TVOC INDOOR EMISSION FROM WOOD BASED MATERIALS AND LACQUERS

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ABSTRACT
In the Department of Environment Protection in the Wood Technology Institute we carried out research of emission of Volatile Organic Compounds from materials used in furniture production.

VOC emission research from lacquered veneers made from nitrocellulose and acrylic lacquer put on glass board showed minimal higher total TVOC concentration observed in air collected from the chamber filled with lacquered boards comparing with its concentration in air supplied to the chamber. Similar low TVOC concentration was observed in research of basic wood based materials like: chipboard, veneered and laminated chipboard, MDF board and plywood. Coatings from chemsetting and polyurethane lacquer were emitted higher amounts of volatile organic compounds. Our research confirmed that lacquers play a main role in VOC emission from wood-borne materials applied in furniture production.

INDEX TERMS
VOCs, chamber method, formaldehyde, indoor air quality, VOC emission

INTRODUCTION
Quality of indoor air is especially important for human health taking into account that we spend most time indoors. Volatile Organic Compounds (VOC) are emitted to indoor environment from large number of man-made building materials, furnishing and equipment used in buildings (Berglund, Clausen De Ceaurriz, et al., 1997, Scheithauer, Aehlig, 1995). Many of these items carry precautionary labels specifying risks and procedures for safe use; some do not. Signs and symptoms of VOC exposure may include eye and upper respiratory irritation, rhinitis, nasal congestion, rash, headaches, nausea, vomiting, dyspnea and, in the case of formaldehyde vapor, epitasis (Rutkowska, 1995). They include hydrocarbons, some toxic chemicals (diethyl sulfate, tetramethyl lead) and some carcinogens (benzene, vinyl chloride). They are in gaseous form under normal atmospheric conditions. Volatile Organic Compounds are suspected to be one of the factors relating to "Sick Building Syndrome" effect (Gots, 1998).

In Germany Federal Environment Office proposed to grant quality mark for furniture which total emission of VOC doesn't exceed 300 µg/m³ (Salthammer, Marutzky, 1995)

In Poland there were determined indoors permissible concentrations of thirty VOC according to Regulation of Health and Social Welfare Minister from 12.03.1996 (Monitor Polski Nr 19, 1996). The problems on effect and emission of TVOC were considered at the 6th Polishwide Conference on Problems of indoor air quality in Poland. It was found that in schoolrooms

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there were exceeded permissible amounts of formaldehyde (Dziewanowska-Pudliszak, Gaca, 2001), toluene, xylene, decane, undecane, pentane, hexane and isopropylbenzene (Sowa, 2001). In the Department of Environment Protection of the Wood Technology Institute in Poznan research on formaldehyde emission from furniture and materials applied to their production there have been lately widening of VOC emissions emitted from elements of indoor equipment made from lacquered wood-borne materials.

MATERIALS AND METHODS
Materials
We applied following wood-borne materials in our research: fiberboard, glass board, beech wood, ash wood, spruce wood, pine wood, MDF board, plywood, chipboard, chipboard veneered with natural beech veneer, chipboard veneered with natural oak veneer, chipboard veneered with artificial finish veneer, laminated chipboard.

From applied lacquers we used: nitrocellulose lacquer, polyurethane lacquer, acrylic water-borne lacquer, chemsetting lacquer, phtalo-carbamide lacquer.

Methods
All wood-borne materials were of dimension 32x32cm and were lacquered with 10 grams of applying lacquer. After 4 hours boards were placed in chamber. All determinations of the emission of VOC and formaldehyde from indoor materials and products were conducted by chamber method (chamber of 0.6m³ capacity). Chamber was made of aluminum and was conditioned for proper temperature and relative humidity according with Polish standard PN-F-06102:1994:

- air temperature in chamber : 23°C±1°C,
- relative humidity of air: 45%±5%,
- air exchange in chamber: 1h⁻¹,
- filling up the chamber with the tested material: 1m²/m³.

The chamber was equipped with suitable accessories such as inlet and outlet ports for airflow and an inlet port for temperature/humidity measurements. This chamber was placed in air-conditioned room.

Formaldehyde was determinated by chamber method according to Polish Standard PN-F-06106-02:1994. Formaldehyde was first adsorbed in distilled water and next determinated by spectrophotometric method. Sorbent tubes constructed of glass were used for collection of emissions. The tubes were packed with one layer of Tenax GR (120mg). Before usage these tubes were conditioned at 240°C for 120 minutes and were exposed to the flow of helium at 100ml/min. In order to maintain one air exchange per hour, the sampling flow rate was set at 100ml/min, collecting for analysis 30 liters of air for a sampling period of 300 minutes. After collection of air samples chemical compounds adsorbed on traps were eluted with 1 ml of ethyl ether and pentane (1:1) mix, which contained 4 µg of tetradecane as an internal standard. After elution samples were concentrated to 20 µl.

To characterize and quantify the target compounds Gas Chromatograph/Mass Spectrometer (GC/MS) system was utilized. Target compounds were identified by retention time, full mass spectra and/or by the presence of some ion fragments. Quantitative evaluation was achieved by comparing the chromatogram peak area of each compound to the corresponding peak area
of an internal standard. Analysis was performed at Hewlett Packard HP-5890 II Gas Chromatograph coupled with quadrupole HP 5971B Mass Spectrometer. Sample (2 µl) was injected onto chromatographic column HP 5 MS. Analysis conditions of samples were as follows:

- inlet temperature - 220°C,
- GC/MS interface temperature - 280°C,
- oven temperature - 30°C (1 min) 30°C/min to 50°C (1 min) 5°C/min to 250°C (10 min),
- carrier gas flow - 0.6 ml/min.

RESULTS AND DISCUSSION
Research was conducted in the Wood Technology Institute in Poznan with the cooperation of Agricultural Academy, where chromatographic analysis of Volatile Organic Compounds has been performed. List of determination results in air of concentration of TVOC and formaldehyde emitted in chambers from materials applying to the production of indoor equipment was enclosed in Table 1.

In our research we found relatively high, changing in time, results of determinations of concentration VOC in air supplied to exchanges in chamber (41-138 µg/m³). For that reason values of TVOC emitted from testing materials were calculated from the difference of the concentration these compounds adsorbed in simultaneously receiving every time air samples at the inlet of chamber and in air supplied to chamber. TVOC values acquired in this way indicated that in comparison with the concentration of TVOC in air supplied to chamber the concentration of these compounds in air chamber filled with wood-borne materials like chipboard, chipboard veneered with natural veneer and laminated board didn’t change practically.

We found minimal increase of TVOC in air in research of MDF board, plywood, fiberboard: hard, lacquered with chemsetting lacquer (20 µg/m³) and pftalo-carbamide lacquer (23 µg/m³) and lacquered with nitrocellulose lacquer chipboards veneered with natural veneer (12 µg/m³) and also lacquered with chemsetting lacquer chipboard veneered with natural, oak veneer (8 µg/m³). However materials lacquered with chemsetting lacquer emitted amounts of formaldehyde exceeded considerably requirements (50 µg/m³) of products applied to indoor equipment purposed to permanent people stay.

Applied in research boards completely non-porous, chemical inert (glass board) and also wood-borne hard fiberboards and chipboards with oak and beech natural veneer allowed to found differences in the amounts of emitted formaldehyde and TVOC from coatings of chemsetting lacquer put on different kinds of boards. Coat of chemsetting lacquer put on glass board and chipboard veneered with oak veneer emitted balanced amounts of formaldehyde in chamber and were larger than 170 µg/m³. Coatings on fiberboard and chipboard veneered with beech veneer emitted lower amounts of formaldehyde (158 µg/m³ and 175 µg/m³ respectively). Results of concentration of TVOC determined in air chamber filled with different kinds of boards lacquered with chemsetting lacquer showed increase of TVOC in case of chipboard veneered with oak veneer and it was equal only 8 µg/m³. The same amount of lacquer put on beech veneer caused emission of volatile organic compounds giving the increase of their concentration (ΔC) was 150 µg/m³, in case of glass board half lower – 75 µg/m³. And how we already mentioned this lacquer put on fiberboard caused increase of TVOC concentration in chamber equal only 20 µg/m³.
Research of volatile organic compounds emission from polyurethane lacquer coatings put on deciduous (beech, ash) and coniferous wood (pine, spruce) and glass board pointed also at influence of kind of lacquered surface on amounts of emitted VOC, which didn’t concern in this case formaldehyde. Independently on sort of surface lacquered with polyurethane lacquer, concentration of formaldehyde in air chamber was at the “background chamber” so-called level and was equal its concentration in air of non-filled chamber.

Table 1. Summary of results of TVOC and formaldehyde concentrations

<table>
<thead>
<tr>
<th>Nr</th>
<th>Testing material</th>
<th>HCHO concentration</th>
<th>TVOC concentration</th>
<th>TVOC emitted from material (ΔC=C-C₀)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Air took from chamber</td>
<td>Air supplied to chamber</td>
<td>Air took from chamber</td>
</tr>
<tr>
<td>1</td>
<td>chipboard - beech veneer chemsetting lacquer</td>
<td>175</td>
<td>138</td>
<td>288</td>
</tr>
<tr>
<td>2</td>
<td>chipboard - oak veneer chemsetting lacquer</td>
<td>250</td>
<td>134</td>
<td>142</td>
</tr>
<tr>
<td>3</td>
<td>chipboard - artificial &quot;finish&quot; veneer</td>
<td>187</td>
<td>63</td>
<td>133</td>
</tr>
<tr>
<td>4</td>
<td>fiberboard</td>
<td>42</td>
<td>96</td>
<td>116</td>
</tr>
<tr>
<td>5</td>
<td>fiberboard - acrylic lacquer</td>
<td>-</td>
<td>101</td>
<td>152</td>
</tr>
<tr>
<td>6</td>
<td>fiberboard - chemsetting lacquer</td>
<td>158</td>
<td>96</td>
<td>116</td>
</tr>
<tr>
<td>7</td>
<td>fiberboard - phthalo-carbamide lacquer</td>
<td>75</td>
<td>65</td>
<td>88</td>
</tr>
<tr>
<td>8</td>
<td>glass board - polyurethane lacquer</td>
<td>5</td>
<td>118</td>
<td>257</td>
</tr>
<tr>
<td>9</td>
<td>glass board - chemsethane lacquer</td>
<td>250</td>
<td>65</td>
<td>140</td>
</tr>
<tr>
<td>10</td>
<td>beech wood - polyurethane lacquer</td>
<td>5</td>
<td>84</td>
<td>198</td>
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<tr>
<td>11</td>
<td>ash wood - polyurethane lacquer</td>
<td>7</td>
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<tr>
<td>12</td>
<td>spruce wood - polyurethane lacquer</td>
<td>6</td>
<td>136</td>
<td>207</td>
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<tr>
<td>13</td>
<td>pine wood - polyurethane lacquer</td>
<td>7</td>
<td>60</td>
<td>134</td>
</tr>
</tbody>
</table>

However increase of TVOC in air chamber in case of polyurethane lacquer veneer put on glass board and deciduous wood (ΔC=139 µg/m³, 114 µg/m³ and 176 µg/m³) was twice larger than in case of lacquered coatings on coniferous wood (ΔC=71 µg/m³ – spruce and 74 µg/m³ – pine). For example part of distribution of emitted VOC from polyurethane lacquer coat put on deciduous and coniferous wood was showed at graphs (fig.1 – beech, fig.2 – pine). Findings of concentration of particular compounds were average values from simultaneously acquired air samples supplied to the chamber and also took from it. In air chamber filled with
lacquered boards there was identified 28 from beech wood and 21 from pine volatile organic compounds. We also noticed some differences in the concentration of particular chemical compounds in both determinated samples.

![Figure 1. Distribution of emitted VOC from polyurethane lacquer coat put on beech](image1)

![Figure 2. Distribution of emitted VOC from polyurethane lacquer coat put on pine](image2)

Research of VOC emission in chamber which made possible the simulation of indoor conditions (temperature, relative humidity, air exchange) from materials like wood-borne boards and lacquers commonly applied to indoor equipment production, allowed to found the effect some materials on increase the VOC concentration in air. Testing materials that filled the chamber in 1m³ per 1m³ of chamber in case of chemsetting and polyurethane lacquer put on boards or deciduous veneer caused that the concentration of volatile organic compounds was equal 200-300 μg/m³. Conduct research in chamber with one air exchange per hour we controlled simultaneously air quality supplied to the chamber in 0.6 m³ amount per hour at every measure. Air supplied to chamber despite filters set contained some amounts VOC, which however were hard to eliminate.
Amounts of compounds emitted from material were calculated taking into account presence of VOC in air supplied to chamber. For the sake of that these amounts calculated from difference of determined concentrations in air chamber and at the inlet were less (100-180 µg/m$^3$) in case of above-mentioned lacquered materials. Evaluated in this manner basic wood-borne materials (chipboards, plywoods, MDF boards, laminated boards) didn’t have any effect on the presence of TVOC in air.

CONCLUSIONS
Performed research confirmed common presence of Volatile Organic Compounds in human surroundings. That’s why there exists the need to define limit concentration values of these compounds in rooms purposed to permanent people stay. Influence research of different materials applied to indoor equipment on air quality cause however many difficulties, not only analytical. Permanent air quality control applied to exchanges in chamber showed that the air wasn’t volatile organic compounds free. Evaluated, taking the concentration of these compounds in supplied air into the consideration, basic wood-borne materials didn’t have practically any effect on increase the concentrations of VOC in air. Lacquers applied to finish materials in furniture making caused the increase of TVOC concentration in air and should be evaluated however in their practical application conditions. So it is according to its predicted application to cover specific kind of material, because there was observed certain influence sort of finished surface on TVOC concentration from lacquered coatings.

REFERENCES


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