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# Characteristic of volatile organic compounds (VOCs) released from coating particleboards using small chamber method

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## ABSTRACT

Volatile organic compounds (VOCs) emissions from three typical varnish (water base ployurethane resin varnish, nitro varnish and alkyd resin varnish) finishing particleboards were studied using 0.5m3 small chamber method. The varnishes applied on veneered particleboards with a coating weight of 10g per surface. After 24/1 hours of curing, the concentration of VOCs were monitored for 28 days. VOCs concentrations of all finishing boards increased rapidly at the first day and then decreased to a equilibrium level during the following days. VOCs emissions from water base ployurethane resin varnish finishing particleboards showed the fastest decrease at the early stage and lowest concentration after 28 days exposure. Aromatic and alkyl hydrocarbon were main emissions from finshing particleboards. Eight major VOCs including toluene, ethylbenzene, xylene, decane, undecane, dodecane, pentadecane and hexadecane were identified and quantified, and most of them were hardly detected after 28 days exposure. Terpenes and esters were also detected in finishing particleboards at the early stage with a quite low level. 

## KEYWORDS

VOCs;
Particleboard;
Varnish;
Finishing;
Small environmental chamber.

## INTRODUCTION

Variety of wood-based panels are being used in indoor decoration and furniture, which are recognized as the important sources of VOCs and formaldehyde that contribute to indoor air pollution[6, 15]. Main contaminants from the wood products are α-pinene and β-pinene, formaldehyde, methanol, other aldehydes, ketones, hydroxyl groups, other terpenes and non-terpene acids such as formic, propionic and acetic acid and various other hydrocarbons[8]. Large amount of VOCs and formaldehyde emit from wood products have the potential to cause adverse health effects to occupants. Motivated by growing environmental concern, many studies are worked on new technologies for enhancing environmental friendly of wood in residential construction.

More than 60% of wood coatings are applied as liquid coatings with either organic solvent or water as the carrier for the other coatings ingredients[10, 13]. Traditionally, lac coating, alkyd varnish, nitro varnish, acrylic coating are used for wood products. Wood coatings can provide wooden materials with the desired aesthetical properties like color and gloss, but are mostly also of vital importance in the protection of wood against environmental influences like moisture, radiation, biological deterioration or damage from mechanical or chemical origin. But a number of investigations on the VOC emissions from indoor sources have shown that varnishes contribute to indoor air pollution[2, 7, 11, 5]. And long term exposure to organic solvents might also induce neuropsychiatric symptoms like memory impairment, concentrating difficulties, fatigue, headache or personality changes. This potential danger has been recognized by the responsible occupational health authorities in many countries, which have led to restrictions in the use of solvent rich coatings[12]. In the modern coatings industry, high productivity, and performance and also low emission of volatile organic compounds (VOCs) from formulations are three major challenges. The aim of the recently issued Chinese directive is to reduce VOC emissions. It is observed that many experts have taken considerable effort to reduce VOCs from coating application. Studies have been conducted to identify the chemical constituents in varnish products. McCrillis et al. identified that the major VOCs emitted from oil-based varnishes were isobutanol, ethylbenzene, m,p-xylene, o-xylene and formaldehyde[9]. Saturated aliphatic, cyclic hydrocarbons, aromatic hydrocarbons and oxygenated hydrocarbons have been identified both in oil-based varnishes and spirit varnishes. The VOCs emissions and aldehyde types were varied according to the different coating weights under specific test conditions.

In the last decade, many studies focused on the emission characterization VOCs from building materials[4, 3, 15, 16]. To learn more about the emission characteristics of VOCs from wood products and explore the clean production technology, VOCs emissions from veneered particleboards finishing with 3 typical varnishes were measured by employing a small-scale chamber system.

## MATERIALS AND METHODS

### Materials

Among various wood-based panels on the market, we chose particleboards (PB) as substrate. PB was produced from poplar particles (approximately 1 mm in diameter) and boned with urea formaldehyde (UF) resin. Then fraxinus mandshurica decorative veneers (0.25mm thick) were laminated on both sides of PB panels bonded with UF resin. The press condition for veneered PB were 120! press temperature, 2.5MPa pressure and 180s press time. All samples were cut into pieces of 260 mm×260 mm. The surface of the veneered PBs were sanded before varnishing treatment. Three typical finishing varnish (water base ployurethane resin varnish, nitro varnish, alkyd resin varnish)were selected and purchased at local market. The application of varnish on veneered PB was conducted by a short-haired brush, and the average weights applied were 10g per surface. VOC emissions from three finishing veneered PBs were compared and evaluated after curing. The characteristics of finishing varnishes used are shown in TABLE 1.

### Methods

The emission of VOCs from different furnishing panels were determined by using 0.5m$^3$ small chamber method according to JIS A1901-2003. The edges of all samples were sealed with aluminum-coated adhesive tape. 4 test pieces with total surface area of 0.5m$^3$ of each samples were put in a controlled chamber. The air temperature and relative humidity inside the chamber were 28±1°C and 50±5% respectively, and the air change rate was 0.5 h$^{-1}$.

Before testing each sample in small scale chamber, one chamber blank sample was analyzed to en-

**TABLE 1 : Characteristics of three different finishing varnishes**

| Varnish | Water base ployurethane resin varnish | Nitro varnish | Alkyd resin varnish |
|---|---|---|---|
| Solid contents/% | 30 | 32 | 55 |
| Viscolity/s | 80 | 120 | 45 |
| Fineness/μm | 35 | 20 | 35 |
| Preconditioning time/h | 24 | 1 | 24 |

sure TVOC concentration in the chamber below 5 μg/$m^3$. Air samples were taken after 1, 3, 7, 14 and 28 days. VOC were sampled using 30-min samples with a Tenax trapping agent (Tenax TA) (Thermo Ltd., USA), using a portable pump (ANB3025, Weicheng Co, China) at 100 mL/min. Before sampling, all tubes were preconditioned in the lab by heating for 8h at 350°C with helium at a flow rate of 50mL/min. After a sampling, The compounds absorbed by the Tenax TA were analyzed by a gas chromatography/ mass spectrometry system. The type of column used in the GC is DB-1 with the size of 60m×0.25mm×1.0μm. The GC injector temperature was set at 280°C. The carrier used was helium with a flow rate of 1ml/min. The GC oven temperature was started at 40°C and held for 5 min, then heated to 40°C at a rate of 5°C/min, and finally held at 240°C for 5 minutes. After the compounds passed through the GC, a mass detector at the GC column outlet was used to detect the variety of VOC. The ionizer voltage of MS detector was 70ev, the ionizer temperature was set at 230°C and scan range of molecular weights was from 15 to 260amu. All samples were quantified according to the internal standard method JIS 2009. In this study, TVOC calculation was defined as the conversion of all areas of the peaks between C6 and C16 to concentrations using the toluene response factor.

## RESULTS

### TVOC emissions of different finishing particleboards

Figure1 showed the TVOC emissions from different type of finishing veneered particleboards by using 0.5$m^3$ small chamber method. The preconditioning time of varnishes, which is the time after varnish was applied to the panel surface, was classified as 24 hours curing for water base ployurethane resin varnish and alkyd resin varnish, 1 hour curing for nitro varnish. During the emission experiments, the concentrations of TVOC emissions from different finishing particleboards reach the peak very sharply at first day, and then decay fast during the following days. The TVOC emissions from the water base ployurethane resin varnish finishing board,

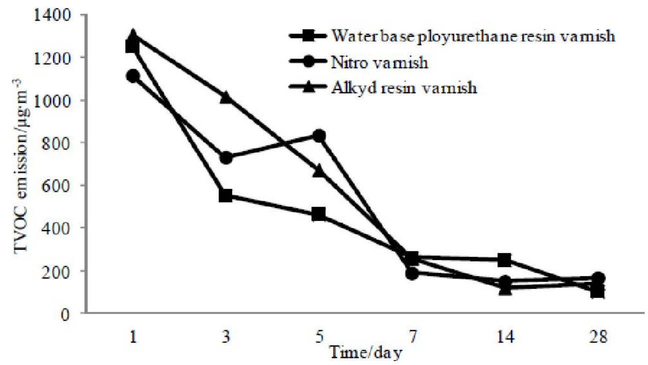


**Figure 1 : TVOC emissions of varnished particleboards in 28 days**

alkyd resin varnish coating board and nitro varnish coating board were 1253.84μg/$m^3$, 1308.99 μg/$m^3$ and 1177.17 μg/$m^3$ at the first day. After 7 days, the emission were stabilized, and TVOC concentrations of water base ployurethane resin varnish coating board, alkyd resin varnish coating board and nitro varnish coating board decreased to 262.37μg/$m^3$, 258.61μg/$m^3$, and 190.32μg/$m^3$, respectively. The decrease of TVOC emissions from 3 type of finishing boards were quite slow in the next 14 days. The water base ployurethane resin varnish finishing particleboards showed the lowest TVOC emission as 102.72 μg/$m^3$ after 28 days exposure. The TVOC concentrations of water base ployurethane resin varnish coating board, alkyd resin varnish coating board and nitro varnish coating board were 102.72 μg/$m^3$, 141.76 μg/$m^3$ and 167.25 μg/$m^3$ after 28 days exposure, which were 91.80%, 89.17% and 85.03% lower than that of the first day.

### VOCs identification and main VOCs emissions from finishing particleboards

After the vanished particleboards had been introduced into the chamber, the concentrations of the different VOCs varied markedly with the varnish. More than 20 kinds of VOCs were identified in finishing boards. Experimental results indicate that aromatic and alkyl hydrocarbon were main emissions from 3 type of finishing boards. TABLE 2 showed the concentrations of major VOCs (toluene, ethylbenzene, xylene, decane, undecane, dodecane, pentadecane and hexadecane) in 28 days. The VOCs concentrations increased rapidly to a maximum value at first day. After that, the concentration decreased towards an equilibrium or undetectable value. The

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TABLE 2 : Main aromatic and alkyl hydrocarbon emissions from different finishing veneered particleboards

| Varnish | Time | Toluene | Ethylbenzene | Xylene | Decane | Undecane | Dodecane | Pentadecane | Hexadecane |
|---|---|---|---|---|---|---|---|---|---|
| Water base ployurethane resin varnish | 1d | 133.32 | 22.36 | 50.92 | 69.56 | 122.36 | 29.20 | 24.84 | 50.28 |
| | 3d | 87.04 | 29.56 | 35.68 | 21.40 | 83.12 | 30.60 | - | 19.88 |
| | 5d | 75.32 | 24.76 | 46.44 | 9.80 | 37.68 | 36.12 | - | 16.52 |
| | 7d | 41.64 | 12.24 | - | 4.44 | - | 17.20 | - | 56.28 |
| | 14d | 41.80 | 19.88 | 18.32 | - | - | 7.32 | 26.68 | 13.08 |
| | 28d | 16.52 | - | - | - | - | - | - | - |
| Nitro varnish | 1d | 415.56 | 41.16 | 55.40 | 59.08 | 98.60 | 26.56 | - | 39.00 |
| | 3d | 189.32 | 22.88 | - | 23.84 | 84.60 | 28.52 | 15.88 | 25.24 |
| | 5d | 273.80 | 55.40 | - | 12.44 | 57.24 | 45.24 | 7.84 | 7.40 |
| | 7d | 57.80 | 9.32 | 19.44 | 4.52 | - | 10.84 | - | 22.96 |
| | 14d | 45.40 | 9.88 | 7.48 | - | - | - | - | - |
| | 28d | 79.88 | 14.36 | - | - | - | - | - | - |
| Alkyd resin varnish | 1d | 387.60 | 32.68 | - | 65.40 | 119.00 | 37.56 | 21.56 | 52.88 |
| | 3d | 288.88 | 25.40 | 33.44 | 21.40 | 76.20 | 27.64 | - | 18.28 |
| | 5d | 116.60 | 40.60 | 42.44 | 12.12 | 61.08 | 45.72 | 9.32 | 10.72 |
| | 7d | 35.12 | 8.92 | 8.36 | - | - | 13.24 | 9.48 | 54.84 |
| | 14d | 36.80 | 4.12 | 9.08 | 2.36 | - | 10.84 | 12.20 | 5.52 |
| | 28d | 11.44 | - | - | - | - | - | - | - |

aromatic types emitted in large qualitities in finishing particleboards were toluene, ethylbenzene and xylene. High toluene emission was observed in nitro varnish finishing board, which was 415.56 μg/m$^3$ at the first day, then it decreased to 79.88 μg/m$^3$ after 28 days exposure. Toluene showed the relatively higher concentration than ethylbenzene and xylene for all 3 type of finishing boards. Ethylbenzene and xylene were hardly detected in finishing particleboards at 28 days. Besides aromatic, large amount of alkyl hydrocarbon were also detected, the proportion up to 30%. The alkyl hydrocarbon types emitted at large qualities at all 3 finishing particleboards were as follows: undecane, decane, dodecane, hexadecane and pentadecane, but most of them were hardly detected after 14 days exposure. Terpenes and esters were also detected in finishing particleboards at the early stage, which were mainly arising from deformer and dispersant, a small part of the them were from wood itself, but the concentration were relatively low.

For the water base ployurethane resin varnish, water is the main solvent, with just relatively low content of organic solvent[1]. The aromatic were mainly arising from the acrylic dispersion. While for nitro varnish and alkyd resin varnish, the solvent-based paint, the content of organic solvent is relatively high. The high aromatic emissions were mainly arising from the organic solvent and thinner. Compared with nitro varnish and alkyd resin varnish, water base ployurethane resin varnish showed better environmental performance, VOCs emissions decreased rapidly to a equilibrium level during measurement. But in some ways, it is difficult to replace solvent-based varnished since it simply does not result in the desired finish.

## DISCUSSION

VOCs emissions from 3 typical varnish finishing particleboards were studied using a small environmental chamber. Varnishes of wood products are a significant source of VOCs in indoor environment, but that exposures to these compounds were predicted to be of relatively short duration. For wood based panels, the majority of varnish penetrated into porous surface and become relatively dry shortly after application, the VOCs emitted rapidly while the varnish were still relatively wet. After curing, the rest of the VOCs, which imbedded in the porous surface at the early stage, diffused through the substrate. The same results were observed that the emission of TVOC from every varnish was highest during the earlier storage, the VOCs in the varnish, which are in the liquid phase, release and diffuse in the air as soon as they were applied to panel surface. The data showed that total volatile organic compounds emissions from finishing veneered particleboards increased to the peak value very sharply at the first day, and then decay fast to equilibrium during the following days. These phenomenon indicated the occurrence of both adsorption and internal diffusion of VOCs from the varnish into those substrates. The results also indicated that the most abundant VOCs were aromatic and alkyl hydrocarbon at the early stage. High emission levels were observed in nitro varnish finishing boards, and water base ployurethane resin varnish finishing boards showed better environmental performance. However, the VOC emission behavior of varnish is affected by coating condition, which is a critical issue for liquid samples, the main VOCs emitted differed according to different coating condition, therefore, an optimal coating condition must be established for better curing and diffusion.

Previous studies found a relation between sick building syndrome and exposure to emission from recently applied paint, particularly wood painting. The chemical composition of wood paints used in China has changed drastically during the last few years. Nowadays, water-based paints account for 50% of wood paints in China. Solvent based paints, which have rapid and high emission of non-polar organic solvent, are still widely used because of its cheap and abundant raw material. The principal ways to reduce VOC emissions have been source control. Good manufacturing processes, improved application efficiencies and the paint technology route, especially waterborne, high solids solvent based and radiation curable coatings technologies can effectively reduce VOCs emission.

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