VOLATILE ORGANIC COMPOUNDS AND FORMALDEHYDE IN BEDROOMS: RESULTS OF A SURVEY IN VIENNA, AUSTRIA

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ABSTRACT
Despite increasing public concern about indoor air pollution in Austria there are no systematic investigations of typical exposure to VOCs (volatile organic compounds) in households.

Air samples were taken in bedrooms of 160 randomly selected households in five districts. Formaldehyde was measured by photometry, VOCs by adsorption on charcoal and solvent extraction. To determine individual volatile compounds GC/MS was used.

Formaldehyde levels ranged from 0.007 to 0.092 ppm. All but six samples were below 0.05 ppm. Total VOC levels ranged from 11 to 6045 µg/m³. Out of the samples 131 were below 300 µg/m³ and 5 exceeded 1000 µg/m³. Aliphatic compounds were the most prominent (14% of total VOC), followed by aldehydes (12%) and aromates (8%).

Overall the concentrations were fairly low. However, in about 4 percent of households further analysis and special considerations are warranted. Average VOC concentrations were similar to those recently reported for households in Germany.

INDEX TERMS
VOC, Formaldehyde, Survey, Households

INTRODUCTION
In Germany a large, frequently quoted survey in households was performed during 1985/86. For the first time information on level and type of exposure to air pollutants in households was available (Krause et al., 1991). Recent studies indicate that elevated levels and spectra of the 80's do not reflect today's situation. In the meantime particularly the VOCs (volatile organic compounds) spectrum changed as a consequence of the substitution of classical solvents in paints, lacquers and adhesives (Lux et al., 2001, Schleibinger et al., 2001, Scholz et al., 1998, Plieninger, 1998).

As there is an increased public awareness concerning indoor air quality and health in Austria, public health services are increasingly confronted with inquiries from the public concerning indoor air pollution (Hutter et al., 2002, Hutter and Walter, 1997). The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management responded to these needs and established a Working Group in order to set up indoor air quality guidelines. Procedures for measurement, assessment and evaluation of indoor air quality should be harmonized (Hutter et al., 2002).

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In contrast to Germany no systematic investigations of typical exposure conditions of VOCs and Formaldehyde have been conducted in Austria. Until now most data has been collected in response to complaints from occupants. The Working Group decided to survey the exposure to common indoor air agents - VOCs and formaldehyde - in typical urban households of Vienna. Indoor air situation concerning important VOCs should be compared to German findings reported recently (Lux et al., 2001).

METHOD

During summer 2001 a random sample of 180 households was selected in different urban areas (two near and three far from the center) of Vienna. The consent of 160 inhabitants (89 percent) was obtained and measurements were performed following the proposals of the VDI-Guidelines 4300 (part 1 general aspects, part 6 E for VOC and part 3 for formaldehyde). Inhabitants were instructed to keep the windows closed for at least 5 hours before sampling. The samples were drawn in each participant's bedroom by use of an active sampling device. The sampler was located in the center of the rooms with the inlet 1.0 to 1.5 meters above the floor.

VOC air samples were taken by using adsorption tubes containing a special activated charcoal (SKC, Anasorb 747) according to the Austrian Standard ÖNORM M 5700 - 2 proposal (Austrian Standard Institute, 2002). Sample flow rates were about 2 liters per minute. Typical total air sample volumes were 70 - 100 liters.

VOCs were extracted from activated carbon with 1 milliliter of CS_2 and quantitatively analyzed by gas chromatography/mass spectrometry (Shimadzu QP 5000), using a 30 meter fused silica capillary column (DB 624, J&W Scientific) following the German Standard VDI 3482 part 4 (VDI, 2000). Fifty target VOCs were selected for analysis.

These compounds are representative of the major chemical classes of compounds that occur in indoor air, indicative of specific indoor sources, or of interest because they have low odor thresholds or are potent sensory irritants. Many of the selected compounds are listed as target VOCs recommended to be included in analyses of TVOC by ECA (European Concerted Action "Indoor Air Quality and its Impact on Man", 1997). Compound confirmation and quantification was achieved using prepared standards of known compounds. As internal standards cyclooctane and toluene-d8 were used.

Different methods for calculating the sum of VOC or TVOC have been described (Seifert, 1999). In our study the total-ion current (TIC) for a sample was integrated over a retention time range bounded by ethylacetate and n-hexadecane. The mass of the compounds represented by the sum of the TIC area was calculated relative to the amount and area of toluene.

The method of solvent extraction was chosen to be compatible with the method used in different German studies (e.g. Lux et al., 2001). Due to budget restriction it offers a cheap and extensive predication about quantity and composition of VOCs. However, it should be noted that not all of VOCs could be detected as defined by ECA (ECA, 1997).

Formaldehyde was measured using active air sampling in accordance with the German standard VDI 4300 part 3 E (VDI, 1997). Analyses were subsequently performed by using the acetylacetone photometric method following the Austrian Standard ÖNORM EN 717 - 1

(Austrian Standard Institute, 1995). As environmental factors such as temperature and relative humidity have strong influences on the actual levels of formaldehyde and to facilitate the comparison of the results of the study to those of other studies it seemed reasonable to convert the results of the formaldehyde measurements to typical Middle European standard climatic conditions (23°C room temperature, 45 percent relative humidity) by using the Anderson equation.

RESULTS

Total VOC levels (n = 160) ranged from 11 to 6045 micrograms/m³ (Median 155 µg/m³). Eighty-two percent (n = 131) were below 300 µg/m³ and five (3 percent) exceeded 1000 µg/m³. The highest concentration (6045 µg/m³) was recorded in a non smoking home.

Formaldehyde levels (n = 160) ranged from 0.007 to 0.092 ppm (Arithmetic mean: 0.025 ppm, Median 0.02 ppm). All but six samples (4 percent) were below 0.05 ppm (WHO level of no concern, 1983).

Aliphatic compounds were the most prominent (14% of total VOC), followed by aldehydes (12%) and aromates (8%).

DISCUSSION

Overall the concentrations of total VOC and formaldehyde were fairly low. However, in 3 to 4 percent of households higher levels occurred warranting further analysis and special consideration. The highest concentration found (6045 µg/m³) constituted a mixture of aliphates that were traced back to recent applications of solvent containing paints.

In another 15% VOC levels were within the range of 300 to 1000 µg/m³, with a potential of exceeding guideline levels of single substances.

Concentration as well as distribution of important components of VOCs (aliphatic and aromatic hydrocarbons) are similar to the VOC mixture described recently for German households. Levels of aliphatic and aromatic compounds and terpenes in Viennese and German homes (Lux et al., 2001) are shown in table 1.

Only small differences are seen between the two studies concerning aliphatic and aromatic compounds, although aromatic hydrocarbons particularly toluene was lower in Vienna. More pronounced differences were seen in terpene levels. One reason could be that highest levels in the German study were found in children’s rooms while in Vienna only bedrooms were monitored.

CONCLUSIONS AND IMPLICATIONS

For the first time representative data regarding residential exposures to common indoor air contaminants in Vienna are available. Both concentration and distribution of the detected VOCs are similar to those in Germany where the VOC-level decreased in the last 15 years. On the basis of these data it can be hypothesized that this trend has also taken place in Vienna.

Table 1. Average concentrations and peak levels (in µg/m³) of aliphatic, alicyclic, aromatic hydrocarbons, and terpenes. Comparison between Viennese (V) and German (G) (Lux et al., 2001) results.

Compounds	*Mean*		*Peak*	
	V	*G*	*V*	*G*
n-Heptane	10.8	3.8	111.6	95.1
n-Octane	0.8	1.7	88.7	29.4
n-Nonane	3.3	2.2	506.3	30.0
n-Decane	2.1	5.4	149.9	37.0
n-Undecane	4.4	6.9	554.5	63.1
n-Dodecane	3.2	6.4	463.4	128.0
n-Tridecane	0.6	3.4	46.2	59.4
n-Tetradecane	0.1	2.2	12.7	21.7
n-Pentadecane	0.0*	0.9	0.0*	4.9
n-Hexadecane	0.0*	1.2	0.0*	11.0
Cyclohexane	6.2	1.3	63.5	7.9
Aliphatic, alicyclic hydrocarbons	*31.5*	*35.4*		
Benzene	0.2	2.8	8.5	10.0
Toluene	15.2	26.2	118.8	155.0
Ethylbenzene	2.3	3,2	21.7	12.8
m,p-Xylene	2.7	5.3	72.0	33.8
o-Xylene	0.4	2.0	20.3	19.1
Styrene	0.0*	3.4	4.5	30.5
Propylbenzene	0.0*	1.3	2.5	15.9
2-Ethyltoluene	0.1	1.2	13.7	19.7
3-Ethyltoluene	0.1	2.1	4.8	36.4
1,3,5-Trimethylbenzene	0.1	1.1	7.6	20.9
1,2,4-Trimethylbenzene	0.4	3.5	31.7	60.2
1,2,3-Trimethylbenzene	0.0*	1.4	6.9	14.6
Aromatic hydrocarbons	*21,3*	*53,5*		
Alpha-pinene	10.7	87.5	234.9	755.0
Limonene	11.0	23.6	636.5	833.0
Terpenes	*21.7*	*111.1*		

* below detection level

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