

PERSONAL EXPOSURE OF PARISIAN OFFICE WORKERS TO BENZENE

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ABSTRACT

In France, only few data on personal exposure to benzene are available and these measurements were performed prior to the new regulation on benzene concentration in gasoline, in force since January 2000. The objectives of this study were to assess the personal exposures of a randomized sample of 100 non-smoking Paris office workers to benzene and then to identify and quantify their micro-environmental determinants. 24-hour samplings took place between June 2000 and June 2001. Each participant was equipped with two active devices in order to assess total personal exposure over 24 hours and exposure during transportation. In-house and in-office fixed measurements were performed only when the subject was present in these micro-environments. Benzene was collected on a sorbent tube, thermally desorbed and analyzed by gas chromatography and flame ionization detection. Measurements were supplemented by questionnaires related to residential and occupational environments, mean of transportation used and time activity patterns during the 24-hour sampling period. On average, benzene personal exposure was $4.6 \pm 5.4 \mu\text{g.m}^{-3}$ (percentiles 50, 75 and 90 were respectively equal to 3.2, 5.1 and $7.4 \mu\text{g.m}^{-3}$). Highest levels were observed during transportation (mean $8.6 \mu\text{g.m}^{-3}$) while in-house and in-office concentrations were respectively equal to 4.1 and $3.5 \mu\text{g.m}^{-3}$. Linear multiple regressions show that in-house, in-office and in-transit exposures explain 95% of variations in personal exposure to benzene. Finally, in this study, direct and indirect methods to assess personal exposure to benzene are in good agreement; only few measurements show some noticeable differences in relation to atypical situations.

INTRODUCTION

Accurate estimation of exposure to air pollution is important for evaluation of health risks. Due to economic and practical reasons, personal exposure measurements are rare and assessment of exposure is often based on fixed site measurements provided by the local air quality monitoring network.

During the last decade, personal exposure to benzene of urban adults without specific occupational exposure, such as office workers, was determined in the North and Central America [1, 2] and in European countries as Life Macbeth programme [3] or Expolis study [4]. The number of these studies is still relatively limited in France [5, 6]. Few studies have been carried out on randomized populations.

Personal exposure studies aim to assess the distribution of individual exposure, and to identify and quantify the contribution of different factors. This is why outdoor and indoor levels are often determined at the same time as personal measurements.

The objectives of this study were (i) to assess the distribution of personal exposure to benzene in a specific population of non-smoking office workers living in the Paris metropolitan area, (ii) to evaluate the relative contribution of different micro-environments to personal exposure by performing measurements in houses, in workplaces and during transportation.

MATERIALS AND METHODS

Study design

Personal and micro-environmental benzene measurements were performed simultaneously with active samplers during a period of 24 hours. They were carried out in the house, workplace and during transportation (walking, car, subway, train, bus), the three micro-environments most frequented by city-dwellers. Measurements took place from June 2000 to June 2001, and were supplemented by three questionnaires related to micro-environmental characteristics and time activity patterns. Indoor measurements were only taken when the subject was present at home or at work.

Subject selection

The personal exposure study was conducted on Paris office workers recruited in a Paris municipality service in charge of social action, childhood and health (DASES). 500 subjects were selected by randomization from the 2100 DASES office workers living and working in the Ile-de-France region. After excluding 128 smokers (smoking status interfering with personal measurements), 372 workers were invited to participate among them 100 accepted. The order of passage of participants was also determined by randomization.

Measurements

Measurements of personal exposure were performed during working days using a pump sampling air at a flow rate of 12 mL.min⁻¹ (SKC pocket), connected to an external supplementary battery. Another similar sampler was used to measure concentrations during transportation at a flow rate of 50 mL.min⁻¹. During the day the two pumps were carried in a small rucksack. The same day, in-house and in-office measurements were taken when the subject was present; he just had to turn the pump on (SKC 224-52, 25 mL.min⁻¹) as soon as he arrived and off as soon as he left. During the night personal and indoor samplers were placed on a table in the living room.

Benzene was captured on chromosorb 106 tubes (60/80 mesh, 300 mg), thermally desorbed (ATD 400, Perkin-Elmer) and analyzed by capillary gas chromatography and flame ionization detection (Hewlett-Packard, 5890).

Exposure conditions survey

Three questionnaires were used to describe for each subject (i) the general characteristics of residential and occupational environment (topographic situation, local traffic, attached garage,...), (ii) time activity diary with 15 minutes resolution, and (iii) unusual exposure during measurements (exposure to environmental tobacco smoke – ETS-, cooking activities...).

Quality control

Each pump was equipped with a device which allows systematic duplicate sampling. Flow rates were calibrated at the beginning and at the end of each sampling. Sample is validated if the difference between the two flow rates stays lower than 10%.

165 control tubes were analyzed and the results were used to calculate the limit of detection (LOD) defined by the blank signal plus three standard deviations of the blank. The LOD is equal to 5 ng in the sample that is to say about 0.9 µg.m⁻³ for the smallest volume air sampler corresponding to transportation time.

Statistical analysis

Statistical analysis was performed with Statgraphics (Uniware) and BMDP software (University of California). Results are expressed in terms of concentration (C) and time weighted average (TWA). For each microenvironment, TWA is the product of the concentration, measured or estimated, multiplied by time fraction spent in each micro-environment. The distributions of concentrations and TWA were tested for normality (Shapiro-Wilk test). Results were summarized by mean \pm standard deviation (SD), median, minimum and maximum. Linear multiple regressions were used to identify and quantify determinants of personal exposure.

RESULTS

Population and time activity patterns

The study sample consisted of 71 women and 29 men. The average age was 45.5 ± 8.5 years (min 28; max 61). In the initial randomized population (n=500) the percentage of women was 75%. A minority of subjects lived in Paris (34%) with 72% dwelling in an apartment, the remainder living in a house. The mean surface of the dwelling is $80 (\pm 36) \text{ m}^2$. Exposure to tobacco smoke was not frequent (17%) at home. Around 64% of volunteers had a room directly exposed to traffic ; 45% lived near busy streets. 18 dwellings had an attached garage. 35% of participants owned an individual gas heating system and 64 % used a gas or mixed cooker.

87% of the workplaces were located in Paris, the other in the suburbs. Participants worked in an office with a surface area of $26.7 (\pm 33.6) \text{ m}^2$ on average. 63% of participants declared working in an office that was either not or little exposed to traffic; 9% were exposed to ETS.

During the 24-hour personal measurements, volunteers spent on average 21.8 hours indoors (house: 13.4 hours, office: 7.5 hours, other: 0.9 hour), <0.1 hour outdoors and 2.2 hours in transport. The most frequently means of transport were walking (29%) and subway (24%) followed by car (19%), train (18%) and bus (10%).

Distribution of personal exposure and micro-environmental concentrations

Most of time, personal exposure, micro-environmental concentrations and their TWA were not normally distributed. It was also the case after log-transformation, so log-data were not considered.

	Personal exposure	Indoor home	Indoor office	In-transit
n	80	88	93	90
m \pm SD	4.6 ± 5.4	4.1 ± 6.0	3.5 ± 3.2	8.6 ± 16
Median	3.2	2.6	3.0	5.7
[Min-Max]	[<1-40]	[0.5-49]	[0.5-26]	[<1-155]

Table 1: Personal and micro-environmental concentrations ($\mu\text{g.m}^{-3}$)

According to the data validation criteria, some samplers were invalidated. A summary of the results is given in table 1 .Personal exposure to benzene is higher than indoor concentrations but significantly lower than in-transit concentrations. Median and mean values at home and workplace are similar with however larger standard deviation at home. Due to the use of

various means of transport, large variations in concentrations are observed with some high levels such as $155 \mu\text{g.m}^{-3}$ occurring in an old car.

In order to compare personal measurements and cumulated TWA, only 66 participants had been selected according to two criteria : all data (personal and micro-environmental measurements) had to be available and the difference between duplicates had to be lower than 20%. Exposure assessed by personal measurements ($4.9 \mu\text{g.m}^{-3}$) is greater than the indirect estimation from time activity data and micro-environmental concentrations, the sum of the TWA being $4.2 \mu\text{g.m}^{-3}$.

It appears that housing TWA_H is the major contributor to the cumulated personal exposure, whereas the influence of working TWA_W and in-transit TWA_T is lower. Relative contribution of the three environments to benzene exposure is shown on figure 1.

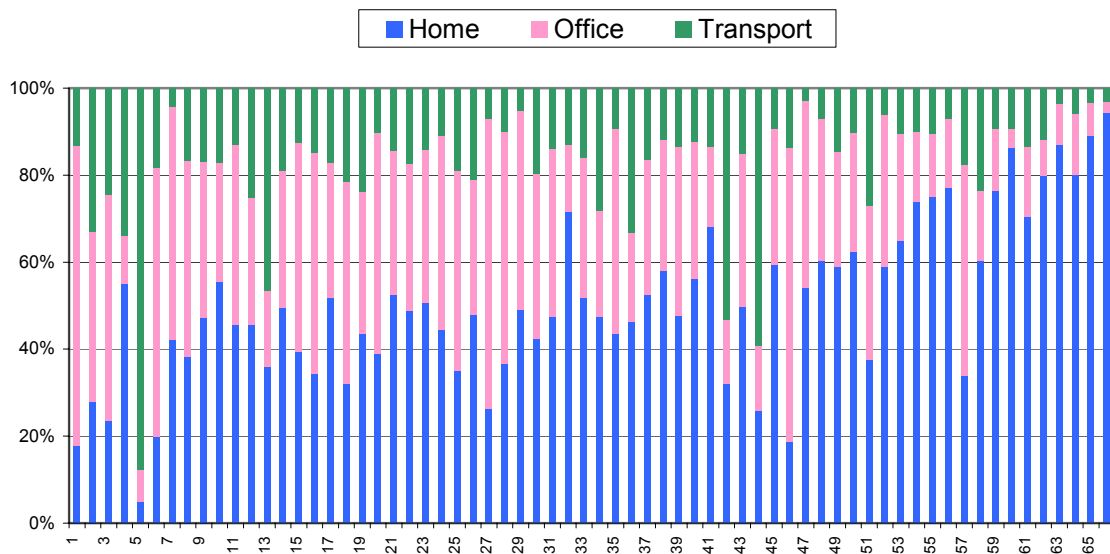


Figure 1: Relative contribution of the three major environments to benzene exposure for each participant

Determinants of personal exposure

The stepwise regression model shows that TWA_H , TWA_W , TWA_T and cigarettes smoked in indoor places different from houses and offices (ETS) explain 96% of variations in personal exposure to benzene (Table 2). TWA_H is the first contributor (70%) followed by TWA_T , TWA_W and ETS in other indoors.

(a)	Reg. Coeff.	Std. err.	p	r^2 (b)
TWA_H	1.31	0.04	<0.001	0.70
TWA_T	1.79	0.10	<0.001	0.92
TWA_W	1.04	0.15	<0.001	0.95
Cigarettes smoked in other indoors	0.11	0.05	0.05	0.96

(a) TWA_H time weighted average in house TWA_W time weighted average in workplace TWA_T time weighted average in transport (b) r^2 from the stepwise regression model

Table 2: Determinants of benzene personal exposure: multiple linear regression (n = 66)

Home exposure is the main contributor to personal daily exposure except in some particular cases where time spent inside car is predominant. Direct and indirect approaches for exposure assessment are in good agreement even if statistically the results are significantly different ($p > 0.05$, Wilcoxon). The difference is lower than 20% for 75% of the subjects ; generally indirect method gives lower values.

DISCUSSION

Methodological considerations

This study was carried out on a randomized sample with 71% being women, which does not differ from the DASES population composed of more than 80% women. The sex-ratio in this administration is consistent with French statistics that indicates a high proportion of women in health social services (77.2%). The sample studied can thus be regarded as representative of this field of activity.

Our subjects spent a long time indoors (21.8 hours). Time spent outdoors was very low during working days. Participation rate (27%) was moderate but measurements were performed in satisfactory conditions in spite of constraints related to the sampling device.

Simultaneously with personal measurements, indoor samplings were only recorded when subjects stayed in dwellings or occupational premises. This strategy accurately measured the indoor benzene concentrations to which subjects were exposed.

Some factors can affect the accuracy of these results: one bias is due to the fact that, at work, the indoor sampler was not stopped during lunch time or when the volunteer temporally left his office. Major differences occur in some atypical situations with high values in one micro-environment. For example, one in-office concentration was $26 \mu\text{g.m}^{-3}$ but, according to diary of this worker, it appeared that he only spent 130 minutes in his own office. This non representativeness of the TWA_w can explain why the calculated exposure ($10.1 \mu\text{g.m}^{-3}$) is higher than the measured personal exposure ($8.6 \mu\text{g.m}^{-3}$).

Comparisons with other literature

Concerning benzene personal exposure (PE), our results are consistent with those provided by some other studies: $3.4 \mu\text{g.m}^{-3}$ in Helsinki in the framework of the Expolis study in 1996-97 [4], $3.5 \mu\text{g.m}^{-3}$ (geometric mean) in case of 63 police office workers in Rome during the first six months of 1999 [7]. In the opposite, various other studies gave higher values: in Rouen, at first in 1997-98 [5] during six campaigns including 20 indoor workers (PE from 7.9 to $15.3 \mu\text{g.m}^{-3}$), then in 1999 for 22 adults recruited on a voluntary basis (mean PE = $14.4 \pm 7.7 \mu\text{g.m}^{-3}$) [6]. High personal values were also measured in the United Kingdom in a panel of 50 office workers: day and night exposure were equal respectively to 12.2 and $7.7 \mu\text{g.m}^{-3}$ [8]. Similar high values were also found in Germany (mean PE = $13.5 \mu\text{g.m}^{-3}$) for 113 adults selected at random in the framework of the second German Environmental Survey 1990-92 [9], in Milano (100 office workers, mean PE = $21.2 \mu\text{g.m}^{-3}$) [10] or in Mexico City where 90 volunteers from 30 families were followed over a 1-year period (mean PE = $14 \mu\text{g.m}^{-3}$) [2].

The difference with our results can be partly explained by the decrease of the urban levels since January 2000, due to regulation on benzene concentration in gasoline. Thus, on Parisian urban background monitoring sites, mean benzene concentration was $5.5 \mu\text{g.m}^{-3}$ in 1997 and $1.9 \mu\text{g.m}^{-3}$ in 2000. During the same period, concentrations on a site very close to traffic decreased from 29 to $12 \mu\text{g.m}^{-3}$.

As observed in other works [11], benzene concentrations in houses with attached or integral garage tend to be higher than those without such garage, but the difference is not significant, probably due to the weak number of such cases in our study.

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