measurements of outdoor (O), indoor (I) and personal exposure (P) to benzene, toluene, ethylbenzene, o-xylene and m,p-xylene (BTEX) in 107 pregnant women from two areas in Spain, namely Valencia and Sabadell. BTEX samplers were installed for 48 hours both inside and outside of the women's homes, along with personal samplers. In addition, the test subjects filled out a questionnaire about the activities they carried out during the sampling period.

BTEX levels were higher in Valencia than in Sabadell (median O, I and P benzene levels in Valencia were 1.40, 2.40 and 3.05 µg/m^3, respectively, while in Sabadell they were 0.01, 0.32 and 1.02 µg/m^3). In both locations, an O<I<P pattern was observed. In the multivariate analysis an association was found between personal levels of total BTEX and indoor and outdoor levels, environmental tobacco smoke (ETS), and use of deodorant, perfume or hairspray in Valencia whereas in Sabadell an association between personal levels of total BTEX and indoor levels, age and working status was observed.

We found that, in comparison with other studies, our sample population's exposure to these compounds was not excessively high. This is one of the few studies to determine the personal BTEX exposure levels of pregnant women, who comprise a vulnerable population. Still, due to the small sample size of the present study, further studies are needed to be carried out in this field.

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Corresponding Author:
Sabrina Llop
Tel: +34-96-1925941
Fax: +34-96-1925703
E-mail: llop_sab@gva.es

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1. Introduction

Benzene, toluene, ethylbenzene, o–xylene and m,p–xylene (BTEX) are the volatile organic compounds most frequently found in both outdoor and indoor environments (Lee et al., 2002; Hinwood et al., 2007). BTEX are generated mostly by combustion sources such as vehicles, heating systems and tobacco, but they are also found in commonly used items such as glues, paints, cosmetics, solvents and cleaning products (Holgate et al., 1999). Occasionally, indoor levels are significantly higher than those found outdoors. This is especially relevant considering that people usually spend most of their time in indoor environments (80% of the total) (Myers and Maynard, 2005; Sexton et al., 2007). Individual exposure to BTEX levels also depends on certain patterns of behavior such as the use of motor vehicles, do–it–yourself work and the use of air conditioning, all of which increase personal exposure levels (Hinwood et al., 2007). In contrast, these levels tend to be lower for individuals who leave their windows open or regularly ventilate their residence (Sexton et al., 2007). In addition, personal, indoor and outdoor levels of BTEX exhibit seasonal variations, being generally higher in winter than in summer due to the increased use of heating and the consequent decrease in ventilation (Rehwagen et al., 2003; Hoque et al., 2008). In outdoor environments, the presence of heavy traffic, gas stations and petrochemical plants in the vicinity are the main determinants of the levels of these pollutants (WHO, 1999; Jia et al., 2008; Symanski et al., 2009).

BTEX have long been an object of study in occupational epidemiology; thus, the health effects of these compounds among highly exposed populations are well–known, especially those caused by chronic exposure to benzene, which is considered to have more serious consequences than exposure to other compounds of this type. Indeed, there is scientific evidence that benzene exposure is one of the risk factors for leukemia (Johnson et al., 2007) and other types of cancers (Miligi et al., 2006; Smith et al., 2007) and that it has immuno–toxic effects (Veraldi et al., 2006). In this context, one study found a significant amount of liver damage, or hypertransaminasemia, among workers at a petrochemical plant (Perez et al., 2006) while an increase in chromosomal aberrations was noted among workers in petrol refinery plants (Roma–Torres et al., 2006).

Other studies have assessed the health effects of BTEX exposure in non–work oriented indoor environments, such as refurbished or recently painted buildings. For example, the results of the LARS study (The Leipzig Allergy Risk Children's Study) suggest that the refurbishment of flats is associated with the development of acute respiratory inflammations in two–year–old children (Diez et al., 2003).

Because BTEX have an affinity for lipid–rich tissues and are capable of crossing the placenta (Lindbohm, 1995; Bukowski, 2001), a growing number of studies have focused on the effects that high prenatal exposure to BTEX may have on both foetal and infant development. Studies have suggested that prenatal exposure to toluene, for example, can cause delays in neuronal development, facial dismorphology, ear anomalies (Bowen and Hannigan, 2006), spontaneous abortions and decreases in fertility (Bukowski, 2001). By the same token, prenatal exposure to solvents may lead to leukemia in children between 0 and 10 years of age (Infante–Rivard et al., 2005).

Several studies have also examined the possible effects of moderate exposure to BTEX during pregnancy. For instance, in a study carried out within the LISA cohort (Lifestyle–Immune System–Allergy), an association was observed between maternal exposure to several VOCs and the immune status of the newborn, particularly in relation to the profile of cytokine secretion through umbilical cord T cells (Lehmann et al., 2002).

Finally, a considerable number of publications have quantified individual levels of indoor (I), outdoor (O) and personal (P) exposure to VOCs with the aid of passive samplers (Son et al., 2003; Sexton et al., 2004; Serrano–Trespalacios et al., 2004; Fondelli et al., 2008).

Using a common methodology, the INMA project (*Infancia y Medio Ambiente* or Childhood and Environment) focuses on the effects of pre and postnatal exposure to environmental pollutants, as well as that of diet, on both foetal and infant development in several distinct geographical regions of Spain (Ramon et al., 2005; Ribas–Fito et al., 2006).

The aim of the present study is to describe the outdoor, indoor and personal BTEX exposure levels for a subsample of the cohorts of pregnant women belonging to the INMA project in Valencia and Sabadell and to identify their emission sources.

2. Methodology

2.1. Study population

The study population was made up of pregnant women from the INMA Project cohorts of Valencia (n= 855) and Sabadell (n= 657). The study area of Valencia presents a high socio–demographic and environmental variation, comprising part of the city of Valencia (800 000 inhabitants) and 34 towns or cities of medium to small size (i.e., from more than 60 000 to less of 1 000 inhabitants). The area was divided into 4 zones: urban (the area within the city of Valencia), metropolitan (cities within the ring road of the city of Valencia), semi–urban (cities where agricultural and industrial activities are combined with residential areas) and rural (small villages). The area of Sabadell covers exclusively this medium–size city (200 000 inhabitants). The inclusion criteria and recruitment strategy for the INMA cohorts have been described elsewhere (Ribas–Fito et al., 2006).

The subsample consisted of 50 women from Valencia and 57 from Sabadell who were selected during their third trimester of pregnancy to take part in this study. Geographic and population criteria were both taken into account in order to represent all the zones under study.

2.2. Determination of BTEX

Three passive BTEX samplers were installed in each home for 48 hours. The personal sampler was hooked onto the woman's clothes near the breast while the interior sampler was installed in the woman's house in the room in which she claimed to spend most of her time (excluding her bedroom) about 2–2.5 meters from the floor and away from any window and air conditioning unit. A third sampler was placed outside the house, on a window or balcony. This installation procedure was carried out during 4 campaigns in Valencia (November 2003, April 2004, November 2004, and February 2005) and 3 in Sabadell (April 2005, October 2005, and March 2006).

We used radial symmetry passive samplers (Radiello®, Fondazione Salvatore Maugeri, Padua, Italy). These trap BTEX by adsorbing them in a graphitized charcoal cylinder. The analytes are then recovered through thermal desorption. We analyzed the compounds using capillary gas chromatography and flame ionization detection. The BTEX were separated on a 60 m × 0.32 mm × 1 μm J&W capillary column (J&W DB–1) with helium as the carrier gas. The GC oven was maintained at 45 ºC for 2 min, after which the temperature was increased to 150 ºC at a rate of 4 ºC/min for 10 min.

The limits of detection were as follows: 0.01 μg/m^3 for benzene, toluene and o–xylene, 0.02 μg/m^3 for ethylbenzene and 0.03 μg/m^3 for m,p–xylene.

The methodology and the technical and analytical specifications of the air pollution sampling campaigns have all been described elsewhere (Esplugues et al., 2007; Aguilera et al., 2008). Concentrations below the limit of detection (LOD) were replaced by LOD/2.

2.3. Covariates

The women participating in the study filled out two questionnaires during their pregnancies. The first was administered during the 12th week of gestation and concentrated on socio-demographic data and information concerning any previous health problems. In the second questionnaire, given during the 32nd week of pregnancy, the women were asked about the environmental characteristics of their place of residence, including the frequency of vehicles on their street and the distance of their home from a heavily–trafficked street.

The women selected for this particular study also filled out another questionnaire after the 48–hour sampling period. This included questions about the activities they carried out during the time in which the samplers were installed, such as the time spent inside the home; their use of tobacco; their environmental tobacco smoke exposure; the amount of time during which the windows remained open; their use of cosmetics, solvents and cleaning products, and any construction work in their residence up to six months before the sampling. Time spent indoors and the amount of time the windows remained open were categorized according to the average (15 and 2 hours, respectively).

From GIS data, we were able to obtain variables related to the levels of traffic as well as to land use of the surrounding area. We were thus able to determine the % of urban use within a 500 m buffer zone around the home, the % of industrial use within a 500 m buffer zone around the home and the distance of the residence from a street with a traffic density of more than 50 000 cars (D50). This last variable was only applicable to the Valencia cohort.

2.4. Statistical analysis

Outdoor, indoor and personal levels of the 5 pollutants individually, as well as their sum (total BTEX), were analyzed (percentage below LOD, median, percentile 95, range). The various distributions were compared by means of the non–parametric Mann–Whitney test. Spearman correlation coefficients between outdoor, indoor and personal levels of benzene, toluene, ethylbenzene, o–xylene, m,p–xylene, and total BTEX were calcu-lated, along with the Spearman correlations between the outdoor levels of each compound and the variables % of urban use, % of industrial use, distance from a street with heavy vehicle traffic (obtained by questionnaire) and the minimum distance of the home from a street with a traffic density of more than 50 000 vehicles.

Two multiple linear regression models were then constructed; the dependent variables were the personal levels of total BTEX in both the Valencia and Sabadell cohorts. The covariates studied were: age, educational level, work status, tobacco use, environmental tobacco smoke exposure at home, time that the windows remained open, time spent indoors, repairs carried out in the building up to 6 months before the sampling, use of deodorant spray, perfume or hairspray during the 48 hour sampling period and frequency of normal/heavy vehicle traffic near the place of residence. Those variables which gave a level of significance of $p<0.1$ in the likelihood ratio test were maintained in the model.

Because the data distributions did not reach the level of normality, they were log-transformed.

We also attempted to construct multivariate linear regression models for each of the compounds, but due to the high percentage of samples with levels below the LOD, the distributions did not approach to normal.

Statistical analyses were carried out with an SPSS v.15 and Stata v.9 statistical package. Statistical significance was considered to have *p–values* ≤0.05.

3. Results

Table 1 provides descriptive information about the population under study, grouped according to place of residence. The Valencia cohort had a larger proportion of women between the ages of 26–30 (45%) while the Sabadell cohort had more 31–35 year olds (42.6%), which proved to be a statistically significant difference (p=0.021, test chi^2). In both areas, most of the women had finished secondary school and were mainly from a working class background, although a high percentage of women were on maternity leave (33%). The percentage of smokers and women exposed to environmental tobacco at home was greater in Valencia (30.6 and 44%, respectively) than in Sabadell (12.5 and 25%), which was a statistically significant difference ($p<0.05$). The percentage of women who used deodorant spray, perfume or hairspray during the 48–hour sampling period was similar in both cohorts, as was the time spent ventilating the home. There were, however, more women who lived near a street with continuous traffic in Valencia cohort (37.5%) than in that of Sabadell (29.6%), although this difference was not statistically significant.

A high percentage of samples with levels below the limit of detection (LOD) were found (Table 2). Outdoor samples of benzene presented the highest percentages below the LOD both in Valencia and Sabadell (31.3 and 52.6%, respectively), whereas personal levels of toluene had the highest percentage of detection in both cohorts.

In general, outdoor, indoor and personal levels of all the compounds were higher in Valencia than in Sabadell with the exception of the indoor and personal levels of toluene, which were higher in the latter cohort. These differences were statistically significant in the case of benzene (outdoor, indoor, and personal levels), ethylbenzene (outdoor and indoor levels), o–xylene and m,p–xylene (outdoor levels) and total BTEX (outdoor levels).

Table 1. *Sociodemographic and life–style characteristics of the sample groups of the INMA cohorts in Valencia and Sabadell*

		Cohort		
		Valencia	Sabadell	
		n (%)	n (%)	p chi ^{2}
Age [a]	16-25	8 (16.3)	2 (3.7)	0.021
	26-30	22 (44.9)	17 (31.5)	
	31-35	15 (30.6)	23 (42.6)	
	>35	4 (8.2)	12 (22.2)	
Educational level [a]	Primary or no studies	17 (39.5)	17 (29.8)	0.474
	Secondary studies	19 (44.2)	26 (45.6)	
	University studies	7 (16.3)	14 (24.6)	
Working status [a]	Employed	17 (35.4)	24 (42.1)	0.744
	Unemployed	10 (20.8)	11 (19.3)	
	Housewife and other	5 (10.4)	3 (5.3)	
	Work leave	16 (33.3)	19 (33.3)	
Tobacco use [b]	Smoker	15 (30.6)	7 (12.5)	0.023
	Non smoker	34 (69.4)	49 (87.5)	
Environmental tobacco exposure in the home [b]	Yes	22 (44.0)	14 (25.0)	0.039
	No	28 (56.0)	42 (75.0)	
Repairs in the home [c]	Yes	12 (25.0)	9 (15.8)	0.240
	No	36 (75.0)	48 (84.2)	
Use of deodorant spray, perfume or hairspray [b]	Yes	43 (86.0)	48 (85.7)	0.966
	No	7 (14.0)	8 (14.3)	
Windows opened [b]	≤2 hours	26 (52.0)	34 (59.6)	0.426
	>2 hours	24 (48.0)	23 (40.4)	
Time spent indoors [b]	≤15 hours	15 (32.0)	23 (40.3)	0.371
	>15 hours	34 (68.0)	34 (59.7)	
Frequency of vehicle traffic near residence [c]	Hardly ever	4 (8.3)	10 (18.5)	0.551
	Not very often	14 (29.2)	16 (29.6)	
	Very frequent	12 (25.0)	12 (22.2)	
	Continuous	18 (37.5)	16 (29.6)	
Frequency of heavy vehicle traffic near residence [c]	Hardly ever	21 (43.8)	27 (50.0)	0.665
	Not very often	14 (29.2)	14 (25.9)	
	Very frequent	7 (14.6)	5 (9.3)	
	Continuous	6 (12.5)	8 (14.8)	

n: Sample size
[a] During all pregnancy
[b] During the 48 hour sampling period
[c] Up to 6 months before the sampling period

The outdoor, indoor and personal levels of total BTEX (the sum of the five compounds) were also logically higher in Valencia than in the Sabadell cohort. In both Valencia and Sabadell, personal BTEX levels were higher than indoor levels, which were, in turn, higher than the outdoor levels observed (Table 2).

Spearman correlation coefficients between outdoor, indoor and personal levels of the different BTEX are given in Table 3. The correlation coefficients were positive and statistically significant between outdoor, indoor and personal levels of the same pollutants. Outdoor levels of BTEX showed a positive and statistically significant correlation among themselves: outdoor benzene was the pollutant that correlated worst with the rest. The best correlation for outdoor levels was found between ethylbenzene and m,p–xylene while toluene and ethylbenzene exhibited good correlations that were statistically significant with both xylenes.

Indoor levels of the five BTEX compounds also showed significant correlations, with indoor levels of benzene once again presenting the lowest correlation coefficient. The best correlations were found between indoor levels of ethylbenzene and the two xylenes. This same pattern was repeated with regard to the personal levels.

Table 2. *BTEX levels (μg/m^3) in the subgroups of pregnant women from the INMA Project (Valencia and Sabadell cohorts)*

	Valencia						Sabadell						
	n	%<LOD[a]	Median	P95[b]	Min[c]	Max[d]	n	%<LOD[a]	Median	P95[b]	Min[c]	Max[d]	p value[e]
Outdoor Benzene	48	31.30	1.40	4.16	0.01	4.63	50	52.60	0.01	2.53	0.01	12.85	<0.001
Indoor Benzene	50	26.00	2.40	10.61	0.01	21.99	53	40.40	0.32	6.66	0.01	14.29	<0.001
Personal Benzene	48	22.00	3.05	7.83	0.01	9.55	54	33.30	1.02	9.76	0.01	17.15	0.001
Outdoor Toluene	48	4.20	4.82	15.99	0.01	16.81	50	12.00	4.26	33.92	0.01	46.75	0.712
Indoor Toluene	50	0	9.31	49.04	1.63	88.34	54	5.60	10.82	63.94	0.01	75.50	0.772
Personal Toluene	49	0	10.69	58.30	2.19	67.04	54	0	13.01	63.42	0.22	232.17	0.734
Outdoor Ethylbenzene	48	16.70	1.17	4.16	0.01	4.21	50	40.00	0.60	4.67	0.01	9.48	0.047
Indoor Ethylbenzene	50	14.00	3.07	11.55	0.01	15.12	54	31.50	1.27	13.24	0.01	121.89	0.007
Personal Ethylbenzene	46	15.20	2.92	10.97	0.01	11.86	53	34.00	1.42	53.84	0.01	69.54	0.112
Outdoor o-Xylene	48	25.00	0.86	3.44	0.01	5.96	50	52.00	0.01	4.08	0.01	5.72	0.014
Indoor o-Xylene	49	18.40	1.94	9.67	0.01	16.69	54	42.60	0.38	11.87	0.01	41.59	0.193
Personal o-Xylene	46	19.60	2.11	9.34	0.01	11.61	53	37.70	0.53	19.93	0.01	58.66	0.295
Outdoor m-p-Xylene	48	16.70	3.59	9.38	0.02	10.26	50	44.00	2.62	16.33	0.02	24.98	0.087
Indoor m-p-Xylene	50	12.00	7.11	30.41	0.02	37.41	54	19.60	4.04	33.36	0.02	254.16	0.118
Personal m-p-Xylene	48	14.60	7.31	29.90	0.02	31.35	53	35.80	4.00	72.78	0.02	156.45	0.189
Outdoor total BTEX	48		12.20	30.30	0.04	36.30	50		8.54	64.97	0.04	79.22	0.046
Indoor total BTEX	49		20.70	105.40	2.57	161.10	53		12.96	107.53	0.04	475.36	0.092
Personal total BTEX	43		28.90	104.10	2.23	123.70	51		21.06	203.66	0.26	523.95	0.428

[a] percentage of samples below the limit of detection
[b] percentile 95
[c] Minimum
[d] Maximum
[e] Mann-Whitney-test

Table 3. *Spearman correlation coefficients between outdoor, indoor and personal BTEX levels*

	Outdoor benzene	Indoor benzene	Personal benzene	Outdoor toluene	Indoor toluene	Personal toluene	Outdoor ethylbenzene	Indoor ethylbenzene	Personal ethylbenzene	Outdoor o-xylene	Indoor o-xylene	Personal o-xylene	Outdoor m,p-xylene	Indoor m,p-xylene	Personal m,p-xylene
Outdoor Benzene		0.639**	0.696**	0.311**	0.190	0.178	0.482**	0.393**	0.474**	0.512**	0.205*	0.420**	0.253*	0.180	0.338**
Indoor Benzene			0.832**	0.240*	0.455**	0.379**	0.306**	0.463**	0.477**	0.345**	0.317**	0.357**	0.188	0.258**	0.336**
Personal Benzene				0.271**	0.468**	0.453**	0.342**	0.470**	0.588**	0.415**	0.336**	0.494**	0.209*	0.289**	0.430**
Outdoor Toluene					0.548**	0.604**	0.641**	0.317**	0.572**	0.716**	0.501	0.632**	0.654**	0.445**	0.625**
Indoor Toluene						0.760**	0.303**	0.625**	0.684**	0.460**	0.724**	0.672**	0.313**	0.659**	0.639**
Personal Toluene							0.307**	0.483**	0.699**	0.486**	0.599**	0.688**	0.308**	0.511**	0.666**
Outdoor Ethylbenzene								0.338**	0.499**	0.642**	0.469**	0.586**	0.814**	0.542**	0.639**
Indoor Ethylbenzene									0.844**	0.435**	0.763**	0.707**	0.394**	0.812**	0.739**
Personal Ethylbenzene										0.686**	0.797**	0.863**	0.553**	0.803**	0.896**
Outdoor o-xylene											0.629**	0.774**	0.601**	0.467**	0.613**
Indoor o-xylene												0.876**	0.519**	0.812**	0.758**
Personal o-xylene													0.503**	0.686**	0.805**
Outdoor m-p-xylene														0.665**	0.712**
Indoor m-p-xylene															0.891**
Urban Use [b]	-0.115			0.084			-0.011			-0.065			-0.041		
Industrial Use [b]	0.158			0.067			0.055			0.088			0.028		
Street distance [c]	0.048			-0.009			-0.132			0.072			-0.238*		
D50 [a,b]	0.100			-0.373*			-0.372*			-0.305			-0.374		

[a] Minimum distance of the home from a street with a traffic density of more than 50 000 vehicles. Only available for Valencia cohort
[b] Variables obtained by GIS
[c] Distance from a street with heavy vehicle traffic. Variable obtained by questionnaire
[*] p<0.05
[**] p<0.01

The correlation between outdoor levels of the five BTEX and the variable obtained from GIS data concerning the minimum distance of the home from a street with a traffic density of more than 50 000 vehicles (D50) proved to be negative and statistically significant with the exception of benzene. The correlations between outdoor levels of the five compounds and the variables of land use (urban and industrial) were not statistically significant, nor there was a correlation with the variable obtained from the questionnaire with regard to the distance of the home from a street with heavy traffic (street distance), except in the case of m,p–xylene, for which the correlation was negative and significant.

Table 4 shows the beta coefficients and confidence intervals for the two multivariate linear regression models constructed for both cohorts. The dependent variables were the personal levels of total BTEX. The variables that remained in the model of the Valencia cohort for the personal total BTEX levels were outdoor and indoor levels of total BTEX, environmental tobacco exposure at home and the use of deodorant, perfume or hairspray. These variables explained 70% of the variability in the model.

Table 4. *Multivariate linear regression model of the personal levels of total BTEX in the Valencia and Sabadell cohorts*

	Valencia (r^2=0.71)				Sabadell (r^2=0.44)			
	beta	**95% CI**		**p**	**beta**	**95% CI**		**p**
Outdoor BTEX	0.031	0.008	0.053	0.009	NS			
Indoor BTEX	0.015	0.009	0.021	<0.001	0.010	0.004	0.016	0.002
Passive exposure to tobacco smoke in the home (yes)	-0.314	-0.660	0.033	0.075	NS			
Used deodorant, perfume or hairspray	0.802	0.300	1.304	0.003	NS			
Age	NS							
26-30					2.727	0.628	4.825	0.012
31-35					2.532	0.375	4.689	0.023
>35					2.169	0.029	4.310	0.047
Work situation	NS							
Unemployed					-1.293	-2.373	-0.213	0.020
Housewife					-0.490	-2.263	1.282	0.579
On leave					-0.220	-1.222	0.782	0.659

CI: confidence intervals
Reference categories: Non passive exposure to tobacco smoke in the home, no use of deodorant, perfume or hairspray, 16-25 and employed
NS: not significant

The variables that remained in the multivariate model of the Sabadell cohort were indoor levels of total BTEX, age and work situation. These variables explained 44% of the variability in the model.

Figure 1 shows the individual proportion of each of the 5 compounds contributing to the personal levels of total BTEX in both cohorts. Toluene was the major compound found in total personal BTEX, comprising about 50% of the total in both cohorts, followed by ethylbenzene (24.5 and 27.1% in the Valencia and Sabadell cohorts, respectively). In the Valencia cohort, benzene made up 8.9% of the total personal BTEX levels whereas in the Sabadell cohort it accounted for only 3.7% of the total.

The levels of benzene, toluene, ethylbenzene, o–xylene and m,p–xylene observed in other studies are presented in Table 5. In comparison, the outdoor, indoor and personal BTEX levels found in our study were lower than those found in Korea (Son et al., 2003) or Greece (Alexopoulos et al., 2006). They were also lower than those found in Minnesota (Adgate et al., 2004), with the exception of the xylenes. Nevertheless, the levels were similar to those found in Minneapolis (Sexton et al., 2004). In their study, Jia et al. (2008) calculated the sum of the personal levels of all five BTEX compounds; the levels they found were higher than those measured in the present study. In the LISA birth cohort, indoor BTEX levels were measured in children's bedrooms in order to analyze the association between maternal exposure to BTEX and immune status at birth, specifically with the cytokine secretion profile of cord–blood T cells (Lehman et al., 2002). While indoor levels in Valencia were higher than those found in the LISA cohort (except for that of toluene), the indoor levels measured in Sabadell were lower.

4. Discussion

Through this study, an approximation of the levels of individual exposure to BTEX in pregnant women from two areas in Spain has been obtained. Benzene, toluene, ethylbenzene, o–xylene and m,p–xylene levels are generally lower than those found in other, previously published studies, particularly for women from the Sabadell cohort. This could be due to the fact that women in their last trimester of pregnancy tend to have healthier habits or less mobility than the general population.

Directive 2008/50/CE of the European Parliament and Council has set a target annual limit for outdoor benzene levels of 5 μg/m^3, which must be reached by the year 2010 (European Parliament, 2008). Only one individual in the Sabadell cohort exceeded this limit. The WHO, for its part, has set the limit over which human health is considered to be at risk at 1 μg/m^3 (WHO, 1999). In the Valencia cohort, 66% of the women were exposed to benzene levels above 1 μg/m^3 while in Sabadell the figure was 49%. It must be taken into account, however, that our samples refer to a 48–hour period, which is not directly comparable to the annual mean level referred to by the EU and the World Health Organization.

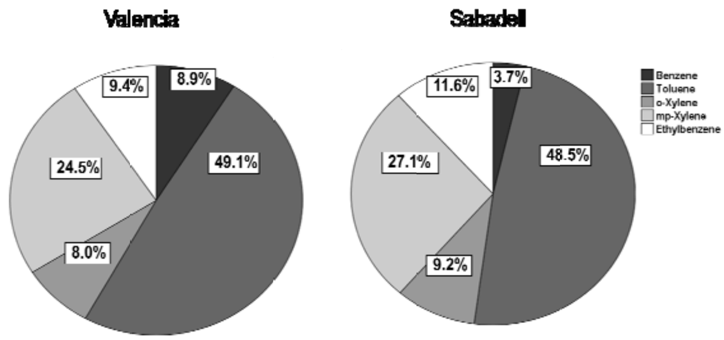

Figure 1. *Individual proportion of each of the 5 compounds contributing to the personal levels of total BTEX in both cohorts.*

Table 5. *Levels of outdoor, indoor and personal BTEX reported in the literature*

	Country	Study population (n)	Sampling duration	Outdoor ($\mu g/m^3$)	Indoor ($\mu g/m^3$)	Personal ($\mu g/m^3$)
Lehman et al. (2002)	Leipzig (Germany)	Newborns (85)	4 weeks		(Median, children's bedroom)	
Benzene					1.5	
Toluene					18.3	
Ethylbenzene					1.9	
o-Xylene					1.6	
mp-Xylene					7.6	
Son et al. (2003)	Asia (Korea)	General population (30)	24 hours	(Median)	(Median)	(Median)
Benzene				24.51	23.83	24.98
Toluene				11.16	13.90	16.84
Ethylbenzene				0.89	0.83	0.99
o-Xylene				6.66	8.28	8.98
mp-Xylene				6.66	8.48	7.98
Adgate et al. (2004)	Minnesota (USA)	Children (284)	6 days	(Median)	(Median)	(Median)
Benzene				3.1	3.1	3.9
Toluene				8.8	18.2	22.0
o-Xylene				1.5	2.0	2.3
mp-Xylene				3.4	4.1	4.9
Sexton et al. (2004)	Minneapolis (USA)	General population (132)	2 days	(Median)	(Median)	(Median)
Benzene				1.3	1.9	3.2
Toluene				3.0	12.3	17.1
o-Xylene				0.7	1.6	2.3
mp-Xylene				2.0	4.8	7.4
Alexopoulos et al. (2006)	Athens (Greece)	50 non-smokers adults	108 hours	(Median)	(Median)	(Median)
Toluene				63.3	38.9	63.0
Xylene				72.3	36.2	67.4
Fondelli et al. (2008)	Florence (Italy)	67 non-smokers adults	4 days	(Median)	(Median)	(Median)
Benzene (S)				5.5	3.1	2.2
Benzene (W)				6.1	5.7	6.9
Jia et al. (2008)	USA	669 General population	2-3 days			(Median)
Benzene						2.8
Toluene						17.4
Ethylbenzene						2.6
o-Xylene						2.4
mp-Xylene						6.5
BTEX						33.2

The outdoor<indoor<personal level pattern found in our research is consistent with that observed in previous studies (Sexton et al., 2004; Adgate et al., 2004), indicating that the main sources of BTEX are found inside the home. This finding is of particular interest given that the general population spends most of its time indoors and that pregnant women may spend even more time there, at least during the third trimester of pregnancy (Nethery et al., 2009). Moreover, positive and statistically significant correlations were found among the five BTEX compounds for outdoor, indoor and personal levels, indicating that they share the same emission sources.

The further the distance from a street with heavy traffic, (>50 000 vehicles), the lower the outdoor levels of toluene, ethylbenzene and the two xylenes. Other studies have indicated that there is an association between BTEX levels and amount of traffic in the vicinity of the residence. One example is the RIOPA study (Kwon et al., 2006), in which the distance from streets with greater density of traffic in New Jersey (USA) was a predictor for BTEX levels. Another example is a study carried out in Naples (Italy), in which BTEX levels were correlated to vehicular sources (Iovino et al., 2009).

In our study, the personal total BTEX levels for the five compounds to which the women participating in the cohort were exposed exhibited a different pattern depending on the city. In Valencia, these levels depended on both the outdoor and indoor levels, but above all on the former. Other important factors were the passive exposure to tobacco in the home during the 48 hours in which the sampling took place and the use of deodorant, perfume or hairspray. In their study carried out in Korea, Son et al. (2003) also found a significant association between indoor benzene levels and the frequency of the use of cosmetics or insect repellent. In the UK, Saborit et al. (2009) measured personal BTEX levels of 100 non–smoking adults and found a significant relationship between these levels and passive smoking. Surprisingly, in our study the variable encompassing passive exposure to tobacco smoke in the home gave a beta coefficient opposite from that expected. That is, women who were passively exposed to tobacco smoke in the home were exposed to lower personal BTEX levels than those women who were not. This finding may be due to the fact that the small sample size resulting from segmenting the study area leads to inconsistent correlations.

The variables that remained in the multivariate analysis model of the personal levels of total BTEX in Sabadell were the indoor levels of total BTEX, the woman's age, and her work situation. The results obtained are in good agreement with those observed by Sexton et al. (2007), who found that the most important contributing factor to the personal levels to which the women were exposed were the indoor levels.

The relationship between personal BTEX levels and sociodemographic variables has been described in previous studies. Symanski et al. (2009), described the personal levels of benzene, toluene, ethylbenzene and the xylenes found in a sample representative of the general population of the US as part of the NHANES survey (1999–2000). The authors analyzed the association between these levels and certain demographic, residential and life–style characteristics. They discovered a relationship between BTEX levels and the sex and ethnicity of the participants, but not with age. Son et al. (2003), on the other hand, found an association between both indoor and personal BTEX levels and low incoming housing.

The differences found in the multivariate analyses are indicative of the differences in the two study areas. The Valencia study area is larger with more motorways with high traffic density, but with a great amount of variability with regard to outdoor pollution levels (Iniguez et al., 2009). In addition to being indicative of emission sources caused by vehicles and traffic, the presence of motorways is also an indicator for pollution sources due to population density and the agglomeration of people. In Sabadell, the study area is confined to the city itself, which is quite small in area. For this reason, there is less variability in outdoor pollution levels (Aguilera et al., 2008).

One disadvantage of the present study is its small sample size, which limited our ability to perform stratified analyses with sufficient statistical power (to observe the comparative influence of tobacco consumption, for instance). Another limitation is the high percentage of samples with levels below the LOD. This may be due to the fact that 48 hours is not sufficient for the detectable amount of pollutants to be collected by the samplers in environments with moderate or low levels. The same type of Radiello sampler was used in another study during a longer period and showed more consistent results (Fondelli et al., 2008), although good results have also been obtained with shorter sampling periods (Son et al., 2003; Perez Ballesta et al., 2006; Kume et al., 2008). Another explanation for the high number of values below the LOD could be the presence of bias, especially if our study population subjects did not lead their normal lives during the 48–hour sampling period because the samplers attached to their clothes hampered their normal activity, although this would only be valid for personal samplers.

These two limitations – the sample size and the high percentage of samples with values below the LOD – made it impossible for us to analyze the determinant factors of these compounds individually.

Despite these limitations, this is the first study carried out in Spain where outdoor, indoor and personal levels of BTEX are determined among a vulnerable population group such as pregnant women. Although their exposure to these compounds is not very high in comparison with that observed in other studies, still more information is needed on the effects that low prenatal exposure to these compounds could have on foetal development.

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