

**DYNAMICS OF EMISSION CHANGES OF VOLATILE
ORGANIC COMPOUNDS FROM WOOD SURFACE
TREATED WITH SELECTED PRODUCTS OBTAINED
FROM NATURAL OILS AND WAXES**

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ABSTRACT

The paper presents results of investigations on the emission of volatile organic compounds (VOCs) from the surface of oak wood treated with selected products obtained from natural drying oils and waxes. Volatile organic compounds were analysed using the technique of gas chromatography coupled with mass spectrometry and thermal desorption (GS/MS/TD). Tenax TA was used as the adsorption medium.

KEYWORDS: Volatile organic compounds (VOC), chamber tests, surface coatings, natural oil, wax.

INTRODUCTION

The continued tendency for the return to nature observed in recent years has resulted in increased interest in products made of wood. Furniture made of either solid wood or wood-based products finished with natural veneer are considered to be ecological and human-friendly articles. However, ecological nature of furniture depends not only on the employment of construction material used to manufacture. The finishing materials used during the production process are equally important.

Trends prevailing in recent years regarding the finishing of furniture surfaces appear to be dominated, on the one hand, by attempts to obtain finishing coatings of excellent functional traits and high durability and, on the other, by their 'ecologicality', i.e. harmlessness to people and environment. Investigations carried out in numerous research centres showed that finishing coatings of furniture and other wood products constitute a significant source of contamination of internal air (Salthammer 1997, Salthammer et al. 1999, Guo and Murray 2001, Kirkeskov et al.

2009). The principal contaminants emitted by finishing products are volatile organic compounds which may cause serious health hazards (Brinke et al. 1998, Reitzig et al. 1998, Wargocki et al. 1999, Mølhave 2003, Jensen et al. 2001, Nielsen et al. 2007).

The above explains the growing interest observed in West European countries in wood articles finished with pro-ecological products manufactured using natural raw materials, including finishers manufactured on the basis of natural drying oils and waxes.

Wood treatment with oils and waxes can be traced back to ancient times. Wood finished with these materials retains its full natural appearance and, at the same time, acquires slightly warmer colour. In addition, oils and waxes emphasise the natural patterns of wood. Surfaces finished with oils are characterised by considerable resistance to dirt, moisture and temperature changes which is associated with the fact that oils penetrate deep into wood and impregnate it. In contrast to oils, waxes do not infiltrate into deeper wood layers but create a surface protective coating. Wax finishing is not recommended if wood surface is to be exposed to continuous influence of considerable mechanical loads, high temperatures or chemical substances. Wood finished with oils or lacquers is much more resistant to this type of action. Wood surfaces finished with oils or waxes are much easier to conserve and renovate. In addition, wood articles finished using the above materials are promoted by manufacturers as entirely harmless for people.

The aim of this research project is to verify the above opinions by assessing emissions of volatile organic compounds from the surface of oak wood finished with selected products manufactured using natural drying oils and waxes.

Experiments on the type and amount of volatile organic compounds emitted by surfaces of oak wood finished with oil and wax coatings were carried out in the following cycles: 1, 14, 28, and 90 days after the application of the examined products onto the experimental samples. This experimental design allowed the authors to assess trends in the emission levels of volatile compounds in time. This type of research seems to be a necessary precondition on the way to undertake actions aiming at improving air quality in inside rooms.

MATERIAL AND METHODS

Material

The experimental material comprised of oak wood samples (*Quercus* sp.) measuring 280 x 200 x 16 mm. Experimental samples were prepared in industrial conditions. They were prepared from strips 100 mm wide glued with PVAC glue. Wood surface was sanded using sandpaper of 180 and 220 grit. Prior to experiments, sample moisture content and density were determined. Sample moisture content which was determined with the assistance of the gravimetric method ranged from 8.0 – 8.5 %, whereas wood density established in accordance with the PN-77/D-04101 (1977) standard amounted, on average, to about 680 kg.m⁻³. In order to obtain precise characteristics of the wood raw material employed in investigations, VOC emissions from oak wood samples prior to their treatment with the finishing preparations were also determined. These experiments revealed that unfinished oak wood samples emitted volatile organic compounds at the level of 70 µg.m⁻³. Acetic acid was found to be the dominant component of emissions and the amounts released were determined at 63.7 µg.m⁻³. The main reason for the employment of oak wood for the described investigations was the fact that this wood species is widely used by furniture industry.

The total of three finishing products were selected for investigations; two of them were obtained on the basis of natural drying oils (they were designated as No. 1 and 2) and one -

from waxes (No. 3). According to the manufacturers' recommendations, the selected articles are intended for finishing of surfaces of wood materials derived from different wood species used inside buildings.

Experimental samples were finished with the above-mentioned products in the amount of approximately 110 g.m⁻² sample. Oils (No. 1 and 2) were administered at commercial viscosity of 18s measured using Ford cup No. 4, whereas the experimental wax (No. 3), which was as a paste, was applied after heating up to the temperature of about 40 - 50°C. Finished experimental samples were left in the laboratory room for 24 hours which, according to the manufacturer's certificate, was sufficient time to allow samples to attain required level of dryness.

Tab. 1 presents detailed information about physico-chemical properties of finishing products selected for investigations.

Tab. 1: Technical data of the examined oils and wax (on the basis of the manufacturer' data).

Parameters	Unit	Product designation		
		1	2	3
Binding agents		Natural oil, Alkyl resin	Natural oil, Alkyl resin	Bee wax, Carnauba wax, natural oil, siccative (with Co and Zr)
Content of solid bodies	%	70	40	97
Density	g.cm ⁻³	0.90	0.84	paste
Working density	s	18	18	-

Prior to placing samples in the experimental chamber, narrow sample surfaces were covered with low-emission aluminum foil.

Sampling of VOC

Investigations of emissions (into the air) were performed using test chambers which are constructed from glass and have a volume of 225 m³. The examined samples were placed in the experimental chamber 24 hours after the application onto their surfaces of finishing coatings. Determination of volatile organic compound emissions was carried out in typical conditions in accordance with the recommendations of the RAL-UZ 38 standard: temperature - 23 ± 1°C, relative air humidity - 45 ± 1 %, air exchange rate - 1 h⁻¹, product loading factor - 1 m².m⁻³.

Investigations of VOC emissions were performed 1, 14, 28, and 90 days after finishing samples with selected products. During the first phase of experiments, i.e. after the first day, air samples from the chamber in which experimental samples were placed were collected after 2, 5, 24 and 48 hours of their exposure in the research chamber. In the remaining cases, air for analyses was collected after 24 h. The VOC analysis performed after 2, 5, 24 and 48 h made it possible to determine the dynamics of changes of compound concentrations emitted by the examined samples during the period when this emission was the highest and to characterize the impact of the sample exposure time in the research chamber on VOC emission levels.

Air samples were collected onto glass tubes filled with Tenax TA (120 mg, 35/60 mesh, Alltech Company) using a FLEC pump from the Chematec company.

In each case, we took three ambient air samples as well as samples of the air which constituted the chamber background. Air samples were collected in the amount of 1000 mL. The sample flow rate was 50 mL.min⁻¹.

Thermal desorption and GC/MS analyses

Analytes adsorbed on the Tenax TA were liberated thermally in a desorber (at the temperature of) 250°C for the period of 5 min. The released analytes were transferred in a stream of inert gas flowing with the velocity of 20 cm³.min⁻¹ into a microtrap. At desorption termination, analytes from the microtraps were thermally released for 90 sec. (at the temperature of) 250°C and directed to the head of the chromatographic column.

The chromatographic analysis of the desorbed analytes was carried out in gas chromatographer coupled with a mass spectrometer and thermal desorber in conditions shown in Tab. 2.

Tab. 2: Parameters of the TD/GC/MS analytic system.

Elements of measuring system	System's working conditions
Injector	Thermal desorber connected to sorption microtrap; Purging gas: argon at 20 m ³ .min ⁻¹ ; Purge time: 5 min. Desorption temperature: 250°C Sorbent: 80 mg Tenax TA/30 mg Carbosieve III; Desorption temperature: 250°C for 90 s
Microtrap	
Gas chromatograph	TRACE GC, Thermo Finnigan RTX – 624 Restek Corporation, 60 m x 0.32 mm ID; D _f – 1.8 µm: 6 % cyanopropylphenyl, 94 % dimethylpolyoxosilane Mass spectrometer (SCAN: 10 – 350) Helium: 100 kPa, ~2 cm ³ .min ⁻¹ . 40°C for 2 min, 7°C min ⁻¹ to 200°C, 10°C min ⁻¹ to 230°C, 230°C for 20 min.
Column	
Detector	
Carrier gas	
Temperature settings	

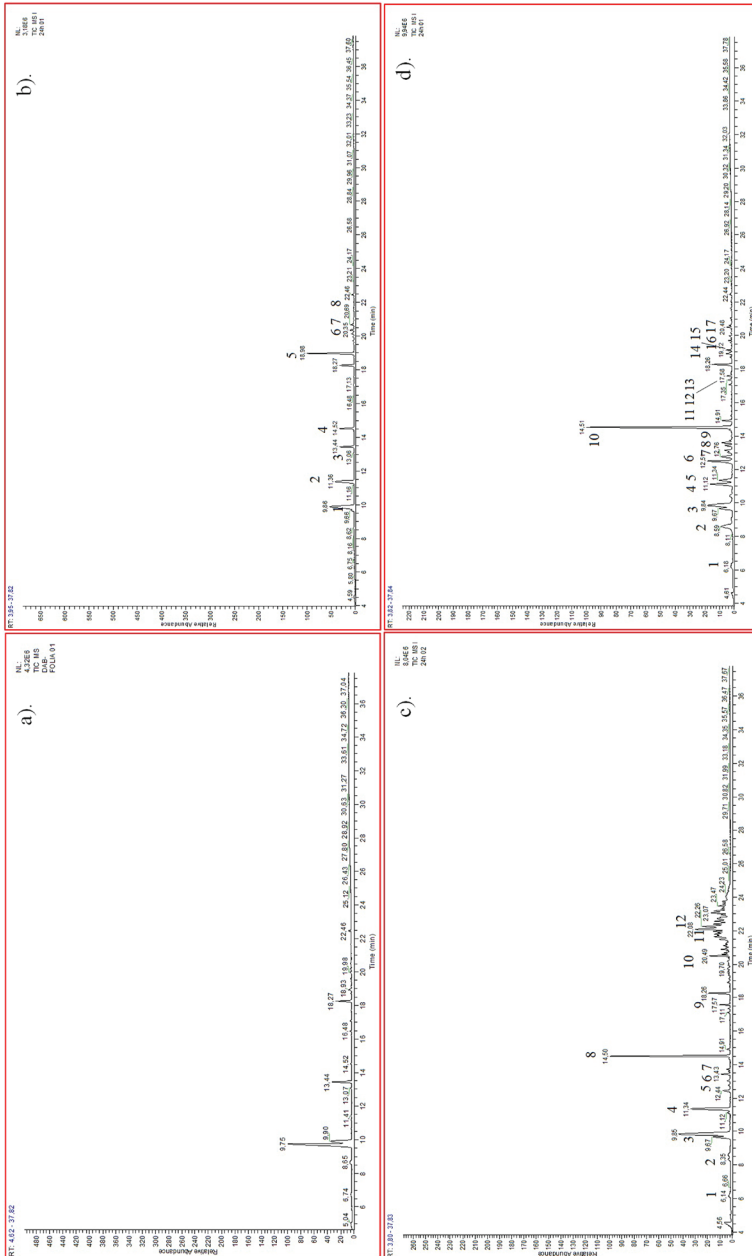
Qualitative and quantitative analysis

All mass numbers between 30 and 350 m/z were recorded (SCAN technique). Individual compounds were identified by comparing the obtained mass spectra with the spectra stored at the NIST MS Search library – program version 1.7 and were then confirmed by juxtaposing mass spectra and retention times of the identified compounds with the spectra and retention times of appropriate standards.

The quantitative analysis of VOC emitted from the examined wood surfaces was carried out using the method of addition of the 4-bromofluorobenzene standard.

RESULTS

Following the performed chromatographic analysis by means of gas chromatography coupled with mass spectrophotometer, chromatograms were obtained illustrating separation of volatile organic compounds emitted by the examined materials. GC chromatograms obtained during the first phase, i.e. 24 h after sample exposure in the research chamber are presented in Fig. 1. On the other hand, Tabs. 3–5 show lists of individual compounds released from oak wood surfaces finished with products manufactured on the basis of natural drying oils and waxes together with the results of their quantitative determinations during the period of 90 days following their treatment.



Tab. 3: Results of emission investigations of volatile organic compounds from oak wood surfaces finished with oil 1.

Compound	Peak number*	RT** (min)	Concentration ($\mu\text{g}\cdot\text{m}^{-3}$)						
			1 day				14 days	28 days	90 days
			2 h***	5 h***	24 h***	48 h***	24 h***		
Acetic acid	1	9.66	26.3	26.6	17.2	13.8	4.5	1.8	-
Pentanal	2	11.36	389.5	308.6	189.4	161.2	80.4	58.7	30.2
Toluene	3	13.03	8.9	13.3	6.4	4.7	3.2	1.1	-
Hexanal	4	14.52	152.2	137.4	116.2	105.9	49.2	31.1	12.8
o-xylene	-	17.08	11.6	-	-	-	-	-	-
2.2.4.6.6-pentamethylheptane	5	18.98	801.6	604.9	386.7	282.7	86.6	51.4	33.1
1.3.5-trimethylbenzene	6	19.96	17.8	13.4	10.3	4.3	2.1	-	-
2.2.4.4-tetrametyloctane	7	20.35	65.8	45.6	26.5	18.4	4.9	2.1	-
n-undecane	8	21.62	99.4	44.1	52.4	46.1	5.1	3.2	2.1
other aliphatic hydrocarbons	-	-	38.2	28.5	14.3	8.2	-	-	-
Σ unidentified compounds	-	-	32.1	26.8	17.2	8.4	1.1	1.2	7.0
TVOC:			1643	1249	837	654	237	151	85

* Peak number correspond with assignments in Fig. 1b.

** RT - retention time

*** Sample exposition time in experimental chamber

Tab. 4: Results of emission investigations of volatile organic compounds from oak wood surfaces finished with oil 2.

Compound	Peak number*	RT** (min)	Concentration ($\mu\text{g}\cdot\text{m}^{-3}$)						
			1 day				14 days	28 days	90 days
			2 h***	5 h***	24 h***	48 h***	24 h***		
Propanal	1	6.14	21.9	18.6	8.9	7.6	4.5	1.2	-
Butanal	2	8.35	25.7	20.4	9.7	8.9	6.7	3.8	3.2
Acetic acid	3	9.67	77.5	50.6	36.4	29.8	4.4	-	-
Pentanal	4	11.34	343.8	250.9	112.5	95.5	14.5	2.8	2.2
Propanoic acid	5	12.44	24.7	22.5	13.8	9.5	2.5	-	-
Toluene	6	13.03	9.3	8.1	7.6	4.2	3.3	1.2	1.2
1-pentanol	7	13.72	15.7	10.3	4.8	4.4	2.1	-	-
Hexanal	8	14.50	708.4	568.2	266.5	182.4	32.4	20.2	6.2
Heptanal	9	17.57	60.4	52.9	42.6	34.5	5.7	1.4	1
Octanal	10	20.49	54.8	49.9	36.8	27.9	6.2	4	3.8
n-undecane	11	21.66	70.8	59.5	32.1	22.5	4.8	4.6	2.6
n-dodecane	12	22.08	117.3	98.9	76.8	47.3	8.6	7.2	4.1
other aliphatic hydrocarbons	-	-	345.8	322.5	243.1	170.6	34.3	24.8	7.5
Σ unidentified compounds	-	-	98.7	79.2	46.5	28.2	5.6	4.2	1.1
TVOC:			1975	1613	938	673	136	75	33

* Peak number correspond with assignments in Fig. 1c.

** RT - retention time

*** Sample exposition time in experimental chamber

Oak wood samples finished with the examined materials one day after their treatment and 2-h exposure in the research chamber emitted volatile organic compounds in amounts ranging from 1643 to 2701 $\mu\text{g}\cdot\text{m}^{-3}$. The concentration of these compounds in the course of 5-h sample exposure in the chamber decreased to the level of 1249 to 1709 $\mu\text{g}\cdot\text{m}^{-3}$, while during 24-h exposure, it fell to 837 to 1185 $\mu\text{g}\cdot\text{m}^{-3}$. After 48 h from the moment the samples were placed in the chamber, the amount of released compounds fluctuated from 654 to 689 $\mu\text{g}\cdot\text{m}^{-3}$.

The obtained research results indicate a significant impact of the sample exposure time in the chamber on the content of VOCs. The comparison of the results obtained after 2-, 5-, 24- and 48-h sample exposure in the research chamber revealed that emission changes were most intense during the first 24 h. During this period of time, emissions of volatile compounds declined in the case of oak wood samples finished using oil 1) by about 49 % and of those finished with oil (2) and wax (3) – by approximately 53 and 56 %. During the 48 h, concentrations of the emitted harmful substances were reduced significantly by about 60-74 %. The dynamics of quantitative changes of volatile substances released by the examined samples in the course of 48-h exposure in the research chamber are shown in Fig. 2.

Tab. 5: Results of emission investigations of volatile organic compounds from oak wood surfaces finished with wax 3.

Compound	Peak number*	RT** (min)	Concentration ($\mu\text{g}\cdot\text{m}^{-3}$)						
			1 day				14 days	28 days	90 days
			2 h***	5 h***	24 h***	48 h***	24 h***		
Propanal	1	6.18	63.3	56.7	21.1	12.7	-	-	-
Butanal	2	8.59	108.9	30.2	81.2	49.4	7.3	5.2	3.2
Acetic acid	3	9.67	151.4	106.3	48	22.8	1.9	1.9	-
1-penten-3-ol	4	11.12	259.9	172.8	117.7	77.4	5.8	2.4	1.9
Pentanal	5	11.34	169.1	113.5	68.9	41.3	2.2	2.2	-
Propanoic acid	6	12.51	158.1	147.3	112.4	72.1	8.5	6.2	-
Toluene	7	13.03	16.1	15.5	14.9	9	7.3	4.2	2.6
2-pentenal	8	13.11	54	40.4	28.4	17	5.2	4.2	-
1-pentanol	9	13.74	59.5	46.9	36.4	21.8	3.1	1.7	1.3
hexanal	10	14.51	1377.4	796.5	496.7	267.6	46.9	38.1	9.1
o-xylene	11	17.07	2.9	3	2.8	1.7	-	-	-
1,2-epoxyheptane	12	17.35	14.2	10.5	10.4	6.2	1.7	-	-
Heptanal	13	17.58	20.7	1.7	11.4	6.8	3.3	3	1.9
1,2,3- trimethylbenzene	14	18.92	13.6	12.6	11.5	6.9	5.9	3.4	1.6
1-ethyl-4-methylbenzene	15	19.98	13.1	12.8	7.1	4.3	2.3	1.2	-
1,3,5-trimethylbenzene	16	20.48	7.1	6.3	6.7	4	3.2	3.2	2.4
other aliphatic hydrocarbons	-	-	45.2	31.2	19.7	17.2	4.2	2.9	-
Σ unidentified compounds	-	-	166.4	105.2	89.2	51.2	11.9	8.8	3.2
TVOC:			2701	1709	1185	689	121	89	27

* Peak number correspond with assignments in Fig. 1d.

** RT - retention time

*** Sample exposition time in experimental chamber

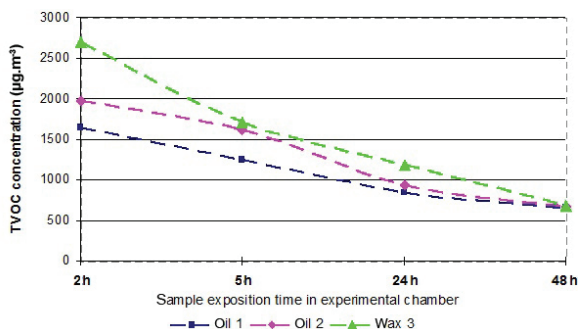


Fig. 2: Dynamics of concentration changes of volatile organic compounds during 48-hour oak wood sample exposure finished with oils and wax.

After 14 days, the amount of released compounds fluctuated at the level of 121–237 $\mu\text{g.m}^{-3}$. The lowest emission drop during this period amounting to nearly 86 % was determined in samples finished with oil (1), while the highest – in the range of 96 % – was determined in samples treated with wax.

In the course of the consecutive 14 days, the amount of volatile compounds released into the air by the examined samples declined to 75–151 $\mu\text{g.m}^{-3}$.

Continued conditioning of samples in laboratory conditions resulted in further changes in the amount of volatile organic compounds released by them. After 90 days, concentrations of VOCs dropped to below 100 $\mu\text{g.m}^{-3}$ in case of all examined samples. The highest emissions – at the level of 85 $\mu\text{g.m}^{-3}$ – were determined in case of samples treated with oil (1). Wood samples finished using oil (2) and wax (3) released significantly lower quantities of volatile organic compounds, namely: 33 and 27 $\mu\text{g.m}^{-3}$, respectively.

Fig. 3 presents trends in quantity changes of volatile organic compounds released by oak wood samples finished with products obtained from natural materials, drying oils and waxes during the period of 90 days.

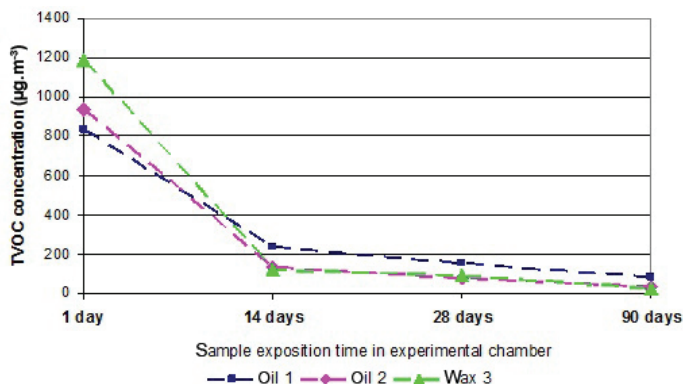


Fig. 3: Change dynamics in the quantities of volatile organic compounds emitted from oak wood surfaces finished using natural oils and wax during the period of 90 days.

The main compounds determined in the air collected from the research chamber filled with oak wood samples finished by natural oils and wax comprised, primarily, compounds from the group of aldehydes, aliphatic hydrocarbons, organic acids and alcohols.

The main constituents of emissions from samples coated with natural oils included aliphatic hydrocarbons and aldehydes. The samples covered with oil (1) released the highest quantities of aliphatic hydrocarbons. During the first stage of investigations, following 24-h sample exposure in the chamber, the proportion of aliphatic hydrocarbons in the total emission was 57 %. Quantitatively, the dominant compound was 2,2,4,6,6-pentamethylheptane and its concentration was determined at $386.7 \mu\text{g}\cdot\text{m}^{-3}$. With regards to aldehydes, pentanal and hexanal were found to be released from the samples treated with oil (1) at the highest quantities. Pentanal concentrations during the first stage of investigations reached $189.4 \mu\text{g}\cdot\text{m}^{-3}$ (24 h), whereas those of hexanal were lower and amounted to $116.2 \mu\text{g}\cdot\text{m}^{-3}$.

The samples finished with oil (2) emitted the highest quantities of aldehydes, with hexanal and pentanal dominating emissions in the first stage. 24-hours after the test started both compounds represented 79 % of all aldehydes and 40 % of all VOC, respectively. Coatings of oil (2) liberated a distinctly wider spectrum of compounds from the group of aliphatic hydrocarbons than coatings of oil (1) but their quantities were noticeably lower. Majority of them were difficult to identify due to closeness of their retention times as well as considerable similarity of fragmentation pathways. The compound from the group of aliphatic hydrocarbons whose quantities released from samples finished with oil (2) were the highest, was n-dodecan – $76.8 \mu\text{g}\cdot\text{m}^{-3}$.

Emissions released from the wax (3) coatings covering the surface of oak wood contained mainly aldehydes which, in total, made up over 60 % of all liberated compounds. In addition, the emissions also contained significant quantities of alcohols (13 %) and organic acids (13.4 %). The compound whose quantities were the highest was hexanal as its concentration 24 h after the treatment of oak samples with wax was determined at the level of $496.7 \mu\text{g}\cdot\text{m}^{-3}$. The remaining identified aldehydes released from oak wood samples at lower levels included: Propanal, butanal, pentanal, heptanal and octanal. In addition, wax-finished oak wood samples released relatively high quantities of 1-penten-3-ol $117.7 \mu\text{g}\cdot\text{m}^{-3}$ and propionic acid – $112.4 \mu\text{g}\cdot\text{m}^{-3}$.

DISCUSSION

The spectrum of identified compounds was consistent with those from earlier studies on VOC emissions in indoor air and emissions from different materials. Tests on refining coats prove that the amount of released volatile substances changes within a very broad range. The level of TVOC emissions depends on many factors e.g. on the type of applied refining material, the type of material onto which the coat was transferred and on the time which has passed from the formation of the coat.

Studies on products based on oils and waxes were also conducted e.g. by Guo and Murray 2001; Jensen et al. 2001; Kreskov et al. 2009.

The ECA report No. 18 (1997) presents results of studies on VOC emissions from wax used in finishing of wooden floors. It was applied to cover prefabricated beech parquet. Analyses conducted after 3, 14, 28 and 42 days showed that VOC emission after three days was high, amounting to $27628 \mu\text{g}\cdot\text{m}^{-2} \text{ h}$. After 42 days it decreased over 30 times to $750 \mu\text{g}\cdot\text{m}^{-3} \text{ h}$. The tested material was the source of emissions of a wide spectrum of compounds. It released compounds belonging mainly to the group of aliphatic and aromatic hydrocarbons, as well as terpenes. Compounds emitted in greatest amounts were α -pinene, β -pinene, limonene as well as

decane and undecane.

Guo and Murray (2001) tested three typical furniture polishes. One was an aerosol spray, one was an emulsion polish, and one was a solvent polish. These products contained natural oils and waxes as their main ingredients. The solvent polish, apart from natural oil, contained also toluene, benzene, xylene isomers, styrene, methylisocyanate, limonene and camphene. Wax was the main component of the aerosol spray polish, while the emulsion polish contained wax, toluene, benzene, xylene isomers, styrene, limonene and camphene.

The measured TVOC concentration released from the aerosol spray furniture polish increased rapidly to the maximum of $4250 \mu\text{g}\cdot\text{m}^{-3}$. The maximum TVOC concentration from the emulsion polish was $4520 \mu\text{g}\cdot\text{m}^{-3}$ and from the solvent furniture polish it increased rapidly to a maximum value of $584 \mu\text{g}\cdot\text{m}^{-3}$ (Guo and Murray 2001).

Results of analyses of aldehyde and hydrocarbon emissions from beech refined with two products based on linseed oil were presented by Jensen et al. (2001). The product based on linseed oil and urethane alkyd emitted greater amounts of both aldehydes and hydrocarbons in comparison to the product, which apart from linseed oil contained also natural resin. Analyses of emissions were conducted in three stages, i.e. after 4, 11 and 27 days. Emission of aldehydes from the product containing urethane alkyd amounted to approx. $550 \mu\text{g}\cdot\text{m}^{-2} \text{ h}$ after 4 days, whereas after 27 days it dropped to $27 \mu\text{g}\cdot\text{m}^{-2} \text{ h}$. In turn, a lower aldehyde emission was recorded from the surface of beech wood covered with the product based on linseed oil and natural resin. After three days it amounted to approx. $300 \mu\text{g}\cdot\text{m}^{-2} \text{ h}$, while after 27 days it was approx. $100 \mu\text{g}\cdot\text{m}^{-2} \text{ h}$.

Emission of hydrocarbons from oiled beech in case of urethane alkyd ranged from approx. $6000 \mu\text{g}\cdot\text{m}^{-2} \text{ h}$ after 4 days to approx. $2000 \mu\text{g}\cdot\text{m}^{-2} \text{ h}$ after 27 days. In turn, the amount of hydrocarbons released from beech refined with the product based on natural resin was lower, similarly as in case of aldehyde emissions. After 4 days it amounted to approx. $2100 \mu\text{g}\cdot\text{m}^{-2} \text{ h}$, while after 27 days it decreased to $1500 \mu\text{g}\cdot\text{m}^{-2} \text{ h}$.

Exotic wood elements coated with oils and waxes were evaluated in terms of their health impact by Kreskov et al. (2009). They tested products refined with waxes and oils. The total amount of emitted volatile compounds ranged from 67 to $6445 \mu\text{g}\cdot\text{kg}^{-1}$. A product (bedside table) made from wax-coated sheesham (*Dalbergia latifolia*) emitted volatile substances at $819 \mu\text{g}\cdot\text{kg}^{-1}$.

A floor element made from oil-coated merbau (*Intsia bijuga*) emitted $6445 \mu\text{g}\cdot\text{kg}^{-1}$ harmful substances, while from a kitchen table top made from oil-coated iroko (*Chlorophora excelsa*) it was $1739 \mu\text{g}\cdot\text{kg}^{-1}$. The qualitative analysis of emitted compounds showed that these materials were sources of emissions of aldehydes, alcohols, ketones, aliphatic and aromatic hydrocarbons, esters and terpenes. The element made from wax-finished sheesham emitted formaldehyde, acetaldehyde, propanal, butanal, hexanal, acetone, 2-methyl-1-propanol, butanol, 1-methoxy-2-butane, 3-methylhexane, toluene, methylcyclohexane, butyl acetate and α -pinene. Oil-coated elements emitted also a wide spectrum of compounds. The element made from merbau emitted formaldehyde, acetaldehyde, butanol, pentanal, hexanal, benzaldehyde, decanal, butyl acetate, 2-butanone, acetone, 2-methyl-1-propanol, 2-ethyl-1-hexanol, 3-methylhexane, tridecane and propanal. The product made from oil-coated iroko released into the air a narrower spectrum of compounds than the product from oil-coated merbau, i.e. formaldehyde, acetaldehyde, hexanal, acetone, 2-butanone, 3-methylhexane and α -pinene.

Based on the recorded results of analyses presented in this paper and studies conducted by other authors it may be stated that VOC emissions from products containing oils and waxes vary in terms of both amounts and types of released compounds. It can also be concluded, that wood materials finished with products manufactured on the basis of natural oils and waxes can lead to temporary air contamination with volatile organic compounds. In addition, the performed

investigations confirmed the need for qualitative and quantitative characterisation of harmful substances released by these finishers.

CONCLUSIONS

1. On the basis of the obtained research results it was concluded that finishing coatings were the main source of emissions of the majority of the determined compounds. Untreated oak wood was found to release, primarily, acetic acid ($70 \mu\text{g}\cdot\text{m}^{-3}$, 24-h sample exposure).
2. From among all the experimental samples finished with products manufactured on the basis of natural oils and waxes, wood samples treated with wax were characterised by higher emissions of volatile organic compounds. Twenty four hours after finishing and 24-h exposure in the research chamber, the samples showed over 20 to 30 % higher emissions than samples finished with the examined oils.
3. The principal constituents released by oak wood samples finished using natural oils comprised of aliphatic hydrocarbons and aldehydes, whereas samples finished with wax liberated, primarily, aldehydes.
4. The TVOC concentration resulting from the tested materials reached increased to a maximum value within 2 h from the moment the samples were placed in the chamber. The maximum concentration was $1643 - 2701 \mu\text{g}\cdot\text{m}^{-3}$.
5. Investigations on the dynamics of the disappearance of emissions of volatile organic compound emissions revealed that the highest decline in the amounts of liberated compounds occurred during the first 24-hour sample exposure in the research chamber. During this period of time, levels of volatile organic compound emissions from the examined samples decreased by about 49 – 56 %. In the course of the 14-day seasoning of samples, quantities of the emitted compounds dropped by about 72 to 90 %, while after 3 months – by about 90 to 98 %.

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