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## **FORMALDEHYDE CONTENT IN AND VOC RELEASE FROM PARTICLEBOARDS MADE OF FIBROUS CHIPS**

*The aim of this research was to investigate formaldehyde content in and volatile organic compounds release from particleboards produced from fibrous chips. The object of the tests were panels produced from fibrous chips of black locust Robinia Pseudoacacia L. and willow Salix Viminalis L., as well as from typical industrial particles. The results show that formaldehyde content in the panels produced from willow fibrous chips is similar to the content in the panels made of industrial particles. The concentration of total volatile organic compounds measured after 4 weeks of storage is significantly lower than the required by the existing regulations.*

**Keywords:** formaldehyde, VOC, HCHO, fibrous chips, particleboard, willow, black locust

### **Introduction**

The possibility of furniture panel production from willow and black locust fibrous chips was confirmed by mechanical strength tests and machining experiments [Kowaluk 2009; Kowaluk et al. 2010]. To produce a complete characteristic of the new, designed material the information about its hygienic properties, such as formaldehyde content and concentration of volatile organic compounds, is needed. An exceedance of safe levels of concentration of some chemical compounds, including formaldehyde, hexanal and other VOC, can be dangerous to human health. The issue is especially important when particles are bound using urea-formaldehyde resin. A systematic reduction of the perforator value during the last

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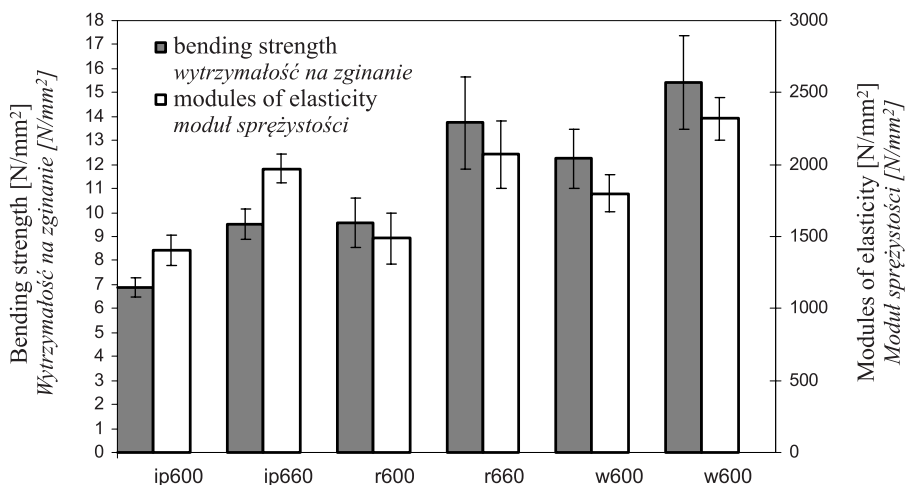
5 decades [Roffael 2006] can be an effect of the attention given to hygienic indoor environment. It is a common knowledge [Yrieix et al. 2010] that in Europe people spend almost 90% of their time inside buildings. It can substantiate the validity of research on formaldehyde content in and VOC release from the investigated panels which can be used as indoor equipment in the future.

The aim of this research was to investigate formaldehyde content in and volatile organic compounds release from particleboards produced from fibrous chips. The tested objects were panels made of fibrous chips of black locust *Robinia Pseudoacacia* L. and willow *Salix Viminalis* L. For comparison panels from typical industrial particles were produced at the laboratory scale as well.

## Materials and methods

### Particleboards

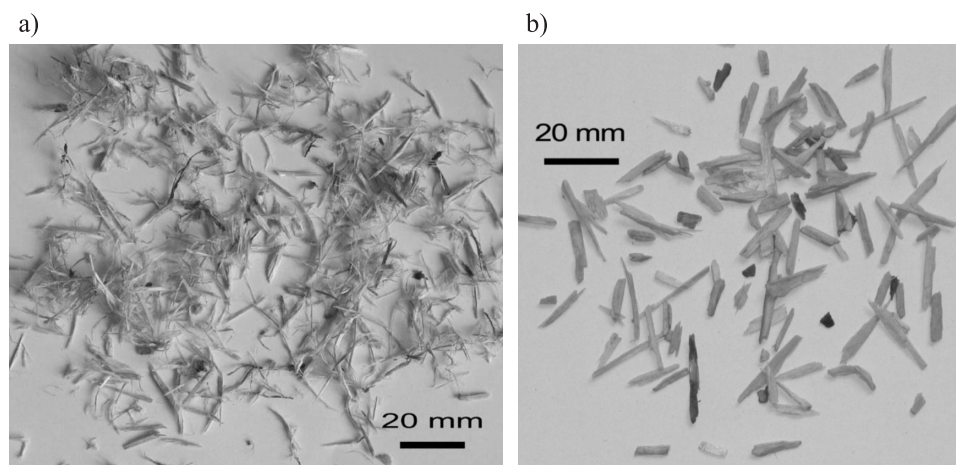
The investigated 3-layer panels were produced at the laboratory scale from fibrous chips obtained from 2 years old offshoots of black locust *Robinia Pseudoacacia* L. and 2 years old offshoots of willow *Salix Viminalis* L., as well as from industrial softwood particles. The main production parameters were: density (assumed) 600 and 660 kg/m<sup>3</sup>, core layer particles' mesh size between 2 and 8 mm, thickness 16 mm, face layers share 32 %, urea-formaldehyde resin Silekol W-1C, resination in the core 8 % and in the face layers 12 %, pressing time coefficient 10 s/mm. Finally, 6 types of the panels were produced: 2 panels of different density from industrial particles (ip600 and ip660), 2 panels of different density from black locust (r600 and r660) and 2 panels of different density from willow (w600 and w660).



**Fig. 1. Bending strength and modulus of elasticity of investigated panels**  
**Rys. 1. Wytrzymałość na zginanie oraz moduł sprężystości badanych płyt**

The tests of the produced panels showed that density variations between the assumed and the real values were less than 5 %. The mechanical parameters of the panels are presented in fig. 1. The panels were calibrated on the industrial grinding machine to achieve equal panel thickness as well as better surface roughness. A layer of the thickness of about 0.3 mm was removed from each side of a calibrated panel. After grinding, particleboards were conditioned to the equilibrium moisture content at a temperature of 20°C and relative humidity of 65 %.

The innovation in this study is the new type of the particles used to produce furniture particleboards. As it can be seen in fig. 2, fibrous chips are totally different from industrial chips. Fibrous chips are longer and have many free fibres at the ends as well as on the whole body. They are springier. The average bulk density of fibrous chips for core layer was about 20-30 kg/m<sup>3</sup>; while typical industrial core layer chips have bulk density about 150 kg/m<sup>3</sup>.



**Fig. 2. The differences between the form of fibrous chips (a) and the form of typical industrial particles (b)**

*Rys. 2. Różnice pomiędzy postacią wiórów włóknistych (a) i postacią typowych wiórów przemysłowych (b)*

### Formaldehyde content measurement

The formaldehyde content measurement was conducted according to PN-EN 120:1994 standard. Two parallel tests of one type of the panel were carried out. The results of the tests represent formaldehyde content in panels of moisture content converted into 6.5%. All panels produced at the laboratory scale were tested for formaldehyde content.

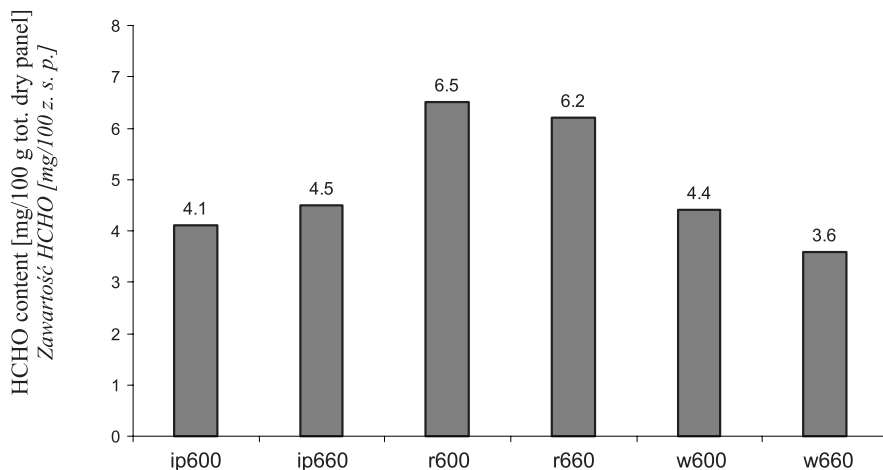
## Volatile organic compounds (VOC) measurement

Qualitative analysis and quantitative determination of VOC was carried out on GC/MS TRACE 2000 Thermoquest/Finnigan apparatus, equipped with a mass detector Finnigan Trace MS and a capillary column RTX-VMS 30m  $\times$  0.25mm  $\times$  1.4  $\mu$ m, using thermal desorption technique according to PN-EN ISO 16000-9:2006. Samples of the panels were prepared according to PN-EN ISO 16000-11:2006 and samples of emitted gas for analyses were taken in line with PN-EN ISO 16017-1:2006 regulations. The following parameters of the chamber were used: temperature 23 $\pm$ 2°C, air relative humidity 50 $\pm$ 5 %, air exchange rate 1 per hour, chamber loading rate 1 m<sup>2</sup>/m<sup>3</sup>, chamber capacity 0.025 m<sup>3</sup>. The following samples were taken for VOC tests: r660, w660 and industrial 3-layer particle-board with the density of 645 kg/m<sup>3</sup>. The VOC emission test was conducted four weeks after the production date, including conditioning time.

## Results and discussion

### Formaldehyde content

The results of the measurement of formaldehyde content in investigated panels are presented in fig. 3. As it can be seen, panels produced from black locust fibrous chips were characterised by the highest formaldehyde content. The panel of lower density had slightly higher formaldehyde content.



**Fig. 3. Formaldehyde content in investigated panels**  
*Rys. 3. Zawartość formaldehydu w badanych płytach*

This remark is true also for panels produced from willow fibrous chips. However, taking into account the notice from PN-EN 120:1994 standard stating that 20 %

differences in formaldehyde content between two parallel tests of the same panel can be acceptable, the presented differences in formaldehyde content between panels of different densities are of no practical significance.

The average formaldehyde content was comparable in the case of panels produced from industrial particles (ip600 and ip 660) and from willow fibrous chips (w600 and w660).

In the light of the study of Weigl et al. [2009], where softwood had higher wood-borne formaldehyde content, it seems interesting that higher formaldehyde content was found in panels produced from willow and black locust, i.e. from hardwood species.

### **Volatile organic compounds (VOC)**

From the point of view of particleboard end-user it is worth mentioning that the emission of VOC from tested panels made of fibrous chips, as well as from the industrial panel, was significantly low (table 1). This observation was made based on the comparison of the further presented results of VOC measurements with the research of Dziejwanowska-Pudliszak and Gaca [2004] where industrial 3-layer and 16 mm thick particleboards were tested. The above-mentioned researchers obtained the following results of tests for total VOC (TVOC): 2269 mg/m<sup>3</sup> after 5h, 1279 mg/m<sup>3</sup> after 24h, and 921 mg/m<sup>3</sup> after 48h. One of the reasons for such a low emission can be the 4 week long storage time of tested panels. Such a storage time before tests gives more useful information about the VOC emission level. The research of Kowaluk et al. [2010], which were conducted on particleboard samples conditioned unwrapped for 4 weeks, proved that panels made of maritime pine and glued with urea formaldehyde (UF) resin contained significant concentrations of  $\alpha$ -pinene and hexanal (50.3 mg/m<sup>3</sup> and 65.5 mg/m<sup>3</sup>, respectively, after 3 day emission test in a chamber). In panels produced from willow fibrous chips the concentration of hexanal was almost twice as high as the Yrieix's result (121 mg/m<sup>3</sup>), but the amount of  $\alpha$ -pinene was half the Yrieix's result (25 mg/m<sup>3</sup>) after 2 day emission test in the chamber (table 1). The concentration of the above-mentioned compounds for the panel made of black locust fibrous chips equalled 1 or less than 1. The variation of the concentrations of  $\alpha$ -pinene and hexanal for industrial panels was high, but after 2 day emission test in the chamber the amount of the above-mentioned compounds was lower than for the panels tested by Yrieix et al. [2010]. The low emission of phenolic compounds from black locust panel can be confirmed by the conclusions of Dünisch et al. [2010] stating that the juvenile wood of black locust has low content of such a component. In that research the amount of VOC sum (TVOC) was also 218.1 mg/m<sup>3</sup>. In the light of this result, panels produced from willow were characterised by TVOC of about 431 mg/m<sup>3</sup>, panels from black locust by TVOC of 50 mg/m<sup>3</sup>, and industrial panel by TVOC of 117 mg/m<sup>3</sup>. The above-mentioned values do not exceed the TVOC limits

proposed by the Committee for Health-related Evaluation of Building Products [AgBB 2008].

**Table 1. The concentration of chemical compounds in the chamber air for tested panels**

*Tabela 1. Stężenie związków chemicznych w powietrzu komory dla badanych płyt*

Chemical compound <i>Związek chemiczny</i>	Concentration in the chamber air [mg/m <sup>3</sup> ] <i>Stężenie w powietrzu komory [mg/m<sup>3</sup>]</i>		
	Exposure time [h] <i>Czas ekspozycji [h]</i>		
	48		
	w660	r660	industrial <i>przemysłowa</i>
acetone/ <i>aceton</i>	<1	4	23
acetic acid/ <i>kwas octowy</i>	77	25	5
pentanal/ <i>pentanal</i>	11	<1	8
toluene/ <i>toluen</i>	5	1	6
pentanol/ <i>pentanol</i>	25	<1	5
hexanal/ <i>heksanal</i>	121	<1	19
ethylbenzene/ <i>etylobenzen</i>	15	<1	6
<i>m</i> - and <i>p</i> -xylene/ <i>m</i> - i <i>p</i> -ksylen	12	1	8
<i>o</i> -xylene/ <i>o</i> -ksylen	14	6	1
$\alpha$ -pinene/ $\alpha$ -pinen	25	1	7
heptanal/ <i>heptanal</i>	17	<1	<1
3-carene/ <i>3-karen</i>	5	<1	6
benzaldehyde/ <i>benzaldehyd</i>	15	<1	15
octanal/ <i>oktanal</i>	26	<1	2
2-ethyl-1-hexanol/ <i>2-etylo-1-heksanol</i>	7	4	6
phenol/ <i>fenol</i>	12	<1	<1
acetophenone/ <i>acetofenon</i>	12	<1	<1
decanal/ <i>dekanal</i>	32	8	<1
SUM = TOTAL VOC <i>SUMA = TVOC</i>	431	50	117

## Conclusions

Presented results are promising as regards the production of particleboards from tested raw materials and particles (fibrous chips). The following conclusions can be drawn from this study:

- formaldehyde content in panels produced from fibrous chips of *Robinia Pseudoacacia* L. was higher than in panels produced from fibrous chips of *Salix Viminalis* L.,
- after 4 weeks of storage the concentration of volatile organic compounds, measured in the 48 h of exposure time, was the highest for panels produced from *Salix Viminalis* L. fibrous chips and the lowest for panels from *Robinia Pseudoacacia* L. fibrous chips,
- compared with other laboratory tests [Dziewanowska-Pudliszak and Gaca 2004, Roffael 2006], VOC concentration for panels produced from fibrous chips was significantly lower than for industrial particleboards.

## Acknowledgements

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## References

- AgBB** [2008]: Health-Related Evaluation Procedure for Volatile Organic Compounds Emissions (VOC and SVOC) from Building Products. <<http://www.umweltbundesamt.de/produkte-e/bauprodukte/archive/AgBB-Evaluation-Scheme2008.pdf>>
- Dünisch O., Richter H.-G., Koch G.** [2010]: Wood properties of juvenile and mature heartwood in *Robinia pseudoacacia* L. Wood Sci. Technol. 2010 [44]:301–313
- Dziewanowska-Pudliszak A., Gaca P.** [2004]: How many organic compounds does the furniture emit? *Gazeta Drzewna* 11[73]: 15, 16 (in polish)
- Kowaluk G.** [2009]: Influence of the method of milling on the geometry of fibrous chips and bending strength of produced particleboards. Proc. 3<sup>rd</sup> Int. Sc. Conf. Woodworking Techniques. Zalesina: 323-331
- Kowaluk G., Zbiec M., Beer P.** [2010]: The quality of milling of the particleboards produced from fibrous chips. Ann. WULS-SGGW, For. and Wood Technol. 71
- Roffael E.** [2006]: Volatile organic compounds and formaldehyde in nature, wood and wood based panels. *Holz als Roh- und Werkstoff* [64]: 144–149
- Schäfer M., Roffael E.** [2000]: On the formaldehyde release of wood. *Holz als Roh- und Werkstoff* [58]: 259-264
- Weigl M., Wimmer R., Sykacek E., Steinwender M.** [2009]: Wood-born formaldehyde varying with species, wood grade, and cambial age. *Forest Product Journal* [59] 1/2: 88-92
- Yrieix Ch., Dulaurent A., Laffargue C., Maupetit F., Pacary T., Uhde E.** [2010]: Characterization of VOC and formaldehyde emissions from a wood based panel: Results from an inter-laboratory comparison. *Chemosphere* [79]: 414–419

### List of standards

- ISO 16000-6:2004** Indoor air – Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID
- PN-EN 120:1994** Wood based panels. Determination of formaldehyde content. Extraction method called the perforator method
- PN-EN ISO 16000-9:2006** Indoor air – Part 9: Determination of the emission of volatile organic compounds from building products and furnishing - Emission test chamber method
- PN-EN ISO 16000-11:2006** Indoor air – Part 11: Determination of the emission of volatile organic compounds from building products and furnishing - Sampling, storage of samples and preparation of test specimens
- PN-EN ISO 16017-1:2006** Indoor. Ambient and workplace air - Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/ capillary gas chromatography - Part 1: pumped sampling

## ZAWARTOŚĆ FORMALDEHYDU I EMISJA VOC PŁYT WIÓROWYCH WYTWORZONYCH Z WIÓRÓW WŁÓKNISTYCH

### Streszczenie

Celem badań było określenie zawartości formaldehydu w płytach wiórowych wytworzonych z wiórów włóknistych i emisji lotnych związków organicznych z tych płyt. Do badań użyto wiórów włóknistych z dwuletnich odrostów korzeniowych robinii (*Robinia Pseudoacacia* L.) oraz wierzby (*Salix Viminalis* L.), jak również typowych wiórów przemysłowych. Badania wykazały, iż zawartość formaldehydu w płytach wytworzonych z wierzby jest zbliżona do zawartości formaldehydu w płytach z wiórów przemysłowych. Stężenie lotnych związków organicznych, mierzone po 4 tygodniach przechowywania płyt, jest istotnie mniejsze niż obowiązujące ograniczenia.

**Słowa kluczowe:** formaldehyd, VOC, HCHO, wióry włókniste, płyta wiórowa, wierzba, robinia