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STUDY OF VOC EMISSIONS AND ODOURS FROM FOAM MATERIALS IN FURNITURE PRODUCTION

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ABSTRACT

The issue of volatile organic compounds (VOCs), odours or smells emitted from materials is researched in terms of our environment and human health. The Department of Furniture at Mendel University in Brno has been dealing with this subject for a long time. Main direction of this research is defined by composition of quantitative and qualitative emissions of VOCs which are emitted into the air from chosen materials used in the manufacturing of upholstered furniture such as polyurethane foams and latex rubber. Emission measurement is determined in space chamber with pre-defined conditions. This methodology is described in the standard ČSN EN ISO 16 000-9. The samples of air from the climate chamber, where the test sample is placed, are then analyzed by gas chromatography (GC) on a gas chromatograph with mass spectrometer and thermal desorption. Another part of this research is olfactometric assessment of odours emitted from tested materials, by the indirect olfactometry method. The relevance of the individual components on emissions of odour intensity and hedonic effect will be determined according to the chemical analyses of the achieved results.

This study investigates the problem of VOC emissions and odours emitted from polyurethane foam, viscoelastic foam and latex at the temperature of 23 °C and a relative humidity of 50 %. The time aspect in connection with the amount of volatile organic compounds released to the air are examined in this document. Particularly it was pointed on the identification of substances which release from these foams. These substances express the characteristics of the foam materials from the point of the release of volatile organic compounds and odours.

Key words: VOC emissions, odours, gas chromatography, olfactometry, foam.

1. INTRODUCTION

Quality of life in populations is becoming an ever-growing concern. Higher demands are made in regard to for example comfort and safety. Low emissions of volatile organic compounds and odour criteria have become key performance requirements in most applications. To address this issue, the entire supply chain, from producers to end-users attempts to find ways and means to identify, understand and reduce unexpected emissions and odours (Hillier et al. 2008).

Indoor odours are usually mild and intermittent, and the sources of indoor odour are varied and usually nonspecific; therefore, it increases the difficulty to characterize indoor odours and to identify the odour sources. Still, characterization of odours (qualitative and quantitative) can help to identify pollution sources and play an important role in evaluating indoor air quality due to greater human sensitivity to odour (Duffee et al., 2000; Knudsen et al., 2007).

Foam materials, based on polyurethane or latex, are commonly used as construction materials for upholstered furniture, especially for mattresses. There is a little information about these materials in terms of

VOCs emissions and odours. It is important to deepen this knowledge, because upholstered furniture surrounds us in each interior. Everyone has his mattress and spends there a substantial part of his life on it. It is clear that the whole interior affects the quality of indoor air.

The influence of the individual materials on indoor air quality is connected with the term of TVOC (total volatile organic compounds), which is used to describe the total amount of volatile organic compounds in indoor air. TVOC value indicates the level of indoor air pollution.

The aim of the research was to find the hedonic tone or odours and diversity of VOCs emitted from polyurethane foam, viscoelastic foam and latex foam depending on the time. This study examined the release of chemical substances from selected materials and their amounts, which are gradually released versus time. Samples were prepared from a block of polyurethane foam from the vendor (not the manufacturer). Quantitative difference of entire emitted organic compounds showed the measured values of TVOC.

2. USED MATERIALS, EQUIPMENT AND METHODS

2.1. Tested materials

Tested materials:

1. Polyurethane foam N5063 dimensions: 0.65 x 0.65 x 0.05 meters, sample size: S = 0.98 m^2,

2. Viscoelastic foam V5020 dimensions: 0.65 x 0.65 x 0.05 meters, sample size: S = 0.98 m^2,

3. Latex foam dimensions: 0.65 x 0.65 x 0.05 meters, sample size: S = 0.98 m^2.

2.2. Used equipment for measuring emmited emissions and assessment odours

- Short path thermal desorption tube, Silco trated Thermal Desorption Tube 786090-100, inner diameter 4 mm, fill in with 100 mg of Tenax TA Scientific Instrument Services company) for collection of VOCs emissions emitted from tested samples in to the air in chamber
- Air sampler Gilian–LFS 113 SENSIDINE with air flow 12 $l.h^{-1}$
- Gas chromatograph Agilent GC 6890 N with MS (mass spectrometer) detector 5973 with cryofocusation, thermal desorption and library of spectra NIS 05, column type HP – 5 (AGILENT USA)
- VOC equipment small-space chamber for VOCs testing with these **Technical parameters during the collection of emissions VOC** (Tesařová, 2014):

Inner dimensions of space in chamber 1 m^3

Conditions in chamber during the collection of emissions

Air temperature in chamber 23 °C

Air humidity in chamber 50 %

Air changing rate in chamber 1 m^3 per 1 h

Air speed over the tested samples from 0,1 to 0,3 $m.s^{-1}$

Sniffer 9000 is connected to a gas chromatograph with FID HPST 4890 with thermal desorption TD4 which sample through humidifier. Where it is moistened and warmed.

2.3. Standards used for voc testing and odours assessment odours

ISO 16000: 2004 Indoor air;

ISO 16000-1: 2004 General aspects of sampling strategy;

ISO 16000-5: 2005 Measurement strategy for (VOCs) volatile organic compounds;

ISO 16000-6: 2005 Determination of volatile organic compounds indoor and test chamber air by active sampling on Tenax TA® sorbent, thermal desorption and chromatography using MS/FID;

ISO 16000-9: 2004 Determination of the emission of volatile organic compounds Emission test chamber method;

ISO 16000-11: 2004 Determination of the emission of volatile organic compounds – sampling, storage of samples and preparation of test specimens;

EN 13725-2003 – Air quality – Determination of odour concentration by dynamic olfaktometry.

3. RESULTS AND DISCUSSION

The results of measurements of TVOC emissions released from visco-elastic foam V5020 are shown in Table 1. The results of measurements of TVOC emissions released from latex foam are listed in Table 2. The results of measurements of TVOC emissions released from polyurethane foam N5063 are listed in Table 3. Identified characteristic VOCs of the individual measured foam materials are listed in Table 4. The results of olfactometric assessment of odours are listed in Table 5. and in Table 6. The samples of foams were evaluated by four reviewers (2 males, 2 females) of age from 27 to 34 years old.

Table 1: The values found TVOC emissions emitted by the sample visco-elastic foam V 5020

Value TVOC	After 24 hours*	After 48 hours*	After 72 hours*	After 672 hours*
Unit	**[µg/m³]**	**[µg/m³]**	**[µg/m³]**	**[µg/m³]**
$TVOC_{MS}$	(303 ± 91)	(326 ± 98)	(323 ± 97)	(138 ± 41)

* Average of result ± expanded measurement uncertainty

Measured values of the emission of VOCs terpenes, aldehydes, aromatic hydrocarbons and benzene derivatives are negligible. The value TVOC in connection with the time characterizes a growing trend after 48 hours. After 72 hours, the TVOC value slightly decreased, but still significantly higher than the measured value TVOC after 24 hours. Even after 672 hours (28 days) TVOC value is relatively high in relation to the optimal value of around 100 mg / m3.

Table 2: The values found TVOC emissions emitted by the sample latex foam

Value TVOC	After 24 hours*	After 48 hours*	After 72 hours*	After 672 hours*
Unit	**[µg/m³]**	**[µg/m³]**	**[µg/m³]**	**[µg/m³]**
$TVOC_{MS}$	(379 ± 114)	(238 ± 71]	(211 ± 63)	(197 ± 57)

* Average of result ± expanded measurement uncertainty

Measured values of the emission of VOCs terpenes, aldehydes, aromatic hydrocarbons and benzene derivatives are negligible trend. The TVOC value in connection with the time characterizes a downward trend. Even after 672 hours (28 days) TVOC value is relatively high in relation to the optimal value of around 100 mg / m^3.

Table 3: The values found TVOC emissions emitted by the sample polyurethane foam N5063

Value TVOC	After 24 hours*	After 48 hours*	After 72 hours*	After 672 hours*
Unit	[µg/m3]	[µg/m3]	[µg/m3]	[µg/m3]
$TVOC_{MS}$	(311 ± 93)	(192 ± 58]	(123 ± 37)	(97 ± 41)

* Average of result ± expanded measurement uncertainty

Measured values of the emission of VOCs terpenes, aldehydes, aromatic hydrocarbons and benzene derivatives are negligible. The TVOC value in connection with the time characterizes a downward trend. Even after 672 hours (28 days) TVOC value is relatively optimal in relation to the optimum value of around 100 mg / m^3.

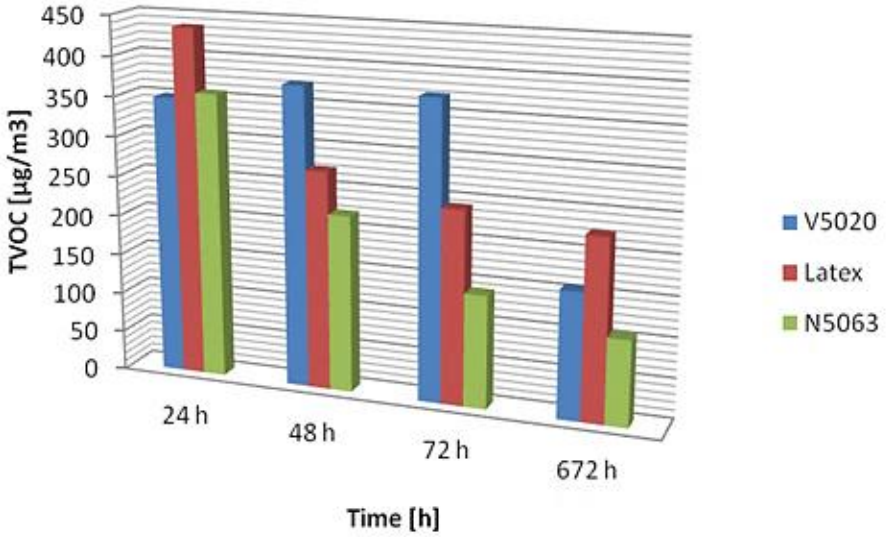

Figure 1: TVOC emissions emitted by foams in time

Table 4: The characteristic of the substance VOC emissions, which significantly affect the TVOC concentration in sample V5020, Latex, N5063

Identified substance	The range of percentages of the total value of TVOC from 24 hours to 672 hours [%]			
	V5020	Latex	N5063	R. T. *
Toluen	-	Insignificant – 4,635	Insignificant – 3,397	6,81
Piperazine, 1,4-dimethyl-	-	2,613 – 3,357	-	9,11
p-xylene	-	2,493 – 5,249	1,995 - 4,395	9,59
Morpholine, 4-ethyl-	3,327 – 13,366	9,465 – 20,747	3,558 – 11,155	9,75
Triethylendiamine	9,710 – 20,189	-	-	13,15
Benzenemethanamine, N, N-dimethyl-	7,060 – 12,530	13,480 – 21,245	10,710 – 15,897	13,74
Undecane	10,410 – 26,676	3,557 – 4,114	1,443 – 4,842	14,84
Dodecane	2,003 – 7,157	3,500 – 6,332	7,612 – 10,110	16,86
Tridecane	2,003 – 7,157	3,164 – 4,952	6,710 – 12,148	18,71

* The retention time

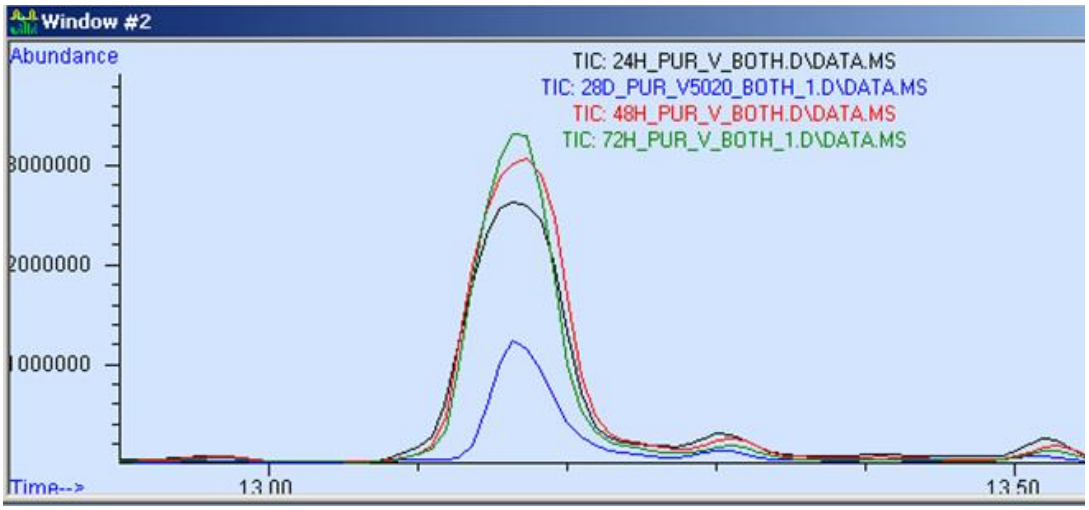

Figure 2: The dependence of the Triethylendiamine peak size on the time of its measurement

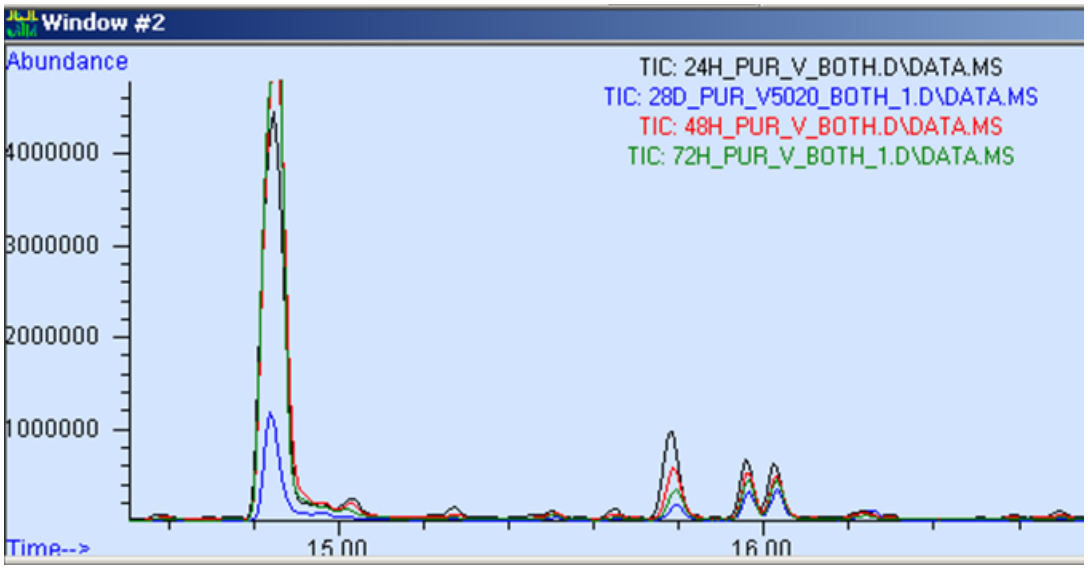

Figure 3: The dependence of the Undecane peak size on the time of its measurement

For these measured results, we can conclude the TVOC concentrations of latex foam and polyurethane foam N5063 gradually decreases over time. In contrast, the visco-elastic foam V5020 shows an increase of TVOC an increase after 48 hours. After 72 hours, the measured value is higher than the TVC was after 24 hours but less than 48 hours. Increasing concentrations of VOCs is caused by Triethylenediamine and Undecane and the decreasing concentration in time are listed in Fig. 2 and Fig. 3. On the contrary, the concentration increases after 48 and 72 hours. Some of the VOCs concentrations that have an effect on TVOC were founded in our selected materials in big amount. It can be said these substances are characteristic for the foam materials. The individual VOCs are listed in Table 4.

Table 5: Identified values of hedonic tone and intensity of odour emitted by the foams after 72 hours

The retention time	Hedonic effect / Intensity			VOC
	V5020	Latex	N5063	
5,7	-2	-2	-	Toluene
9,5	-3	-2	-3	Styrene
10,3	-	-4	-2	Nonan
11,7	-3	-3	-3	Benzaldehyd
13,5	-3	-3	-3	Limonene
15,0	-4	-3	-4	Nonanal
17,2	-	-2	-	Dekanal

Table 6: Identified values of hedonic tone and intensity of odour emitted by the foams after 672 hours

The retention time	Hedonic effect / Intensity			VOC
	V5020	Latex	N5063	
5,7	-3	-1	-2	Toluene
9,5	-	-3	-3	Styrene
10,3	-4	-4	-	Nonan
11,7	-3	-4	-4	Benzaldehyd
13,5	-	-5	-	Limonene
15,0	-5	-4	-4	Nonanal
17,2	-2	-4	-3	Dekanal

By comparing individual foams, we found that the material composition affects the hedonic tone and intensity of an odour. For the same substance VOCs changes either the intensity of the odour but also changes the Hedonic tone. In essence, this means that evaluation e.g. hedonic effect of toluene by individual foams is different are listed in Tab. 6. VOCs that have been evaluated by assessors over time and may vary so that the foam material will not be recorded after 72 hours, but will be examined after 672 hours. For Example such a substance is nonan in viscoelastic foam V5020. These VOCs were possible to identify. Further measurement will complement other VOCs regarding to hedonic tone and intensity of the odour, which could not be identified.

CONCLUSIONS

The aim was to assess the initial measurement of materials used in the manufacturing of upholstered furniture, especially mattresses by method, which is called olfactometry indirect. At the same time, determination of the effect of the emission load of volatile organic compounds (VOCs) including parameter TVOC took place.

From the measured values of the VOCs emissions that were emitted from individual test foams, it can be concluded, that the influ-

ence of time on the amount of volatile organic substances has been shown. This phenomenon is not visible by the amount of the individual concentrations of VOCs, as the concentration itself was too low, but the effect on the TVOC value it is much more significant. TVOC for latex foam and polyurethane foam decreased with time. TVOC with visco-elastic foam on the contrary, increased with time. Increased level of TVOC was caused by VOCs triethylenediamine and undecane which show the largest percentage of the TVOC value.

The method of olfactometric assessment revealed that the foams exhibit negative hedonic tone (odour) and their intensity reaches in some cases grades - 5 (extremely unpleasant). In the performed measurements, using the Olfactometric assessment, it was found that the foams exhibit significantly in connection with odours.

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