7.8 PERSONAL EXPOSURE TO BENZENE IN DIFFERENT URBAN ENVIRONMENTS - A CASE STUDY

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INTRODUCTION

Personal exposure to potential hazardous air pollutants has been the target for environmental research in Sweden during the last decades. It is well known that different kinds of volatile organic compounds (VOC) at high concentrations can have serious adverse effects on human health. Benzene for example is recognised as a human carcinogen (Victorin, 1993). Like other VOC benzene contributes to the ozone formation in and near cities.

The main sources of personal exposure to benzene are associated with personal activities such as smoking cigarettes, driving or riding automobiles and using products that emits benzene. The most important outdoor sources are vehicle exhaust and industrial emissions (Wallace, 1989).

In many developed countries monitoring networks that measure concentrations of VOC has been established. These networks consist of fixed point monitoring stations. These stations are well suited to evaluate the general pollution climate and to monitor trends, but they have shown not to represent the personal exposure of the general population.

In this study, the personal exposure to benzene in different adjacent urban environments in the city of Göteborg was investigated, in order to describe:

- the magnitude and spatial variation of personal exposure to benzene within a city
- the influence of traffic intensity, meteorology, seasonal variation and measuring height

METHODS

The city of Göteborg is with 500 000 inhabitants the second largest city in Sweden. Three adjacent urban environments were selected for the study (Fig. 1). The first is a large urban park with almost no traffic, the second (Urban I) is a densely built-up area with high traffic intensity (950 cars h^{-1}) and the third (Urban II) is densely built-up area with limited amount of traffic (90 cars h^{-1}).

Simultaneous measurements were performed in the three areas at typical heights of breathing of a child (1.0 m) and an adult (1.5 m) between 1100 and 1400 h LST. Twelve case studies were performed, with eight in summer and four in winter. Each person was instructed to make diary notes about time and activity pattern, and they were asked to avoid passive smoking. The samplers consisted of Tenax-ATD (Automatic Thermal Desorption) tubes for active sampling of VOC, attached to Gilian Universal Tube Holder-pumps (LFS 113D). Three different VOC, benzene, toluene and xylene was measured and analysed.

A mobile ultrasonic wind anemometer was used to measure the wind speed and wind direction within the area. Traffic intensity was calculated manually.

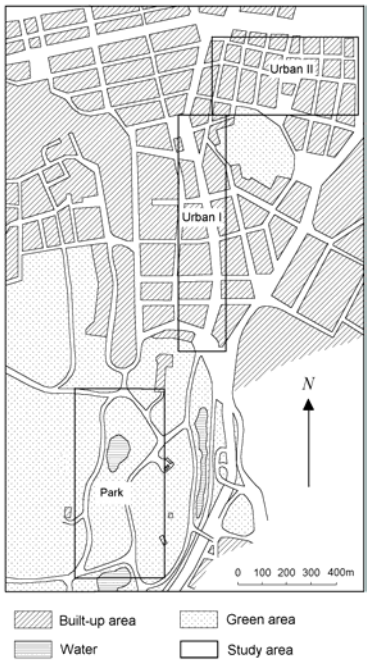

Fig. 1 Map of Göteborg showing the three urban environments (Park, Urban I, Urban II).

RESULTS AND DISCUSSION

3.1 Spatial variation, land use and traffic intensity

The result showed large differences in personal exposure to benzene between the three different adjacent urban environments both in summer and winter (Fig. 2). The benzene exposure in the densely built-up area with high traffic intensity was 1.3 to 2.6 times higher compared to the densely built-up area with limited amount of traffic and 2.1 to 5.8 times higher than inside the park.

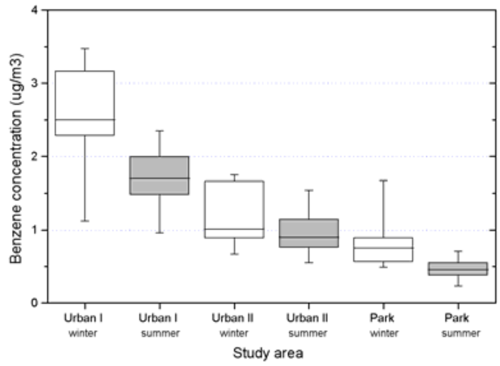

Fig. 2 Personal exposure to benzene in the three urban environments (Urban I, Urban II, Park), in winter (white box) and summer (grey box).

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3.2 Source of emission

The result presented in Fig. 2 indicate that traffic intensity is a major parameter controlling the levels of benzene in Göteborg. In order to characterise the source of emission the toluene/benzene concentration ratio can be used (Palmgren et al., 2001). In Sweden the toluene/benzene ratio in petrol is about 10:1, but since toluene is five times more reactive than benzene, the ratio decreases with time and distance to source (Gelencsér et al., 1997). The toluene/benzene ratio listed in Table 1 indicates that traffic is the main source of emission in Göteborg.

Table 1: The average toluene/benzene ratio in the three urban environments in summer and winter.

Season	Urban I	Urban II	Park
Winter	7.5	3.4	7.3
Summer	8.3	8.2	7.4

3.3 Meteorology

The data was analysed with respect to the mean wind speed and wind direction. The highest benzene concentrations were found in winter under conditions with light winds (Table 2). In summer benzene concentrations could not be related to the mean wind speed.

Table 2: The average benzene concentration in the three urban environments in relation to the mean wind speed, *u*.

	Winter		Summer	
	u < 2 m s^{-1}	u > 2 m s^{-1}	u < 2 m s^{-1}	u > 2 m s^{-1}
Urban I	2.9	1.7	1.7	1.7
Urban II	1.4	1.0	0.8	0.8
Park	0.9	0.7	0.4	0.5

The highest levels of benzene were found under conditions with southerly and northerly winds (Fig. 3). During these conditions pollutants from the heavily traffic roads south and north of the study area are transported into the area.

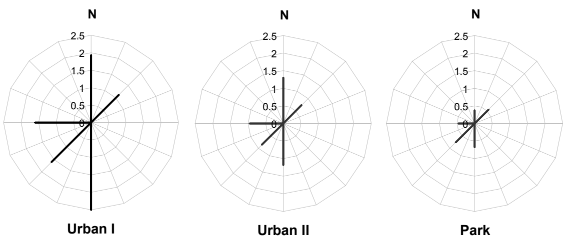

Fig. 3 Benzene concentrations (µg m^{-3}) in the three urban environments in relation to wind direction.

3.4 Seasonal variation

No difference in dispersion conditions or traffic intensity was recorded between the seasons. Although, the benzene concentrations were significantly higher in winter (Fig. 2) compared to summer.

High solar radiation and air temperature increase the reaction rates, leading to lower concentrations of pollutants in summer compared to other seasons. Another parameter influencing the levels of benzene in urban areas are the numbers of cold starts. In winter the high number of cold starts due to the low air temperature will increase the emissions from traffic.

3.5 Measuring height

The difference between the two measurement heights (1.0 and 1.5 m) presented in Fig. 5 was shown to be insignificant, indicating that the air in the street canyons is well mixed during the day.

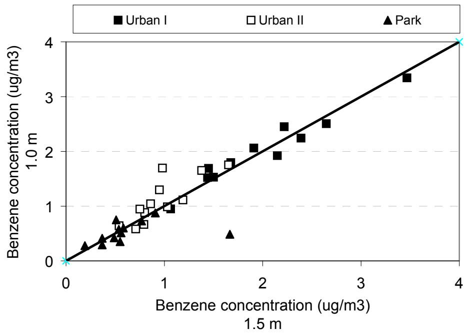

Fig. 5 The personal exposure to benzene at 1.0 m versus 1.5 m height in the three environments.

CONCLUSIONS

Large spatial variations of personal exposure to benzene were recorded in Göteborg both during summer and winter. The benzene concentration in the densely built-up area with high traffic intensity was up to six times higher compared to the adjacent park.

The main parameter controlling the levels of benzene in Göteborg is emissions from traffic. Besides traffic intensity, the number of cold starts, air temperature, solar radiation and dispersion due to the mean wind speed and direction influences the levels of benzene.

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5. ACKNOWLEDGEMENT

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