Determination of Nicotine as an Indicator of Environmental Tobacco Smoke in Restaurants

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KEY WORDS: environmental tobacco smoke; nicotine; restaurants; work environment; occupational health and safety

BACKGROUND

There is an increasing concern regarding the health hazard that exposure to environmental tobacco smoke (ETS) may pose to the general public. In order to protect non-smokers from passive smoking, many countries in the 1990s have established ordinances and policies to reduce or prohibit smoking in public premises. Many workplaces have either restricted smoking to special rooms or prohibited it entirely. In most of the cases, restaurants make an exception to these regulations and both employees and customers are often exposed to high levels of ETS. Ordinances introduced in 1993 in Norway required one-third of the total indoor seating space in a restaurant to be no-smoking areas. Since January 1, 1998, one-half of the seating capacity must be reserved as a no-smoking section; and there are specific requirements for the location of the section and the ventilation system. A maximum nicotine concentration of 10 $\mu g/m^3$ in the no-smoking area is used as an indicator for compliance with the regulations.

From the many indicators of ETS that have been used in the past, nicotine was chosen for this study as it is highly specific for tobacco smoke and relatively easy to measure at the concentration levels at which it occurs in indoor environments [Baker et al., 1990; Chuang et al., 1991; Lambert et al., 1993; Nilsen et al., 1994]. For fresh ETS, more than 95% of the nicotine is in the gas phase [Leaderer and Hammond, 1991]. Thus, passive sampling methods can be used, thereby avoiding complex instrumentation or training of personnel [Scherer et al., 1990].

The aim of the study was to evaluate (a) the practical use in restaurants of the diffusive sampler developed at the Finnish Institute of Occupational Health (FIOH), and (b) the compliance with the ordinance of 10 $\mu g/m^3$ nicotine in no-smoking areas of restaurants, cafés, and bars.

METHODS

Passive Sampling Device

The sampler consists of a glass fiber filter (SKC, Glass Fiber Filter, Type A/E, 37 mm, SKC Inc., Eighty Four, USA) placed on the bottom of a polyethylene device resembling the 3500 Organic Vapor Monitor (3M Corp. Minneapolis, MN, USA). The glass fiber filter was positioned with a polypropene ring to which a wind screen was attached (Isopore® Membrane Filters, ATTP 0.8 µm pore size, 37 mm, Millipore Ltd., Watford). The glass fiber filters used in the sampling devices were washed in acetone for one minute and subsequently dried at 40°C for 30 min. The filters were impregnated for 1 min with a solution prepared by mixing 20% glycerin in methanol (11 ml), concentrated H_3PO_4 (5 ml) and acetonitrile (200 ml). After impregnation, the filters were dried for 30 min at 40°C.

The sampling rate of the sampler was determined in several exposure chamber experiments by utilizing pure nicotine or alternatively ETS. Nicotine was perceived to adhere to the wind screen and the diffusion of nicotine was observed to be temperature dependent [Bjørseth et al., 1986; Odgen et al., 1992]. If the samplers were stored at room temperature for a prolonged period of time, diffusion of nicotine onto the glass fiber filter was observed. For exposed samplers stored in a freezer, this phenomenon was insignificant.

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Accepted 1 May 1999

The sampling rate was determined to be 23.7 ml/min ($\pm$ 4.2 ml/min, n > 30). This sampling rate includes possible diffusion of adsorbed nicotine from the wind screen onto the glass fiber filter, keeping in mind the average time between the sampling and analysis. In this particular case, room temperature storage time was limited to 4 days.

Sampling

Approximately 50 restaurants, cafés and bars voluntarily participated in this study of nicotine measurements in the no-smoking sections. The samplers were produced at FIOH, Helsinki and mailed to the National Institute of Public Health (NIPH), Oslo, which distributed the samplers along with a hook for attachment to the wall, detailed sampling instructions, and a reporting form. Sampling was to be performed on a weekday at times when there were maximum numbers of customers. Restaurant employees were instructed to attach the samplers by means of a hook to a wall at 1.2 m above the floor, and sufficiently distant from textiles. Two samplers were used for each sampling point and the result was reported as the mean of two measurements. The cover of the samplers was to be removed just before opening the restaurant and replaced right after closing, i.e., the sampling time covered the entire opening hours, preferentially a minimum of 8 hr. Samplers were immediately sent back to FIOH, Helsinki for analysis.

Analysis

For desorption of nicotine, the glass fiber filters were transferred to a Kimax glass tube and 1 µl of 0.2 mg/ml quinoline (used as a chromatographic standard) was deposited on the glass fiber filter and 300 µl of concentrated ammonia was added. Nicotine was desorbed from the filter into a solution of methyl-*tert*-butylether (MTBE) with 10% of acetone and 0.1% of triethylamine. Potassium carbonate (0.5 g) was added to the Kimax tube to salt out the nicotine. The desorption time was one hour followed by a centrifugation (10 min, 2500 rpm) and a separation of organic layer which was transferred into an autosampler vial [Pfäffli et al., 1995].

Gas chromatographic analysis was performed on a Hewlett-Packard 6890 instrument equipped with a nitrogen–phosphorous detector and an automatic injector. Data were stored and processed by using a Hewlett-Packard Vectra PC and a Hewlett-Packard Chemstation software.

The temperature of the injector and detector were 230°C and 240°C, respectively. The column used was a NS Amine Noz. 2138, 25 m, 0.32 mm, 0.2 µm (HNU-Nordion Ltd., Helsinki, Finland). Helium was used as carrier gas. The temperature program was from 55°C at the rate of 15°C/min to 150°C, and then 10°C/min to 240°C (1 min). Constant pressure mode and splitless injection were used.

FIGURE 1. Nicotine concentrations (µg/m^3) in no-smoking areas of random restaurants, cafés and bars in Norway. The horizontal line indicates the 10 µg/m^3 reference value.

RESULTS AND DISCUSSION

The nicotine concentration measured varied from 0.7–85 µg/m^3 (Fig. 1). The detection limit of nicotine was 2 ng/ml. The recovery at concentration levels of 40, 130 and 620 ng/ml was 101% ($\pm$14%, n = 6), 98% ($\pm$7.6%, n = 6) and 98% ($\pm$4.3%, n = 6), respectively. The coefficient of variation for sampling and analysis was 11% (n = 23).

At 64% of the sampling sites, the measured average nicotine concentration complies with the Norwegian ordinance for no-smoking sections in restaurants. It has, however, to be borne in mind that the selection of restaurants, cafés, and bars may not be representative. Because the samples were collected on a voluntary basis, the participants may have been primarily restaurants enforcing strict separation of the no-smoking and the smoking areas as well as possessing efficient ventilation systems.

It is our experience that even passive sampling may be difficult to perform for untrained restaurant employees. In spite of detailed instructions, serious mistakes were made with respect to the sampling period, the sampling site, and the week day chosen, etc. Often information given on the reporting form was insufficient. Based on the collected data, no conclusions can be currently drawn with respect to the effect of the location of smoking and no-smoking areas, ventilation, use of electrostatic filters, etc. on the concentration of nicotine in the no-smoking area.

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