INFILTRATION OF VOCs FROM OUTDOOR AIR: AN INDOOR–OUTDOOR COMPARISON

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ABSTRACT

The indoor-outdoor comparison of volatile organic compounds was made in 52 private homes in the City of Munich, Germany. The VOC concentrations were measured by trapping with activated charcoal tubes and analyzed by capillary GC. The infiltrated NO_x was monitored in the indoor air. It can be concluded that the benzene concentration in the indoor air is controlled by the outdoor concentration for approximatively 30 % of the investigated cases.

KEYWORDS

VOC infiltration, indoor-outdoor comparison, benzene, toluene, nitrogen oxides, terpenes,

INTRODUCTION

The energy crisis results in tighter buildings and reduced ventilation (Mage, 1985), also in Germany. In the upper Bavarian region and in the City of Munich the climatic situation leads to a long heating period. The occurrence of volatile chemicals in the indoor environment is often discussed as residues caused by the building technology, i.e. by glues, coatings, or by the use of household chemicals. Infiltration from polluted outdoor air is an additional source (Gebefügi et.al. 1993). Natural ventilation is typical for the Bavarian housing technology, with low air exchange rates between 0.1-0.5/h.

In the following study, the measurements of charcoal trapped organics from indoors and outdoors were made in 53 private flats in Munich inhabited by families (always with children required to attend schools). The goal was to get information about the indoor air concentration of volatile organic chemicals in comparison with the outdoor air pollution. The examined flats were older than six years. The sampling site was always the children's room, at 1 meter height, during three days. The sampling was stopped at night because of the noise of the sampling unit. The outdoor air was sampled at the same time generally one meter outside the window of the sampled room.

The sampling technique was developed for outdoor background level measurements of VOCs and is useful for long term and high-volume measurements too (Kreuzig et.al. 1986). Simultaneously indoor measurements were carried out by a NO_x monitor during the VOC sampling to measure the infiltration from the outdoor air. In the individual sampling sites no indoor NO_x sources were identified, in particular there was no smoking and no gas burning device.

RESULTS AND DISCUSSION

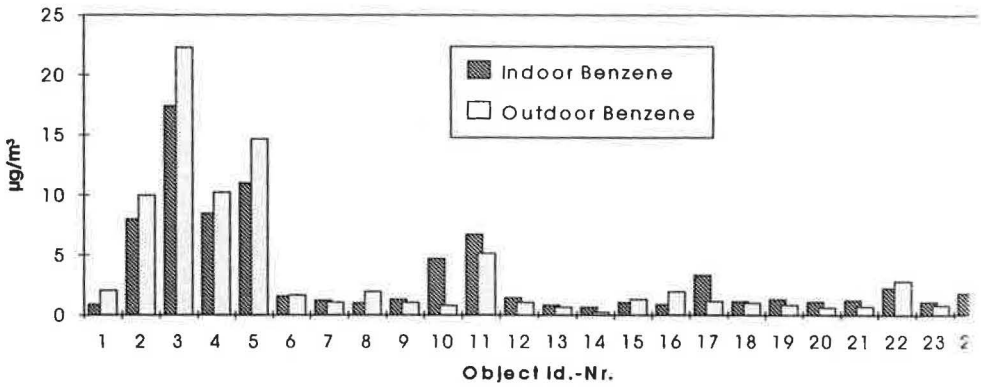
Samples were collected and analysed from 53 flats. In one flat the benzene concentration was extremely high (over 100 µg/m³). The reason was identified as infiltration from the garage. The results of this sampling site were rejected, also for the other VOC´s.
The results are summarized in the Table 1. It shows the mean, median, maximum and minimum concentration values of the volatile organic compounds analyzed in the indoor air, of children's rooms and in the outdoor air. All values of the VOCs are higher indoors than outdoors, except for benzene. In a few cases the concentration of benzene is higher outdoors than indoors. Fig. 1 shows a variety of typical individual benzene values indoors and outdoors.

Table 1: VOC in the indoor and outdoor air in µg/m³

Component	Mean		Median		Max		Min		n
	indoor	outdoor	indoor	outdoor	indoor	outdoor	indoor	outdoor	
Benzene	2,74	2,68	1,61	1,56	17,40	22,26	0,41	0,27	52
Toluene	15,19	5,20	10,15	4,33	131,52	16,04	1,08	1,00	52
m-,p-Xylene	5,71	2,99	3,43	2,40	75,39	16,33	0,20	0,51	52
o-Xylene	1,83	0,93	1,14	0,78	25,71	4,67	0,06	0,19	52
Ethylbenzene	1,27	0,89	1,01	0,71	5,75	4,63	0,06	0,20	52
α-Pinene	2,48	0,20	1,35	0,13	15,92	1,46	0,12	0,03	50
Δ³-Carene	1,28	0,12	0,80	0,08	7,14	0,64	0,04	0,03	49
p-Cymole	0,31	0,04	0,28	0,04	1,40	0,12	0,01	0,01	46
Limonene	3,10	0,21	2,19	0,14	12,31	0,82	0,04	0,03	48

It is remarkable, that the highest indoor values are paired with higher outdoor concentrati (sampling site Id. Nr. 2, 3, 4 and 5). This result suggests the possible infiltration of outdoor benze In the flats Id. nr. 10, 11, and 17 the elevated indoor concentration is significantly higher, than corresponding outdoor value. For the lower concentration range, slightly higher indoor values typical.

Fig. 1: Indoor/outdoor comparison of individual benzene values for illustrative



To look for correlations between the indoor - outdoor concentrations, the Spearman rank correlation coefficient (r_s) was computed with a SAS/STAT STATSGRAPHIC software (SAS/STAT, 1993). The Spearmann correlation coefficient (r_s) is computed by using the rank scores. It is appropriate only when both variables lie on an ordinal scale. It has the range $-1 \leq r_s \leq 1$.(i.e. $r_s = 1$ is full correlation, $r_s = 0$ no correlation). The (r_s) coefficent and the p-value (or significance probability value) are summarized for the VOCs in the Table 2. The correlation for the xylenes is higher, but the correlation coefficients for benzene are moderate, for toluene and ethylbenzene weak.

Table 2: Spearman correlation coefficient (r_s) for the indoor outdoor concentrations of VOCs

Compound	r_S	p-value
Benzene	0,59	< 0,001
Toluene	0,52	< 0,001
m-,p-Xylene	0,74	< 0,001
o-Xylene	0,70	< 0,001
Ethylbenzene	0,42	< 0,005

To study the possibility of infiltration of outdoor air contaminants , monitoring of nitrogen oxides was carried out in indoor air. NO_x are mainly produced by fuel combustion in heavy traffic. NO_x measurements were carried out in 24 sampling sites (flats), at the same time, as the VOC measurements. The NO_X were measured indoors by a commercial NO_X monitor. Table 3. shows the mean , median, maximum and minimum values.

Table 3: NO_X and NO_2 concentrations in the indoor air (ppb)

Component	Mean	Median	Max	Min	n
NO_X	28,9	28	46,8	20,7	24
NO_2	15,6	15,2	24,5	10,1	24

Because of the absence of indoor sources, the observed concentrations of NO_X and NO_2 are a clear indication of outdoor contaminants. The correlations with selected VOCs in the sampled flats are shown in Table 4.

The indoor NO_x values show weak correlation with indoor aromatics and good correlations with outdoor xylenes and ethylbenzene. This confirms that outdoor NO_X and outdoor aromatics may be generated simultaneously, as known for car exhaust (e.g. by diesel engines). Benzene and alkylbenzenes are well known as anthropogenic chemicals coming from the vehicle emissions of petrol (gasoline) burning in a spark-ignition engine. The main components of these emissions are benzene, toluene, ethylbenzene, m/p-xylene, o-xylene, 3-ethyltoluene, and 1,2,4-trimethylbenzene (Oelert, 1974). It was generally found that one of the possible source of aromatic compounds is the infiltration of polluted outdoor air. The constant findings of higher indoor than outdoor concentrations can be explained by indoor sources or accumulation phenomena from infiltrated chemicals. The adsorption on indoor surfaces can cause a retention of VOCs (Colombo et.al. 1993).

Table 4: Correlation of the NO_X/NO_2 values with indoor and outdoor VOCs

	Indoor NO_x		Indoor NO_2	
Indoors	r_S	p-value	r_S	p-value
Benzene	0,44	<0,005	n.c.	n.c.
Toluene	n.c.	n.c.	n.c.	n.c.
Ethylbenzene	0,60	<0,005	0,51	<0,05
m-,p-Xylole	0,50	<0,005	0,53	<0,05
outdoors				
Benzene	n.c.	n.c.	n.c.	n.c.
Toluene	n.c.	n.c.	0,43	<0,05
Ethylbenzene	0,76	<0,001	0,68	<0,005
m-,p-Xylole	0,78	<0,001	0,75	<0,005

n.c. = no correlations

The measurement of indoor VOC levels are useful to detect higher individual exposures. The very important role of infiltration from the outdoor air can be identified by simultaneous measurements indoors and outdoors. An additional pollutant with no indoor source, e.g. NO_x in this study can be useful for the identification of outdoor infiltration. The quality of indoor and outdoor air is interconnected, the indoor VOC level cannot be lower than the outdoor fresh air level in case of a sufficient ventilation. To get representative mean values a sampling period of three days seems suitable.

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