Effect of the Surface Finishing Methods on Particleboard Volatile Organic Compounds and Formaldehyde Emission

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Chemical contaminants from wood-based panels, such as volatile organic compounds (VOCs) and formaldehyde, are the main sources of indoor air pollution. The particleboards were used as the substrate and five common finishing methods, including melamine-impregnated paper, high-density polyethylene decorative film, wood veneer, polypropylene water borne paintings coatings, and polyurethane water borne paintings coatings, were selected for this study. The emission curves in the first 6 h and the equilibrium concentrations of the total volatile organic compounds (TVOC) and formaldehyde processed with the finishing wood-based panel method for 24 h were obtained and measured using an airtight environmental chamber. The ingredients of the VOCs were investigated using the small chamber method and gas chromatography and mass spectrometry (GC/MS). The results indicated that the finishing methods were effective for reducing the emissions of TVOC (except the water borne coating) and formaldehyde of the particleboards. High density polyethylene film was the best finishing material to reduce the release of TVOC. The concentration of the veneered particleboard from the third to the tenth hour was higher than the unfinished particleboards. The veneered particleboard released six volatile ingredients to a lesser extent than the unfinished particleboard.

Keywords: Particleboard; Finishing method; VOCs; Formaldehyde; GC/MS

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INTRODUCTION

Formaldehyde and volatile organic compounds (VOCs) are released from wood-based panel materials (*e.g.*, particleboard, plywood, and medium-density fiberboard), which are mainly hot-pressed with wood particles or wood fibers, urea-formaldehyde resin (UF), and some other ingredients (Yrieix *et al.* 2010; Liang *et al.* 2016; Zhao *et al.* 2018). The VOCs, which include hydrocarbons, organic halides, organic sulfides, carbonyl compounds, organic acids, and organic peroxides, can be present in the air in the form of steam at normal temperatures (Rudnicka *et al.* 2019). However, the toxicity of VOCs, which will influence the skin and mucous membranes or cause chronic damage to the human body, has received widespread concern (Norback 2009; Niu *et al.* 2016). The World Health Organization (WHO) defines TVOC as those whose melting point is below room temperature and whose boiling point ranges from 50 to 260 °C (Mølhave *et al.* 1997). In many disqualified decoration constructions, TVOC and formaldehyde concentrations exceeded the standard by a factor of dozens (Du *et al.* 2014; Chi *et al.* 2016). Hence, controlling the emission of VOCs and formaldehyde in decoration materials, such as particleboards, has become the focus of scholars.

There has been some research on the effects of the hot-pressing condition, adhesive, heat treatment, and secondary processing of panels on VOCs and formaldehyde emissions of particleboards. In those reports it has been shown that the hot-pressing temperature, time, resin, and density affect the pollutants (Lee and Kim 2012; Liu *et al.* 2012; Candan and Akbulut 2013; Sun *et al.* 2020). Furthermore, the drying and hot-pressing techniques were helpful in reducing the formaldehyde and VOCs emission from wood-based panels (He *et al.* 2012). There are some reports on the effects of the adhesive on VOCs and formaldehyde emissions (Navarrete *et al.* 2013), but most of these studies are related to the low percentage of formaldehyde in urea-formaldehyde resin adhesive and formaldehyde-free adhesive, which will decrease the tensile strength of the particleboard and increase the production cost significantly. In addition, heat treatment methods, which evaporate pollutants more quickly by increasing the temperature of the environment, have been reported in some studies (Young *et al.* 2012; Jiang *et al.* 2017).

The surface finishing method of wood-based panels is one of the methods of secondary processing of panels to control VOCs and formaldehyde (Kim and Kim 2005; Akkus *et al*. 2019). Some scholars have studied several surface finishing methods to reduce the release of TVOCs and formaldehyde (Kim *et al*. 2010). The results showed that different surface finishing methods can lessen TVOCs and formaldehyde in wood-based panels and have proposed that the finish materials and coatings can hinder the path of pollutants' evolution from the wood-based panel. However, the principle of VOCs emissions on the surface of finishing particleboard have not been thoroughly studied, and further analysis of emission ingredients is needed. In this study, several surface finishing materials and water borne coatings were used to treat the particleboards. A small environment chamber, handheld VOCs gas detector, and formaldehyde detectors were used to detect TVOC and formaldehyde. The ingredients of the pollutants released from the finished and unfinished particleboard were analyzed by a gas phase mass spectrometer (GC/MS).

EXPERIMENTAL

Materials

E1 poplar particleboards with dimensions of 1220 mm × 2440 mm × 16 mm were purchased from Suiha Wood Composite Factory, Suihua, China. Table 1 shows the hot-pressing parameters of the particleboard. The walnut sliced veneer and pine sliced veneer with thicknesses of 2.5 mm and 45% moisture content were purchased from Mudanjiang Hongye Thin Wood Planer, Mudanjiang, China. The density of the walnut sliced veneer was 0.56 g/cm^3, and the density of pine sliced veneer was 0.51 g/cm^3. The NH_4Cl with 20% concentration, used as a curing agent, was purchased from Lanxing Chemical Co., Ltd. Jining, China. The high-density polyethylene decorative film with 0.1-mm thickness, 1.28 g/cm^3 density, and melamine impregnated paper with 0.2-mm thickness was obtained from the Songjiang Plywood Factory, Harbin, China. The grammage of melamine-impregnated papers was 80 g/m^2 and 120 g/m^2, respectively. Water-borne polyurethane coating (undercoat, topcoat) and water borne polypropylene coating (undercoat, topcoat) were supplied by Ketian Water borne Technology Co., Ltd., Lanzhou, China.

The urea-formaldehyde resin (UF) adhesive was purchased from Bond Corp., Harbin, China. The condition of the UF adhesive was described as follows: 7.8 pH value, 76.8 s of curing time, 0.6% of formaldehyde content, and 51.9% of solid content. The polyvinyl acetate copolymer emulsion (PVAc) adhesive, including 28% of the solid content and 6.2 pH value, was obtained from the Minglang Rubber Industry, Harbin, China. The industrial flour, used as filler, was purchased from Deyun Chemical Co., Ltd. Suzhou, China.

Table 1. Hot-pressing Parameters of E1 Poplar Particleboard

Option	Parameter	Option	Parameter
Hot-pressing temperature (°C)	190	Surface moisture content after sizing (%)	8.5 to 9.5
Surface pressure (MPa)	29.5MPa	Water content of core layer after sizing (%)	8.5 to 10
Unit pressure (MPa)	35	Moisture content of slab after hot pressing (%)	6
Hot pressing time (s)	210 s	Solid content of the adhesive (%)	60 to 65
Density (g/cm^3)	0.7	Surface sizing percentage (%)	10
Curing agent content (%)	1.8	Core layer sizing percentage (%)	90
Moisture content of the particle (%)	1% to 3%	Sizing amount (Kg/m^3)	120

Instruments

The VOCs acquisition device shown in Fig. 1 was developed and designed by Northeast Forestry University (Harbin, China). The acquisition device used to simulate indoor environment includes a small environmental chamber (Northeast Forestry University, Harbin, China), KJG3001 air purifier (Beijing Yadu Environmental Technology Co., Ltd., Beijing, China), and an outlet configuration for collecting exhaust gas from the environmental chamber. The outlet of the environmental chamber is connected to the air inlet of an ANB3025 intelligent vacuum pump (New Weicheng Technology Ltd., Chengdu, China), and the other end is connected to the drying tower. The bottom of the drying tower is filled with calcium chloride as a desiccant to absorb water vapor in the gas. The upper part of the drying tower is filled with activated carbon particles to absorb VOCs. The volume of the small environmental chamber is 0.09 m^3. The inner wall is made of polished stainless steel. The air flow is 1.88 L min, and the air exchange rate is 1.13 h.

Fig. 1. The VOCs acquisition device

Preparation of specimens

The test specimens were prepared according to ASTM D5116-10 (2010) (Wang *et al.* 2017): the E1 poplar particleboard was sawn into small specimens with dimensions of 230 mm × 240 mm × 16 mm. The aluminum tape was used to seal the edges of the specimen to prevent emissions of the VOCs from the edges. The area of the surface of the test sample that was exposed in the chamber air was 0.09 m^2. Then, the specimens were wrapped in polytetrafluoroethylene plastic bags and placed in the refrigerator at -30 ° C.

Methods

Surface finishing process

The surface of the specimen was sanded with 100-mesh sandpaper to remove the paraffin layer of the base material surface. The 50 g of UF adhesive, 12.5 g of PVAc adhesive, 7.5 g of flour, 15 g of water, and 0.5 g of ammonium chloride with 20% concentration was mixed to prepare the UF/PVAc hybrid adhesive (Gáborík *et al.* 2016). The weight of the adhesive on each side of particleboard was 8.28 g. After applying the veneer on the base material for 30 min, the specimens were fed into the hot-pressing machine (BY60222/2; Zhengtai Machinery Manufacturing Co., Ltd., Linyi, China) at conditions of 120 °C, 1 MPa pressure, and 3 min pressing time (Hu *et al.* 2005). Melamine-impregnated paper was put on the surface of the base material directly. The hot press parameters of melamine-impregnated paper particleboard were as follows: 185 °C, 1 min pressing time, and 2.0 MPa pressure (Liu and Zhu 2014). High density polyethylene film was attached to the base material without pressure. The 50 mL polyurethane and polypropylene water-borne coating was diluted with 15 mL (30%) of water, and the calculated density of the water borne coating was 1.02 g/cm^3. The density of the polyurethane emulsion used in the experiment as the undercoat was 1.00 g/cm^3, and 0.98 g/cm^3 was used as the topcoat. 100 g/m^2 of water-borne coating was evenly applied to the sample with a wire rod applicator. The undercoats and topcoats were applied separately.

TVOC and formaldehyde concentration detection

The airtight environment chamber method was used for the concentration detection of TVOC and formaldehyde. Before each experiment, the small environment chamber was cleaned with distilled water, dried, and run for 1h without load. The parameters of the environment chamber were set as follows: the ambient temperature was 23±0.5°C, and the relative humidity was 45%±5%. The TVOC concentration in the cabin was less than 10 kg /m^3. The gradual emission of TVOC and formaldehyde concentration of the specimen was detected in the first 6 h, and the total concentration after 24 h. The gas outlet of the small environment chamber was separated by a shunt tube, and the concentration of TVOC and formaldehyde are measured from a ppbRAE Plus handheld VOC detector (RAE Systems, Inc., San Jose, CA, USA) and the formaldehyde concentration from an INTERSCAN 4160 formaldehyde analyzer (Interscan Co., Ltd., Simi Valley, Canada).

VOCs composition analysis

The finished specimen was placed in a 15-L glass dryer on the side with Vaseline coating to prevent air leakage. After 24 h of airtight sampling, the dryer was connected to the inlet of a smart vacuum pump that was connected to the drying tower. The upperpart of the drying tower was filled with 300 g of activated carbon particles used for absorbing VOCs for 24 h. During pumping, the drier stopper was slightly aerated to maintain a positive pressure to absorb VOCs in the drier. Then the activated carbon with adsorbed

VOCs was soaked with dichloromethane as a solvent for 20 to 30 min. According to similar intermiscibility, the adsorbed VOCs were desorbed into the solvent. The activated carbon immersed in the solvent was filtered, and the filtrate was concentrated by a rotary evaporator to prepare a sample for GC/MS detection (Uchiyama *et al.* 1999).

The components of the volatiles emissions from particleboards were analyzed using a GC/MS (Trace DSQ II; Thermo Scientific, Waltham, MA, USA) system consisting of a Trace gas chromatographic and a DSQ °C mass selective detector. A TR-V1 capillary column with 0.25-mm ID, 30 m, and 1.4 µm film thickness was used to separate the chemical compounds. The GC inlet temperature was set at 250 °C with a split ratio of 1:40. The GC oven temperature started at 40 °C and was held for 2 min. The temperature program ranged from 40 to 150 °C at a rate of 4 °C per min and was then heated to 250 °C at a rate of 10 °C per min. The ionizer voltage of the MS detector was set at 70 eV, and the temperature was set to 230 °C. The mass scan range was 40 to 450 amu. The carrier gas was high-purity helium with a flow rate at 1.0 mL/min. The interface temperature was set at 270 °C. The compounds were identified by the retention time and comparison with mass spectra library. The concentrations of volatile components were quantified with the peak area of Toluene-D8. In the experimental analysis, the software of the GC-MS was used to analyze the total ion flow chromatogram, and the NIST and WILEY spectrum library were used to search and determine the main components of volatiles. Finally, the compounds, similarity, and mass fraction of volatiles from particleboards were analyzed.

RESULTS AND DISCUSSION

Effects of Surface Finishing Methods on the TVOC Emission of Particleboard

As shown in Fig. 2, different surface finishing methods had a remarkable effect on TVOC concentration in 6 h.

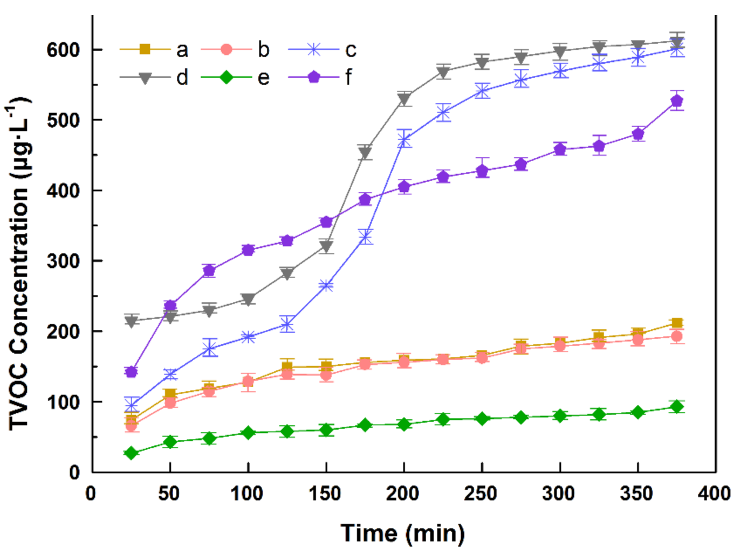


Fig. 2. TVOC emission concentration curves of the finishing samples: (a) finishing particleboard with melamine paper (80 g/m^2); (b) finishing particleboard with melamine paper (120 g/m^2); (c) finishing particleboard with pine veneer; (d) finishing particleboard with walnut veneer; (e) finishing particleboard with high-density polyethylene film; and (f) unfinished particleboard

Compared with unfinished particleboard, a 84.2% reduction of TVOC was achieved with the finishing of high-density polyethylene film, followed by melamine-impregnated paper. Melamine-impregnated paper with 120 g/m^2 grammage, which means the weight of paper expressed as grams per square meter selected in the experiment, had a better barrier effect than that of melamine-impregnated paper with 80 g/m^{2}grammage. However, the TVOC concentration of pine-veneered and walnut-veneered particleboard at 6 h was slightly higher than that of unfinished particleboard, which indicated that the VOCs of UF/PVAc hybrid adhesive affected the results. For the hardwood species with few ducts, such as walnut, the tylosis are quite rich, and the parenchyma cells are densely packed, resulting in the low concentration of walnut-veneered particleboard. For soft-wood species, such as pine veneer, because pine itself is rich in resin channels, it needs to be digested to remove the resin, and the retention of resin channels increases the degree of gas volatilization. Therefore, the TVOC concentration of pine-veneered particleboard was always higher than that of walnut-veneered particleboard.

Figure 3 shows the TVOC emission concentration of the finishing samples after 24 h. The barrier effect of various finishing methods by the dryer method was displayed in the following descending order: the high-density polyethylene film, melamine-impregnated paper with 120 g/m^2 grammage, the melamine-impregnated paper with 80 g/m^2 grammage, then the pine veneer, and finally walnut veneer. The initial concentration of pine- and walnut-veneered particleboard was lower than that of unfinished particleboard, showing that the TVOC emission rate of unfinished particleboard was higher in earlier stages of the experiment. Due to the use of adhesives for finishing, the TVOC concentration of veneered particleboard was higher than that of unfinished particleboard as time passed. However, the later concentration of the unfinished particleboard exceeded that of the veneered particleboard, indicating that the influence of adhesives was weakened, and its role as a barrier to VOCs dominated after 24 h. In addition, the TVOC concentration of the veneered particleboard at hour 24 was approximately 50% lower than that of the unfinished particleboard.

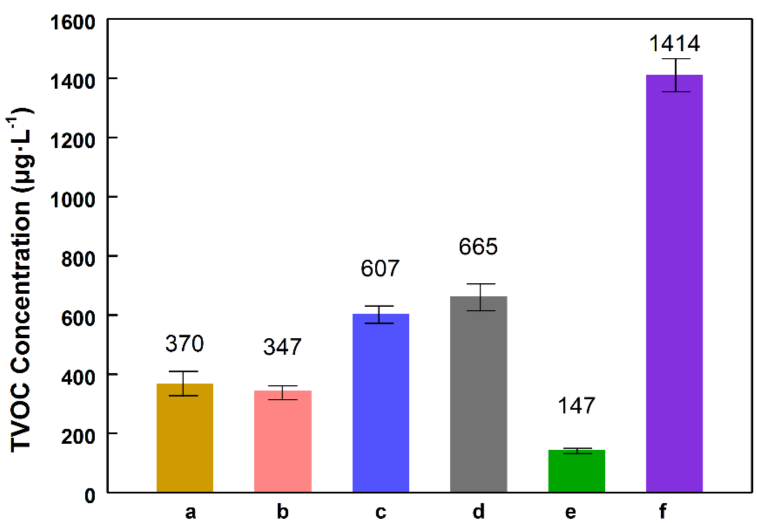


Fig. 3. TVOC emission concentration of the finishing samples after 24 h: (a) finishing particleboard with melamine paper (80 g/m^2); (b) finishing particleboard with melamine paper (120 g/m^2); (c) finishing particleboard with pine veneer; (d) finishing particleboard with walnut veneer; (e) finishing particleboard with high-density polyethylene film; and (f) unfinished particleboard

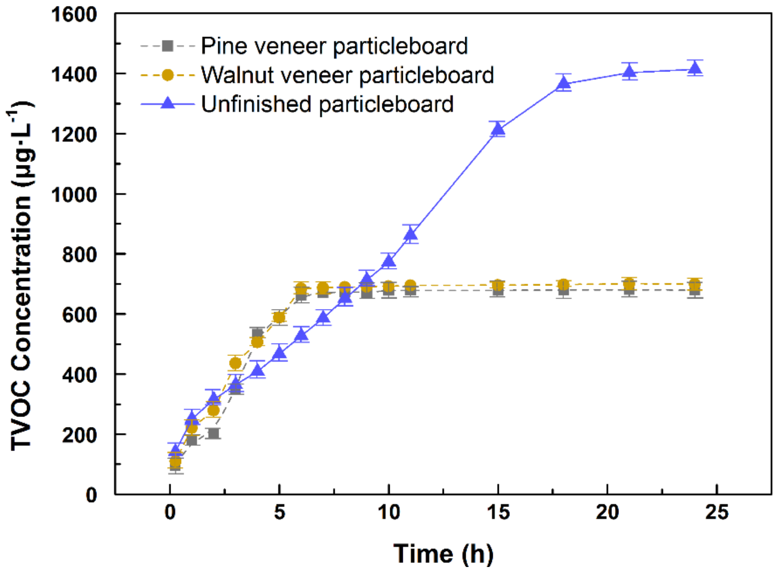


Fig. 4. TVOC emission concentration curves of the veneered samples and unfinished sample

To specifically research the emission trend of veneered particleboard, the TVOC concentration of the veneer finishing method and unfinished particles each hour is shown in Fig. 4. Based on the comparison of the TVOC emission curves of veneered and unfinished particleboard, the TVOC concentration emission of veneered particleboard can be divided into three stages in 24 h: earlier stage, medium stage, and later stage.

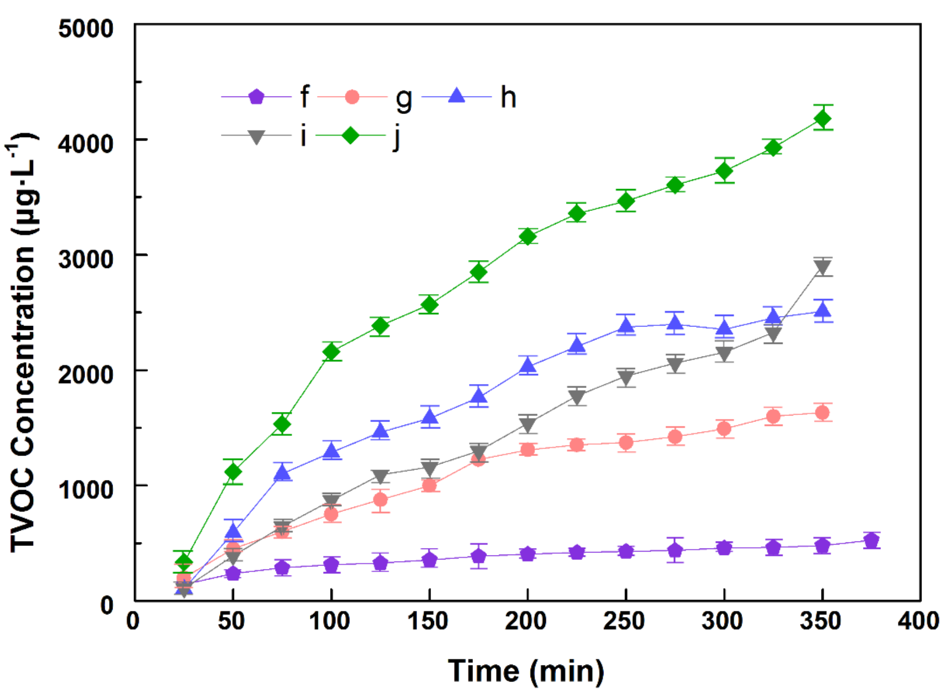


Fig. 5. TVOC emission concentration curves of the water borne paint coating samples: (f) TVOC emission concentration of unfinished particleboard; (g) water-borne polypropylene emulsion undercoat particleboard; (h) water-borne polypropylene emulsion topcoat particleboard; (i) water-borne polyurethane emulsion undercoat particleboard; and (j) water-borne polyurethane emulsion topcoat particleboard

The TVOC concentration of the thin wood veneered particleboard was lower than that of the unfinished particleboard at the earlier stage. From the 3rd hour to the 10th hour, the TVOC concentration emission rate of the veneered particleboard was slightly faster than that of the unfinished particleboard, for the veneer adhesive volatilized VOCs in this period. From the 10th hour to the 24th hour, the effect of the veneer adhesive on the TVOC concentration was weakened, and the barrier property occupied a dominant position. It was obvious that the wood veneer still had a barrier effect on the emission of TVOC after 10 h, and the TVOC concentration of veneered particleboard at the 24th hour was approximately 50% lower than that of the unfinished particleboard.

The VOC emission concentration of the finishing samples after 24 h is shown in Fig. 5. Water-borne coatings were shown to be highly volatile and to have a long drying time, resulting in a higher TVOC concentration for the water borne coating samples. Among them, the TVOC concentration released by the undercoat-coated particleboard was slightly lower than that of the top-coated particleboard. The water-borne polypropylene coating particleboard had a better barrier effect of harmful pollutants than the water borne polyurethane coating. Judging from the results of analysis, the decorative materials decorated with water borne paints should be ventilated at an early stage to accelerate the drying of water borne coatings and lessen the emission of VOCs.

Effects of Finishing Methods on the Formaldehyde Emission of Particleboard

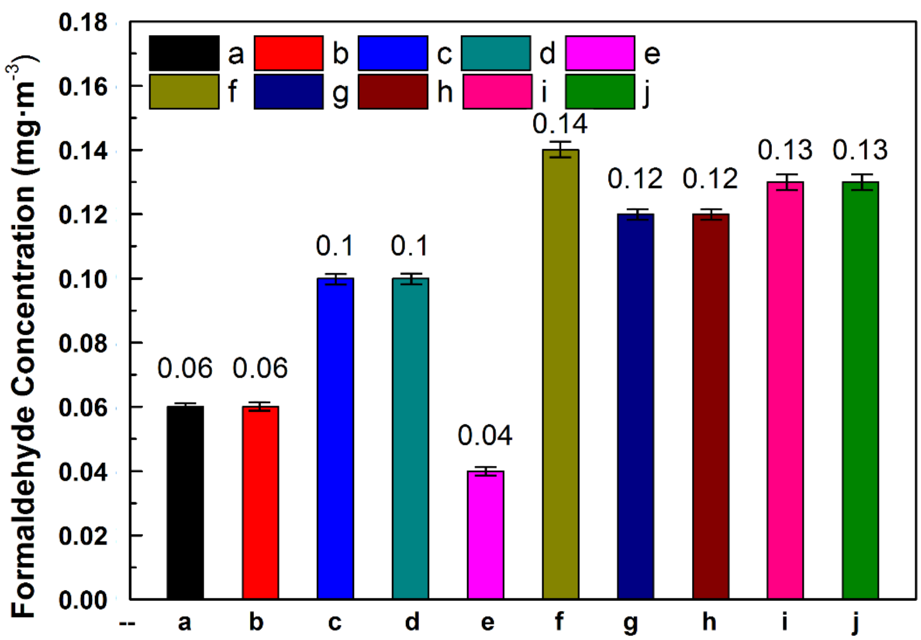


Fig. 6. Formaldehyde emission concentration of the finishing samples after 24 h: (a) finishing particleboard with melamine paper (80 g/m^2); (b) finishing particleboard with melamine paper (120 g/m^2); (c) finishing particleboard with pine veneer; (d) finishing particleboard with walnut veneer; (e) finishing particleboard with high-density polyethylene film; (f) unfinished particleboard; (g) water-borne polypropylene emulsion undercoat particleboard; (h) water-borne polypropylene emulsion topcoat particleboard; (i) water-borne polyurethane emulsion undercoat particleboard; and (j) F water-borne polyurethane emulsion topcoat particleboard

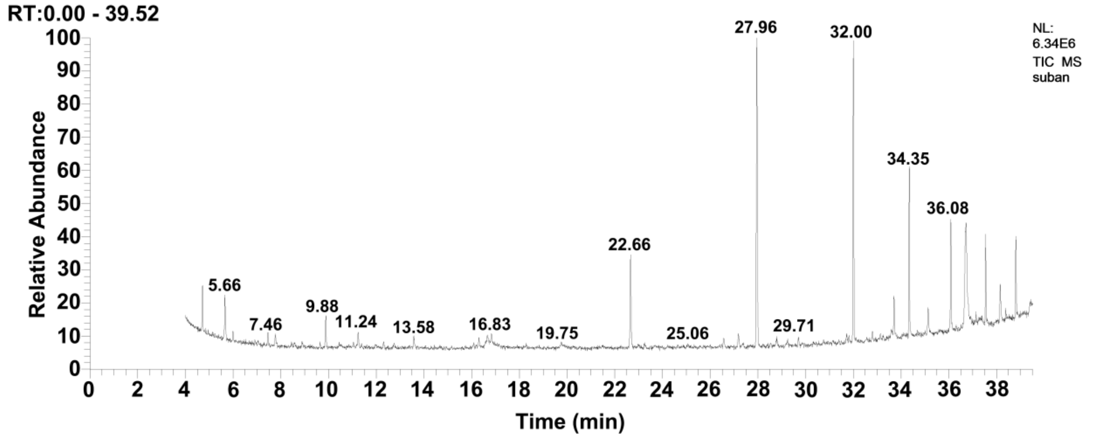
Figure 6 shows formaldehyde emission concentration of the finishing and coating specimen after 24 h. The average formaldehyde concentration released from the finishing samples was lower than that of the unfinished board, indicating that different finishing methods had a barrier effect on formaldehyde. Among them, the high-density polyethylene film finishing method worked best, with a sealing effect of more than 70%. The sealing effect of the melamine impregnated paper finishing method was 57.1%, and the sealing effect of the veneer finishing method was 28.6%. In addition, the water-borne coating had a low sealing effect. The water borne topcoat and undercoat only sealed 14.3% and 4.1% of formaldehyde compared to unfinished particleboard, respectively.

Effects of Pine Veneer on the Composites of Particleboard Volatiles by GC/MS

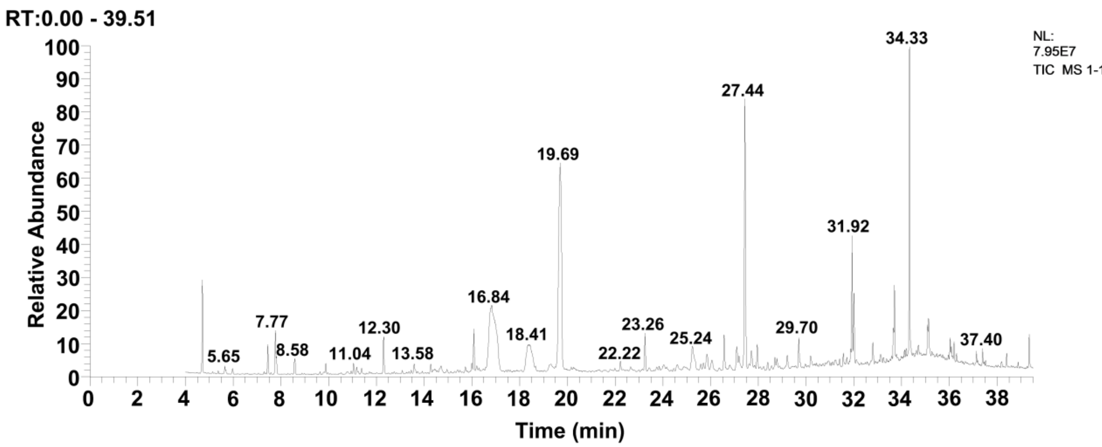
After airtight conditions were maintained for 24 h, a smart vacuum pump was used to allow the gas in the closed container to enter the activated carbon of drying tower for adsorbing volatile gas. Then, the activated carbon soaked in the solvent was filtered, and the filtrate was concentrated by the rotary evaporator to prepare the sample. The specific components and contents of volatiles were analyzed by GC/MS. In the experimental analysis, the instrument's own software was used to analyze the total ion flow chromatogram, and NIST and WILEY spectrum library of GC/MS were used to retrieve and qualitatively determine the main components of volatiles. Therefore, the compounds, similarity, and mass fraction in the volatiles of wood veneered particleboard were obtained through analysis.

The results of the GC/MS analysis in Fig. 7 were converted into the experimental results of the ingredients and percentages of the compounds contained in the samples. The main ingredients that were detected in each chemical substance type and the content percentage are shown in Fig. 8 and Table 2. The main volatiles ingredients were aromatic, alkane, terpene substances, and a tiny amount of quinones, ketones, esters, and acids. The 21 ingredients were detected in unfinished particleboard, and 15 ingredients were detected in veneered particleboard. The amount of volatiles in veneered particleboard was less than that in unfinished particleboard. Six compounds were not detected from veneered particleboard, indicating that these six substances were blocked by the veneer material. In addition to a few aromatic and alkane substances, veneer can effectively control volatiles volatilization of particleboard base material and lessen the emission of more than 50% of the volatiles content. However, the reduction of a small number of aromatic and alkane ingredients released in veneered particleboard did not noticeably demonstrate that volatilization of alkanes and aromatic family substances were the joint effect of veneer, adhesive, and particleboard base material.

The main percentage of volatiles in unfinished particleboard was phthalic acid (2-ethylhexyl) ester accounting for 34.2% of the total volatile organic matter content, which was phthalic acid ester derivatives added to the adhesive as plasticizer. Phthalic acid (2-ethylhexyl) ester and its derivatives, which are generally adsorbed in particleboard base material, and the solid adhesives ingredients are highly toxic and are slowly released into the environment. Alkanes, terpenes, and aromatic compounds are the main components of lignin in particleboard base material, which are cracked in the process of hot pressing and high temperature. During the hot-pressing process, most alkanes and aromatic hydrocarbons are volatilized due to the rising temperature, but some of them were still adsorbed in the particleboard and released slowly. The content of aldehydes, acids, and ketones were low because of their fast volatilization in hot pressing.



(a)



(b)

Fig. 7. GC/MS analysis of volatiles on veneered particleboard and unfinished particleboard: (a) unfinished particleboard and (b) veneered particleboard

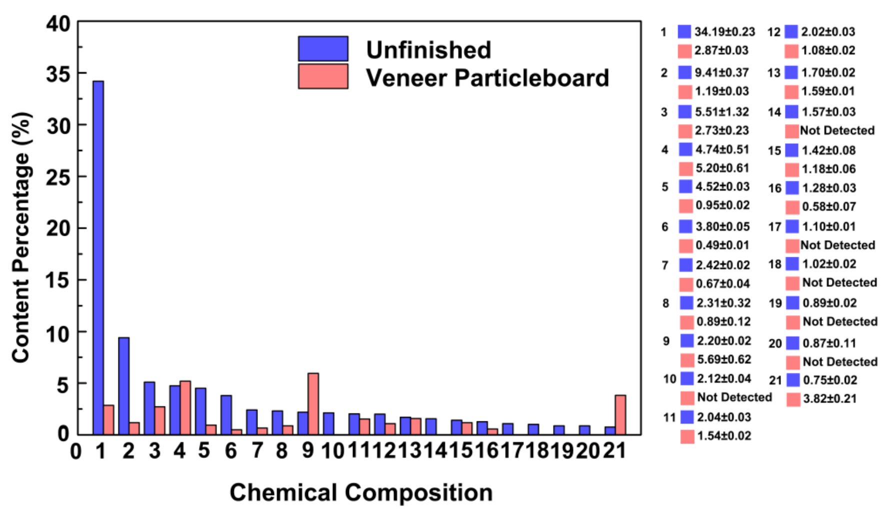


Fig. 8. The main volatile components and content percentage of veneered particleboard and unfinished particleboard

Table 2. Main Volatile Components and Content Percentage of Veneered Particleboard and Unfinished Particleboard.

Sample	Chemical Composition	Content Percentage (%) [a]	
		Unfinished	Veneered Particleboard
1	Phthalic acid (2-ethylhexyl) ester*	34.19 ± 0.23	2.87 ± 0.03
2	2,6, 10-trimethyltetradecane	9.41 ± 0.37	1.19 ± 0.03
3	Toluene	5.11 ± 1.32	2.73 ± 0.23
4	2,6,10, 14-tetramethylhexadecane*	4.74 ± 0.51	5.2 ± 0.61
5	β-pinene	4.52 ± 0.03	0.95 ± 0.02
6	Hexanal	3.8 ± 0.05	0.49 ± 0.01
7	Bis-succinate-2-methylpropyl	2.42 ± 0.02	0.67 ± 0.04
8	Undecane	2.31 ± 0.32	0.89 ± 0.12
9	O-xylene	2.2 ± 0.02	5.96 ± 0.62
10	Furan ketone	2.12 ± 0.04	Not detected
11	2, 5-ditert-butyl benzoquinone*	2.04 ± 0.03	1.54 ± 0.02
12	1-methyl-5 -(1-methyl vinyl)cyclohexene	2.02 ± 0.03	1.08 ± 0.02
13	Ethyl benzene	1.7 ± 0.02	1.59 ± 0.01
14	Bis -2- methyl succinic acid -1- methyl propyl ester*	1.57 ± 0.03	Not detected
15	5, 8-diethyldodecane	1.42 ± 0.08	1.18 ± 0.06
16	9-hexyl-heptadecane*	1.28 ± 0.03	0.58 ± 0.07
17	2-methyl-cyclopentanone	1.1 ± 0.01	Not detected
18	Basilene	1.02 ± 0.02	Not detected
19	Ethyl p-ethoxy benzoate	0.89 ± 0.02	Not detected
20	2, 6-ditert-butyl para-cresol*	0.87 ± 0.11	Not detected
21	Castor acid	0.75 ± 0.02	3.82 ± 0.21

*Compounds with boiling points greater than 260 °C (plasticizers)
[a]The results are given as averages and standard deviations from the mean values

CONCLUSIONS

1. The changes of total volatile organic compounds (TVOC) and formaldehyde concentrations in poplar wood particleboard with different surface materials were studied under airtight conditions. The results showed that different finishing materials of wood-based panels could control the emission of TVOC (except for waterborne paint) and formaldehyde in particleboard. The HDPE film had the best sealing effect, showing an 84.2% reduction of TVOC and 71.4% reduction of formaldehyde. The volatile content of waterborne paint was large, which had a great influence on TVOC emission.
2. The barrier effect of melamine-impregnated paper with 120 g/m^2 grammage was better than that of melamine-impregnated paper with 80 g/m^2 grammage. The reductions of formaldehyde emission of pine wood veneer and walnut were equal, but reduction of TVOC emissions of pine was better after 24 h. Compared to the walnut veneer, the reduction effect of the pine veneered particleboard was better due to the porosity of pine. Water borne topcoat and undercoat only sealed 14.3% and 4.1%, respectively, of formaldehyde compared to unfinished particleboard. The TVOC released from the

undercoated particleboard was slightly lower than that from the top-coated particleboard.

3. The volatiles emission ingredients of veneered particleboard and unfinished particleboard showed that the veneer method sufficiently reduced the volatiles emission of particleboard, except for a few benzene and alkanes. The amount of volatiles in veneered particleboard was less than that in unfinished particleboard. Alkanes, aromatic hydrocarbons, and terpenes were mainly derived from particleboard base materials. The highest mass fraction of the unfinished particleboard was phthalic acid (2-ethylhexyl) ester (34.19%), while the highest mass fraction of the veneered particleboard was o-xylene (5.96%).

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