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Emission of volatile organic compounds from wood of exotic species

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Summary: *The paper presents results of analyses concerning emissions of volatile organic compounds (VOC) from four exotic wood species: teak, zebrawood, wenge and merbau. Tested material came from Polish wood sector enteprises. Emissions of VOC were analysed using the chamber method. It was found that analysed exotic wood species showed low emission levels of volatile organic compounds. They mostly emitted aldehydes.*

Key words: volatile organic compounds (VOC), chamber analyses, exotic wood

INTRODUCTION

Wood and wood products constitute emission sources of volatile organic compounds. The type and amounts of emitted volatile organic compounds from solid wood to a considerable degree depend on the species. This fact was confirmed by studies conducted e.g. (Roffael 2006, Risholm-Sundman et al. 1998). Hardwood species release mainly carbonyl compounds (aldehydes, ketones, carbonyl acids and their derivatives) and alcohols. Compounds emitted by most hardwood species include hexanal and pentanal. They are formed in the reaction of oxidation of unsaturated fatty acids found in wood (Risholm-Sundman et al. 1998). Many hardwoods release also acetic acid. It is formed from the hydrolyses of acetyl groups in hemicelluloses. In turn, softwoods emit considerable amounts of terpene compounds, mainly α- and β-pinene and Δ3-karene. The spectrum of terpene compounds released by softwood is wider and includes not only bicyclic, but also monocyclic monoterpenes (limonene, β-phellandrene, terpinolene and aromatic compounds (p-cymene) (Czajka and Fabisiak 2012).

However, emissions of volatile organic compounds depend not only on wood species, but also on drying and storage conditions (Lavery and Milota 2000, Milota 2000, Manninen et al. 2002, Roffael 2006). A study by Manninen et al. 2002 showed that the composition of emissions from air-dried wood differs from that of heat-treated wood. In turn, Roffael (2006) showed that emissions from wood decrease during storage.

Analyses of emissions of volatile organic compounds from wood of European species were presented in numerous publications, e.g. Risholm-Sundman et al. (1998), Solliday et al. (1999), Banerjee (2001), Jensen et al. (2001), Manninen et al. (2002), Roffael (2006) and Czajka and Fabisiak (2012).

Much less is known on the type and amounts of volatile substances released by exotic wood species. Scientific publications show that exotic material may release hazardous substances (Kirkeskov et al. 2009, Krauss et al. 2011, Waliszewska et al. 2013).

In view of the above the aim of this study was to determine the type and amounts of volatile compounds, which were may be emitted to air by selected exotic wood species, i.e. wenge, zebrawood, merbau and teak. In order to determine the actual hazard posed by this wood it was decided to test raw materials sold by Polish wood sector enterprises.

MATERIAL AND METHODS

Four exotic wood species were selected for analyses: teak (*Tectona* L.f.), zebrawood (*Microberlinia brazzavillensis* A. Chev.*)*, wenge (*Millettia laurenntii* Wild.) and merbau

(*Intsia* sp.). Tested exotic wood came from several wood sector enterprises, from which it was difficult to obtain reliable information concerning storage time and drying conditions. Samples of 280 x 200 x 16 mm were prepared under production conditions. They were collected from strips of 100 mm in width, glued with polyvinyl acetate adhesive. Wood surface was polished using abrasive papers with grit of 180 and 220.

Sample moisture content was determined using gravimetric method in accordance with PN-77/D-04100, while density was determined by stoichiometry according to the standard PN-77/D-04101, which results are presented in Table 1.

Table 1. Moisture content and density of tested wood species

Species	**Moisture content** [%]	**Density** [kg/m^3]
Teak	8,0	637
Zebrawood	7,2	738
Wenge	6,8	824
Merbau	8,5	869

Chamber tests and TD/GC/MS analyses

All the experiments were carried out in a 0.225 m^3 glass chamber under the following conditions: temperature: 23 ± 2°C, relative humidity: 45 ± 5%, air exchange rate: 1 h^{-1} and loading factor: 1.0 m^2/m^3. Air samples were collected on a Tenax TA (35/60mesh, Alltech Company) at a 1l total volume and at a flow rate of 100 ml/min. Analytes adsorbed on the Tenax TA were analysed using a GC/MS apparatus, equipped with a thermal desorber, according to the procedure presented in Table 2.

Table 2. Operating conditions of TD/GC/MS

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
Microtrap	Sorbent: 80 mg Tenax TA/30 mg Carbosieve III; Desorption temperature: 250°C for 90 s
Gas chromatograph	**TRACE GC, Thermo Finnigan**
Column	RTX – 624 Restek Corporation, 60m x 0.32mm ID; D_f – 1.8 μm: 6% cyanopropylphenyl, 94% dimethylpolyoxosilane
Detector	Mass spectrometer (SCAN: 10 – 350)
Carrier gas	Helium: 100 kPa, ~2 cm^{3}min^{-1}.
Temperature settings	40°C for 2min, 7°C min^{-1} to 200°C, 10°C min^{-1} to 230°C, 230°C for 20 min.

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 the mass spectra and retention times of the identified compounds with the spectra and retention times of appropriate standards.

Quantitative analyses of VOCs emitted from the examined wood surfaces were carried out by adding the 4-bromofluorobenzene standard (Supelco).

RESULTS

Results of analyses concerning concentrations of volatile substances from exotic wood species are presented in Table 3.

Table 3. Concentrations of volatile organic compounds from exotic wood species in [µg/m^3]

Związek	Merbau		Wenge		Zebrawood		Teak	
	24h	**72h**	**24h**	**72h**	**24h**	**72h**	**24h**	**72h**
Aldehydes								
pentanal	13,2	8,3	26,1	20,5	16,2	12,1	-	-
hexanal	15,8	14,2	18,6	17,3	12,1	10,5	15,2	14,3
furfural	-	-	5,2	3,5	1,2	<1	-	-
Ketones								
acetone	10,3	6,2	23,1	16,3	15,6	10,4	18,6	12,1
Other								
2-pentyl furan	-	-	3,2	<1	2,1	<1	-	-
TVOC:	**39**	**29**	**76**	**58**	**47**	**33**	**34**	**26**

TVOC: Total Volatile Organic Compunds

It was found that tested exotic wood species showed low emissions of volatile substances. Total concentrations of all identified compounds after 24h sample exposure in the chamber ranged from 34 to 76 µg/m^3. The greatest amounts of volatile substances were released to air by samples of wenge, while they were lowest from teak samples. Amounts of compounds released from merbau and zebrawood were 39 and 47 µg/m^3, respectively. After 72 h concentrations of all compounds changed within a small range of values. After 72 h total concentrations of all volatile substances were 26 – 58 µg/m^3.

The spectrum of compounds emitted by tested exotic wood species was limited. Tested exotic wood species released mainly aldehyde compounds, pentanal and hexanal. Pentanal and hexanal are compounds emitted by many wood species. They are formed through oxidation of unsaturated fatty acids found in wood (Risholm-Sundman et al. 1998). Hexanal is formed as a result of oxidation of linoleic acid, while pentanal is the product of oxidation of linolenic acid (Salthammer et al. 1999). Pentanal concentration ranged from 13.2 to 26.1 µg/m^3 after 24h sample exposure in the chamber. After 72 h it ranged from 8.3 to 20.5 [µg/m^3]. Teak was the only species, which did not release pentanal to air. Hexanal was emitted by all tested species. Concentrations of these compounds ranged from 12.1 to 18.6 µg/m^3 after 24 h and from 10.5 to 17.3 µg/m^3 after 72 h.

Wenge and zebrawood also released slight amounts of furfural and 2-pentyl furan. It may be assumed that furfural emission at 5.2 – 1.2 µg/m^3 was caused by wood drying conditions. Salthammer and Fuhrmann (2000) reported that furfural may be formed under thermal stress from degradation of polyoses (hemicelluloses).

In turn, it is assumed that 2-pentyl furan may be formed by autoxidation of linoleic acid (Krishnamurthy et al. 1967, Min and Smouse 1985).

Acetone was also detected in analysed air. All the tested exotic wood species were emission sources of this compound. Acetone concentration in the testing chamber after 24 h ranged from 10.3 to 23.1 µg/m^3, while after 72h it was from 6.2 to 16.3 µg/m^3.

CONCLUDING REMARKS

It was found that the tested exotic wood species showed low emissions of volatile organic compounds. They mainly released aldehydes. Such low amounts of emitted compounds were most probably connected with the long storage of the material and the earlier drying process.

Based on the results it may be stated that tested samples of exotic woods should not contribute to air pollution with volatile organic compounds. Thus they may be considered safe in terms of their hygienic standard. However, further qualitative and quantitative analyses are required concerning volatile substances released by exotic wood species, including teak, zebrawood, wenge and merbau. Knowledge on this subject is fragmentary and needs to be supplemented, also in terms of determination of volatile organic compounds.

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Streszczenie: *Emisja lotnych związków organicznych z drewna gatunków egzotycznych.* Praca przedstawia wyniki analizy emisji lotnych związków organicznych (VOC) z czterech gatunków drewna egzotycznego: z drewna teakowego, zebrano, wenge oraz merbau. Poddany badaniom surowiec pochodził z polskich zakładów drzewnych. Badania emisji VOC prowadzono metodą komorową. Stwierdzono, że badane gatunki drewna egzotycznego charakteryzowały się niskim poziomem emisji lotnych związków organicznych. Emitowały głównie związki należące do aldehydów.