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Emission of volatile organic compounds from cross section of spruce wood (*Picea abies* (L.) H. Karst)

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Abstract: *Emission of volatile organic compounds from cross section of spruce wood (Picea abies (L.) H. Karst).* This paper presents the results of determinations of emission level of volatile organic compounds from the zones of juvenile and mature spruce wood cross section. The tests were carried out using chamber method based on the requirements of ISO 16000 standards. Air samples were taken from the chamber after 3, 7, 14, and 28 days. During the whole test period the sample originating from mature wood zone emitted higher amounts of volatile organic compounds compared to the sample from juvenile wood zone. In both cases the composition of the analysed air was dominated by terpenes.

Keywords: spruce wood, emission of volatile organic compounds (VOC), juvenile wood, mature wood

INTRODUCTION

In recent years identification of volatile organic compounds (Volatile Organic Compounds – VOC) emitted from various products found in the surroundings of human has been the object of research of many scientific institutions. Those compounds are considered to be one of the main sources of air pollution in rooms intended for occupation by people. The level of VOC concentration is the most often monitored and the most significant indicator of indoor air quality. Most of published studies on that subject matter concern determination of the level of VOC emission from elements of indoor equipment (Cohen 1996, Rufus et al. 2001, Gaca et al. 2008).

The most often tested materials are finished wood-based panels and wood finished with lacquer and oil coatings (Czajka and Dziewanowska-Pudliszak 2011a, 2011b); whilst there is not many papers concerning identification of volatile organic compounds from solid raw wood. In that research area one may enlist the works by Roffael (2006a, 2006b), Risholm-Sundman et al. (1998), Dix et al. (2004), Wilke et al. (2012).

The quality and quantity composition of VOC is different in various wood species and determined by wood structure, climate factors (temperature, precipitation amount, insolation degree, the length of vegetative period), and habitat factors (soil quality, nutrition, tree position in a stand). The level of VOC emission is also differentiated within a tree and that is observed for species characterised by the presence of both coloured and non-coloured heartwood. In the case of coniferous wood the minor components, such as resins, aromatic oils, tannins, dyes, waxes, free fatty acids (saturated and unsaturated), fats, and gums, are primarily responsible for VOC emission. Those substances are found in wood in the amounts ranging from several to dozen or so percent and they can be removed from wood by extraction with solvents. The most often identified volatile organic compounds emitted from coniferous wood are, among others, bicyclic (α-pinene, β-pinene, 3-carene) and monocyclic (limonene, β-felandren, terpinolene, α-terpinene) monoterpenes, aromatic compounds (e.g. benzaldehyde), and aliphatic compounds (e.g. hexanal). Exceeded permissible emission levels of those compounds indoors cause many ailments of people staying in rooms (WHO 2002, Dalton 2002, EPA 2005, Miśkiewicz 2006).

The knowledge of the properties of wood originating from different parts of trunk cross section is important for the assessment of raw wood material quality. In every tree one may

distinguish between juvenile and mature wood. Those tissues are differentiated by submicroscopic, microscopic and macroscopic structure, chemical composition, and properties stemming from those characteristics. The differences between the properties of juvenile and mature wood are the reason for heterogeneity of raw wood material, and thus its technical quality (Alteyrac et al. 2006, Moliński et al. 2008).

In order to carry out a full assessment of the properties of wood and its suitability for various applications, it is also important to identify differences in VOC emission levels from juvenile and mature wood zones.

For a few years research on VOC emission from various materials, including solid fresh wood, has been carried out in the Wood Technology Institute. The aim of the research presented in this paper was to determine differences in VOC emission from juvenile and mature zones of spruce wood cross section. The obtained results will allow completion of former knowledge of the effect of the level of VOC emission from products made of spruce wood on the quality of air in rooms intended for occupation by people.

MATERIALS AND METHODS

Material for the tests was obtained from a 104 years old Norway spruce wood from Forest Inspectorate in Łopuchówko. 5 cm thick discs cut out from the tree diameter breast height were taken for testing. Based on determinations of radial variability of tubule length, which were carried out in previous tests on the same test material, a border between juvenile and mature wood zones was determined on the cross section (Fabisiak et al. 2013). Then samples for determination of VOC emission were cut out from those zones. The dimensions of the samples were so selected that the total surface of the cross section planes exposed in a test chamber was 0.025 m^2 (test chamber load 1 m^2/m^3). The assumption was that only the emission of volatile organic compounds from the cross section would be determined, therefore other edges of the samples were covered with aluminium tape.

All determinations of VOC emission from the tested materials were performed using chamber method according to ISO 16000-6 and ISO 16000- 9. A glass test chamber with a volume of 0.025 m^3 was equipped with suitable accessories such as inlet and outlet ports for airflow and an inlet port for temperature/humidity measurements.

The chamber was placed in an air-conditioned room. Chamber air was sampled after 3, 7, 14, and 28 days. Glass sorbent tubes were used to collect emissions. The tubes were packed with one layer of Tenax TA.

The analysis was carried out using the GC/MS system (Thermoquest Finnigan Trace 2000) coupled with a thermal desorption unit (Master TD made by DANI Instruments), according to ISO 16000-6.

The content of volatile organic compounds was expressed as TVOC sum determined in toluene equivalents based on calibration.

The target compounds were identified using the NITS MS library and an in-house database of the GC retention times for the compounds. Individual VOC and unidentifiable compounds emitted from wood were quantified by the response factor of toluene and expressed as toluene equivalents (TE).

RESEARCH RESULTS AND DISCUSSION

The sums of concentrations of all the volatile organic compounds (TVOC) emitted from the cross section of the samples of juvenile and mature spruce wood after 3, 7, 14, and 28 days of exposure are presented in figure 1. For a given exposure time three air samples were taken for analysis and for particular identified compounds an average result of three determinations was calculated.

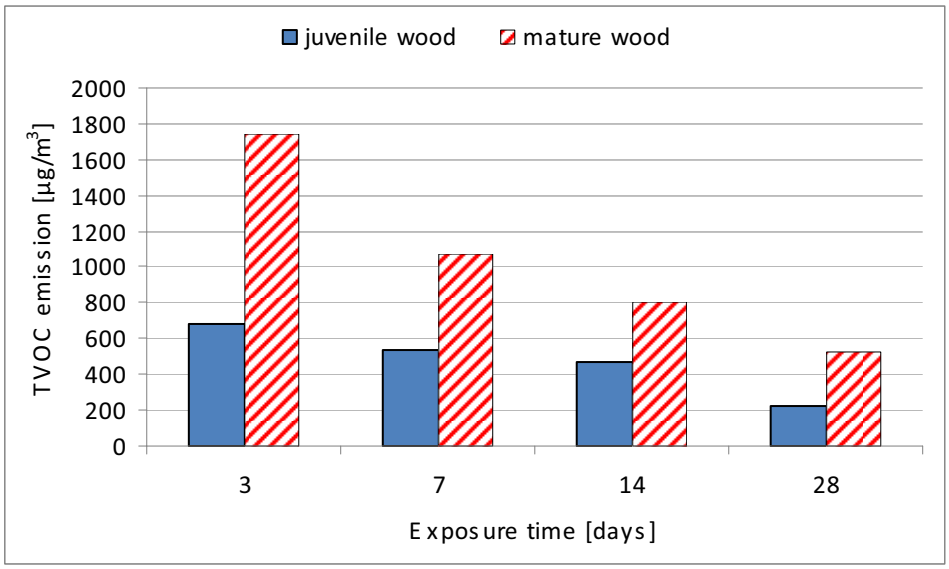

Figure 1. The effect of exposure time on the sum of concentrations of volatile organic compounds (TVOC) from the cross section of juvenile and mature spruce wood

Throughout all the exposure period the emission of all the volatile organic compounds (TVOC) from mature wood cross section was higher compared to the samples from juvenile wood zone. At the beginning of the test period (after 3 days) the sum of concentrations of those compounds was at a level of 650 µg/m^3 in juvenile wood zone and 1730 µg/m^3 in mature wood. After 28 days concentration of compounds emitted from the analysed parts of cross section decreased 2.5 times.

Amongst VOC identified in the compared wood tissues the highest concentrations were observed in the case of terpenes (table 1). Throughout all the test period in mature wood zone those compounds accounted for the same percent (almost 90%) of total sum of the identified TVOC. On the other hand, throughout all the test period in juvenile wood zone their proportion in TVOC increased from 75% to 95%. A higher dynamics of terpene emission decrease was observed for mature wood than for juvenile wood. α-pinene, β-pinene, 3-carene, and D-limonene were the main organic compounds from that group, whose presence in the analysed air was observed.

Table 1. Emission of volatile organic compounds, belonging to particular groups of chemical compounds, from spruce wood (numerator – the results for juvenile wood; denominator – the results for mature wood)

Exposure time [days]	Terpenes	Compounds containing carbonyl group	Aliphatic compounds	Aromatic compounds	TVOC
	[µg/m^3]				
3	497 1539	93 89	44 17	18 85	652 1730
7	427 948	33 58	40 7	18 49	518 1062
14	356 719	54 41	22 8	21 35	453 803
28	212 458	4 35	3 6	5 26	224 525

In terms of emission level, carbonyl compounds were the second group of compounds emitted from both test samples. After 3 days for both tested samples concentration of those

compounds in chamber air was almost identical and equalled approx. 90 µg/m^3. The identified compounds were dominated by aldehydes: hexanal and nonanal. After a 28-day exposure of samples encompassing first dozen or so annual increments in the chamber, the emission of compounds from that group reached trace quantities. Much more of those compounds remained in mature wood, where they amounted to 40% of the initial quantity. A higher emission of aromatic compounds from the surface of mature wood was observed as well. Irrespective of the test period their concentration was 3 times higher compared to the emission from juvenile wood. The dynamics of decrease in the amount of aromatic compounds in both analysed wood zones was the same and after 28 days the level of concentrations of those compounds decreased by 70%.

On comparing the emission levels of particular groups of chemical compounds identified in chamber air, it may be said that only in the case of aliphatic compounds higher concentrations were observed in juvenile wood than in mature wood. The results of the analysis of air sampled after 28 days are some exception, for in that case the emission of aliphatic compounds from juvenile wood decreased almost 15 times and was half lower than in the case of mature wood.

Similar results of quality and quantity composition of volatile organic compounds emitted from spruce wood were obtained by Ohlmeyer (2010) and Steckel et al. (2010) in their research. On testing a spruce sapwood sample they obtained the results at a level of TVOC approx. 2000 µg/m^3, and in the case of heartwood sample of TVOC approx. 500 µg/m^3. Here one should stress that the results presented in this paper concern juvenile and mature wood zones, whose widths do not encompass the same number of increments as heartwood and sapwood zones.

CONCLUSIONS

1. Throughout all the testing period the sum of concentrations of volatile organic compounds (TVOC) emitted from the zone of mature spruce wood was 2.5 times higher than that emitted from the zone of juvenile spruce wood.
2. Amongst the identified volatile organic compounds emitted from the compared wood tissues the highest concentrations were observed in the case of terpenes and those concentrations were higher in mature wood than in juvenile wood. Throughout all the time of exposure of the samples in the chamber the proportion of those compounds in mature wood was 90% of total amount of TVOC from that cross section zone. On the other hand, the proportion of terpenes in TVOC in the juvenile wood zone increased from 75% after the 3rd day to 95% after the 28th day of exposure of the samples.
3. After 3 days of exposure of the compared wood tissues the level of emission of compounds containing carbonyl group was unchanged (approx. 90 µg/m^3). After 28 days only insignificant amounts of those compounds remained in juvenile wood; whilst in the case of mature wood they were still 40% of their initial amount.

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Streszczenie: *Emisja lotnych związków organicznych z przekroju poprzecznego drewna świerku (Picea abies (L.) H.Karst).* W pracy przedstawiono wyniki badań emisji lotnych związków organicznych z młodocianej i dojrzałej strefy drewna świerku. Badania emisji VOC prowadzono metodą komorową. Stwierdzono, że suma stężeń lotnych związków organicznych (TVOC) emitowanych z drewna dojrzałego jest 2,5 krotnie wyższa niż z drewna młodocianego. Analiza jakościowa i ilościowa powietrza pobieranego z komory wykazała wysoką emisję terpenów z porównywanych tkanek drzewnych. W drewnie dojrzałym stanowiły one 90% całkowitej ilości lotnych związków organicznych przez cały czas trwania ekspozycji, a w drewnie młodocianym od 75% (po 3 dobach) do 95% (po 28 dobach). Stężenie związków z grupą karbonylową na początku ekspozycji było porównywalne w obu wydzielonych częściach przekroju poprzecznego i wynosiło ok. 90 $\mu g/m^3$. W miarę trwania emisji, dynamika obniżania się stężeń tych związków była większa ze strefy drewna młodocianego, w którym po 28 dobach pozostały już tylko śladowe ilości a w strefie drewna dojrzałego stanowiły jeszcze 40% początkowej ilości.

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