

Nicotine and surface of particulates as indicators of exposure to environmental tobacco smoke in public places in Austria

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Abstract

As part of a Europe-wide project the amount of exposure to environmental tobacco smoke (ETS) in public places like schools, restaurants, and public transport facilities was investigated. Three methods were applied: nicotine passive samplers (with a filter treated with sodium bisulphate), the same filters with an active sampling device, and the measurement of fine particles' active surface by unipolar diffusion charging. Settings were selected where either high or low ETS concentrations were expected and where non-smokers would have to stay or at least to pass by. Highest ETS concentrations were found in discos (mean nicotine concentration 154.4 maximum 487.1 $\mu\text{g}/\text{m}^3$) and intermediate concentrations in restaurants with no significant difference between smoking ($21.3 \pm 6.1 \mu\text{g}/\text{m}^3$) and non-smoking areas ($23.3 \pm 15.9 \mu\text{g}/\text{m}^3$) but on average higher values in restaurants with no separation between smoking and non-smoking areas ($38.0 \pm 60.6 \mu\text{g}/\text{m}^3$). Concentrations usually below $10 \mu\text{g}/\text{m}^3$ were found in transport facilities ($8.9 \pm 8.0 \mu\text{g}/\text{m}^3$, maximum 20.6 in the restaurant section of a railway station's waiting room) and in schools ($3.0 \pm 4.6 \mu\text{g}/\text{m}^3$). In hospitals "problem spots" were sought and so concentrations from very low to as high as $45.1 \mu\text{g}/\text{m}^3$ next to a smoking area with no physical barrier or separation and $47.7 \mu\text{g}/\text{m}^3$ inside a smoking room could be documented ($21.4 \pm 39.3 \mu\text{g}/\text{m}^3$). The fine particle's surface correlated well with the nicotine concentration ($r=0.8$; $p < 0.001$). Only in one instance (in a pizza restaurant on a busy road with heavy duty diesel traffic and the sampling spot next to the pizza stove) high concentration of fine particles was detected without high nicotine. Tobacco smoke is a key source of indoor fine particles. Health policy must intervene to change the situation found at present in many public places in Austria.

Key words: Passive smoking – ETS – nicotine – particulate matter – public places

Introduction

ETS or "passive smoking" poses a real threat to health. A lot of studies have focused either on the health impact of ETS in private homes or at the work place (Rolle-Kampczyk et al., 2002; Schuster et al.,

2002; Fichtenberg and Glantz, 2002; Radon et al., 2002; Manning et al., 2002). Little is known about the impact of ETS exposure in public places. But especially concerning the pedagogical value of role models (e.g. teachers in schools, doctors in hospitals) promoting smoke free zones in public places is a

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must. But apart from that consideration ETS in some public places could even have immediate impacts on health. As part of a Europe-wide project the amount of exposure to ETS in public places like schools, restaurants, and public transport facilities was investigated. This was done to test the feasibility of several measurement methods and to get a first impression on the possible range of involuntary ETS exposure. Within the scope of the project it was not possible to collect a representative sample of public places but rather to analyse contrast samples with possibly extreme exposure situations. To elucidate the range of concentrations this survey attempted to include pure non-smoking locations and even a few non-smokers' homes on the one hand and places where high exposures were expected like discos, bars or smoking rooms (e.g. in hospitals or schools) and adjacent non-smoking rooms and corridors on the other hand.

Materials and methods

Three methods were applied to assess ETS exposure: nicotine was measured in the vapour phase by passive sampling (Hammond and Leaderer, 1987) and with an active sampling device (personal air pump), and the fine particles' active surface was measured by unipolar diffusion charging (Dahmann et al., 2002).

In short, passive sampling of nicotine utilises a filter treated with sodium bisulfate as a diffusion monitor. Before and after sampling filters were kept at room temperature in tight boxes, used also for air transport to the laboratory of the Public Health Agency in Barcelona. There the nicotine and bisulfate were desorbed in water (pH adjusted by 10 N NaOH) and concentrated into heptane by liquid/liquid extraction. An aliquot of the heptane solution then was analysed by GC/MS. The limit of detection was of 0.01 µg/ml. The quantity of nicotine collected was divided by the flow rate (24 ml/min for passive sampling) and the time the filter had been exposed, obtaining the nicotine concentration (µg/m³).

For the active sampling the same sort of filters were used. Air was drawn through the filter by a sampling pump calibrated and operating at a volume flow between 2 and 2.4 l/min. To enable easy computing a flow of 2.4 l/min was chosen for the first series of samples, but then the flow was reduced to 2 l/min because of the noise of the sampling pump. Flow rate was documented and accounted for in the final calculations.

At least every 10th filter was a blank treated the same way but not exposed to (contaminated) air. Thus in total 15 blanks were drawn. Two filters were exposed by active sampling (2 hours, 2.2 l/min respectively 50 minutes, 2 l/min) to the clean air of a non-smoker household. Nicotine content on these 17 filters was at or below the detection limit of 10 ng.

The LQ 1-DC[®] (LQ) measures the active surface of suspended particles by unipolar diffusion charging: ions are produced in the carrier gas by a corona discharge. The ions attach to the surface of the particles which are collected in an electrically insulated particle filter. The electric charge is converted to a voltage signal. The number of attached ions over a wide size range of particles depends linearly on the active surface (or "Fuchs' surface") which can be interpreted as that fraction of the geometrical surface of the particles which is directly accessible from outside (Burtscher et al., 1982; Keller and Siegmann, 2001).

Settings were selected where either high or low ETS concentrations were expected and where non-smokers would have to stay or at least to pass by. In total 106 locations were analysed by at least one of the three methods. The duration of passive sampling depended on the expected range of nicotine concentration. The higher the anticipated concentration the shorter the sampling time. So in dancing halls and bars passive personal sampling (with the filter cartridge attached to a female and a male non-smoking volunteering student) lasted for several hours only while in schools and hospitals filters (hung on overhead lights, etc.) were placed in the room and exposed for a week or from Monday till Friday. In locations where non-smokers would only stay for a short time period and concentration of nicotine was supposed to be too low for passive sampling in a short time interval, active sampling was chosen as the appropriate method. This was the case in restaurants but also in some instances in hospitals and in lecture rooms and corridors in universities. It was planned to combine the measurement of active surface of particles with the active sampling of nicotine. Because of limited availability, however, the particle sensor (LQ) could not be operated on all occasions. So in the end only 21 paired measurements (active sampling of nicotine and particle surface) were obtained.

Results

Both active and passive sampling proved to be feasible and reliable. One anticipated problem of passive sampling for a longer period without constant control against manipulation with the filter did not turn out to be relevant. Implausible values have been re-checked partly by passive sampling again, partly by short-term active sampling, and have been reproducible in all but one instance.

Active sampling showed a tendency to higher concentrations when similar settings were compared (Figure 1). This was expected because active sampling only took place when people stayed in the investigated room simultaneously with smoking people. In contrast to that passive sampling (if not done by personal monitoring in discos) lasted over

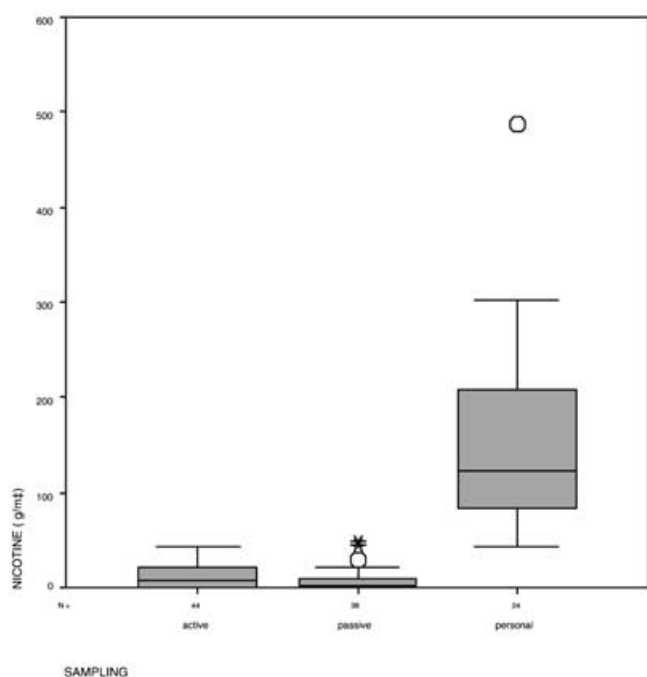


Fig. 1. Nicotine concentration by different sampling strategies (nicotine in $\mu\text{g}/\text{m}^3$)

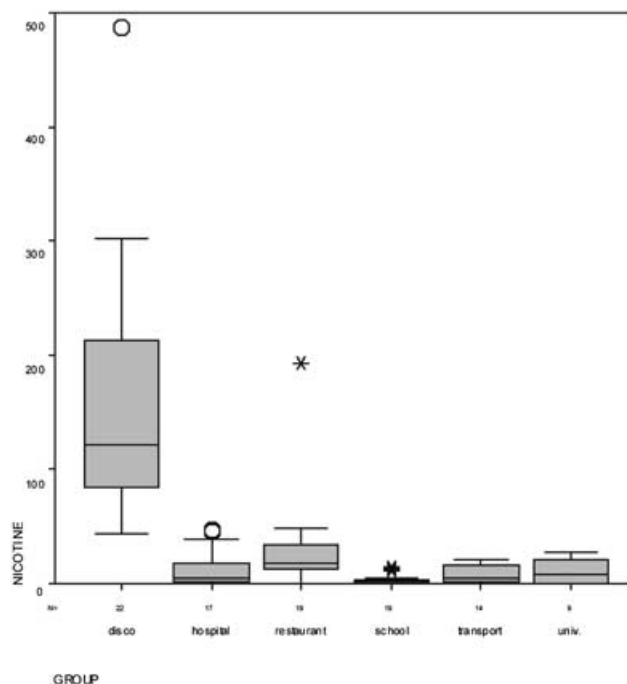


Fig. 2. Nicotine concentration by different sampling locations (nicotine in $\mu\text{g}/\text{m}^3$)

several days and so revealed an average that included periods without relevant exposure (e.g. nights at school). On the other hand we observed that peaks of ETS at schools and similar public places occurred in the early morning when the cleaning staff performs its duties. So low levels at night and high peaks in the early morning might in part balance each other at these locations during the sampling from Monday to Friday.

The nicotine concentrations grouped by location (Figure 2) show remarkable differences. Highest ETS concentrations were found in discos and bars (mean nicotine concentration 154.4 maximum $487.1 \mu\text{g}/\text{m}^3$). These data were obtained by personal sampling: two non-smoking students volunteered to wear the filter cartridges on their shirts while visiting the bars and dancing in the discos. In the first run the values from the filters of the male student were lower than those of the female. By interrogation it was discovered that he had carried the filter attached to the belt of his trousers where it might have been partly concealed by his T-shirt from the open air while she had placed the filter on her shirt. Therefore part of the early measurements in discos might even be an underestimation of the true personal exposure.

Intermediate concentrations were found in restaurants by active sampling (partly combined with the measurement of active surface) with no apparent

difference between smoking and non-smoking areas (mean \pm standard deviation: 21.3 ± 6.1 and $23.3 \pm 15.9 \mu\text{g}/\text{m}^3$ respectively) but on average higher values in restaurants with no separation between smoking and non-smoking areas ($38.0 \pm 60.6 \mu\text{g}/\text{m}^3$), although this difference was not statistically significant.

Concentrations usually below $10 \mu\text{g}/\text{m}^3$ were found in transport facilities ($8.3 \pm 8.0 \mu\text{g}/\text{m}^3$, maximum 20.6 in the restaurant section of a railway station's waiting room) and in schools ($3.0 \pm 4.6 \mu\text{g}/\text{m}^3$).

In hospitals "problem spots" were sought and so concentrations from very low to as high as $45.1 \mu\text{g}/\text{m}^3$ next to a smoking area with no physical barrier or separation and $47.7 \mu\text{g}/\text{m}^3$ inside a smoking room could be documented ($12.9 \pm 16.7 \mu\text{g}/\text{m}^3$).

In two rooms in hospitals and in one room of Vienna University both active and passive sampling was performed. Because of differences of season and length of investigation identical values were not expected. But with both methods in these 3 rooms the values were of the same magnitude.

In addition to the two measurements in non-smoker homes described in the "methods"-section 3 measurements (additional active sampling) were performed in rooms where smoking was not allowed but which were attained by a lot of people (some of

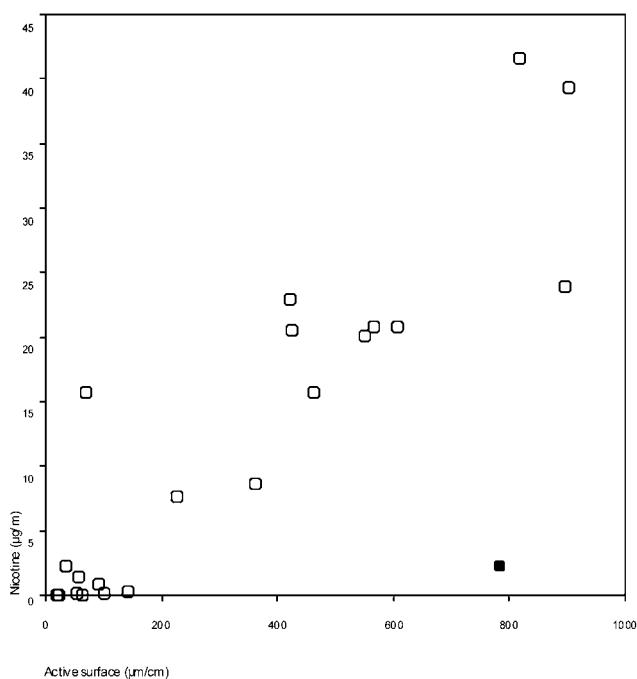


Fig. 3. Correlation between nicotine concentration and total suspended particles' surface. The only place showing high particle surface without high nicotine values (a pizzeria next to a busy road) is depicted in black.

which presumably smokers). These rooms were a conference room and the waiting rooms of a dentist and a family doctor. The nicotine values there ranged between 0.08 and 0.22 $\mu\text{g}/\text{m}^3$ indicating that smokers and their clothes emit nicotine even while they are not smoking. The sixth measurement listed under "others" was performed at an open air festival at the university campus, where 1.43 $\mu\text{g}/\text{m}^3$ could be detected even in the outdoor air.

The fine particle's surface correlated well with the nicotine concentration ($r=0.8$). In spite of the low number of samples this was highly significant ($p < 0.001$). Only in one instance (in a pizza restaurant on a busy road with heavy duty diesel traffic and the sampling spot next to the pizza stove) high fine dust was detected without high nicotine concentration (Figure 3, pizza restaurant indicated by a grey dot).

Discussion

There are still problematic areas in all settings analysed. But the highest concern in Austria should be with discos and similar entertainment facilities for the youth. These first data encourage further

more extensive measurement campaigns. Nevertheless even with these preliminary data the need for prompt action enforcing legal standards and raising public awareness is evident. Acute health hazards from fine particulate matter and irritants associated with nicotine concentrations as measured in discos, bars and restaurants are expected for persons with asthma or hyperreactive airways. Exposures in public places could even contribute significantly to chronic effects of ETS such as lung and heart disease which up to now have been related to domestic and occupational exposures only.

Typical nicotine concentrations in domestic and occupational settings have been reported in the range of several $\mu\text{g}/\text{m}^3$: Hammond (1999) reports a range from 2 to 6 $\mu\text{g}/\text{m}^3$ in offices, from 3 to 8 $\mu\text{g}/\text{m}^3$ in restaurants, and from 1 to 6 $\mu\text{g}/\text{m}^3$ in the workplaces of blue-collar workers. Mean nicotine concentrations from 1 to 3 $\mu\text{g}/\text{m}^3$ have been measured in the homes of smokers. Heloma et al. (2000) found highest mean concentrations of nicotine in service environments (3.0 $\mu\text{g}/\text{m}^3$) and lowest in offices (0.6 $\mu\text{g}/\text{m}^3$). Jenkins et al. (2001) determined median and 95th percentile concentrations of 1.5 to 8.7 $\mu\text{g}/\text{m}^3$. Personal sampling of nicotine in the breathing zone of non smokers exposed to ETS at home or at the work place revealed concentrations (averaged over 7 days or 24 hours) of less than 1 $\mu\text{g}/\text{m}^3$ (Phillips et al., 1996, 1998; Scherer et al., 1999; Eisner et al., 2001; Phillips and Bentley, 2001). Compared to these figures the concentrations of nicotine found in Austrian discos are alarming. A youngster visiting a disco only twice a month for several hours could be exposed to a higher dose of ETS than being exposed to ETS under typical living and/or working conditions which have proven negative effects on respiratory health (Harlap and Davies, 1974), lung function (Neuberger et al., 1985; Strachan et al., 1990), and lung cancer risk (IARC, 1986; EPA, 1992; CEPA, 1997).

The ETS exposure of the personnel at discos and bars must also be considered. An exposure to 100 $\mu\text{g}/\text{m}^3$ for only 4 hours a day would lead to a plasma cotinine level of 2.4 ng/ml (Repace and Lowrey; 1993). This would lead to nearly a doubling of frequent diseases like coronary heart disease (Tunstall-Pedoe et al., 1995).

Apart from these unhealthy effects of ETS on the respiratory system in the special environmental situation of discos combined effects of ETS, noise, and alcohol should be considered also. One should keep in mind that nicotine is not only a marker for carcinogenic and irritative substances but also for toxic substances in tobacco smoke such as carbon monoxide (CO). Previous experiments at our insti-

tute have documented the combined ototoxic effect of noise and CO (Haider et al., 1976; Neuberger et al., 1986). With the growing evidence of a worsening in the hearing threshold in young people (Körpert, 1999) and an increase of tinnitus patients of young age (Holgers, 2003) this aspect would deserve more attention.

High ETS concentrations in discos and bars are not a problem confined to Austria alone. By personal sampling with bar tenders and other restaurant personnel during their working shift Maskarinec et al. (2000) found nicotine concentrations from undetectable to more than 100 µg/m³. Our study was part of a Europe-wide project with data collected from Austria, France, Greece, Italy, Portugal, Spain and Sweden (Nebot et al., 2004). Although measurement strategies differed between these countries in all of them highest values were found in discos and bars. Nevertheless the highest values were reported from Austria.

Even the comparatively low nicotine concentrations in schools should not be neglected. Apart from the psychological relevance of smoking attitudes in schools at least at our “hot spot”-sites nicotine concentrations were higher than in typical smokers’ households. Considering that children spend many hours per day in school these exposures are alarming, especially when recalling the fact that for long term exposure to tobacco smoke and its most important components such as fine particulate matter and carcinogens no “safe” threshold values can be defined (WHO 2000). Cumulative exposures even to moderately elevated concentrations of nicotine (as a surrogate for tobacco smoke) may indicate a serious risk for health.

With long term passive sampling it was not possible to control for the number of smokers or the number of cigarettes smoked. Even with active sampling in restaurants it was evident that the nicotine content in the non-smoker compartment was also influenced by the smokers around the corner while permanent counting of smokers was not possible in this setting. But estimates of room size (volume in cubic meters) and number of persons were documented where appropriate when short term sampling (active or personal) was performed. Although rough estimates are bound to be imprecise especially for large dancing halls etc. a trend (two-sided $p = 0.08$) to lower nicotine levels with higher volume per person was established.

While nicotine is a good and specific indicator of ETS exposure it is not in itself responsible for the health effects anticipated from passive smoking. Although side-stream smoke contains a huge array of toxic substances the fine particles are top suspects.

Therefore measuring a parameter closer to fine particle concentration (be it particle mass, particle number or particle surface) in parallel enables to interpret nicotine levels as to their relevance for health. Leaderer and Hammond (1991) established a linear regression between nicotine (nic) and particle mass (pm): $pm = 20 + 10 \text{ nic}$. From outdoor measurements of particle mass and particle surface in parallel (Moshhammer and Neuberger, 2003) we are able to estimate particle mass (PM₁₀) from particle surface although based on comparisons with particles stemming from other dominant sources and therefore of slightly different particle size distribution. By applying this conversion formula a formula that is similar to the one given by Leaderer and Hammond is derived: $pm = 30 + 7.7 \text{ nic}$.

Conclusion

The high correlation between nicotine and active surface of particles indicates that tobacco smoke is a key source of indoor fine particles. In a recent study (Moshhammer and Neuberger, 2003) we demonstrated that outdoor measurements of particle surface (here the main source was road traffic) predicts short term outcome in lung function and respiratory symptoms in school children. In conclusion health policy must intervene to change the situation found at present in many public places in Austria.

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