Research on VOCs from Indoor Furniture and Influencing Factors of Their Emission

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Abstract
Indoor furniture continuously emits various VOCs, such as aliphatic hydrocarbons, aromatic hydrocarbons, chlorinated hydrocarbons, aldehydes-ketones, and acids-esters, which affect indoor air quality and harm human health. Furniture made of different materials contains varying types and concentrations of VOCs. Dry materials (boards, leather, etc.) and wet materials (paints, adhesives, etc.) are the primary sources of VOCs in furniture. The emission of VOCs from furniture is influenced by multiple factors: the physical and chemical properties of the furniture itself (substrates, paint films and thickness, loading rate, etc.) are the decisive factors affecting VOCs emission, while environmental factors (temperature, relative humidity, air change rate, air flow velocity, etc.) also impact VOCs emission.

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1. Introduction

Humans spend more than 80% of their time indoors, and indoor air quality directly affects human health. As an important component of the indoor environment, furniture is made from various raw and auxiliary materials such as boards, paints, and adhesives through processing. During use, furniture materials continuously emit volatile organic compounds (VOCs) into indoor air. When pollutant concentrations reach a certain level, they severely deteriorate indoor air quality and damage human skin mucosa, respiratory system, nervous system, and other bodily functions [1, 2].Carrying out research on VOCs in indoor furniture and their release can not only provide a theoretical basis for the optimization of furniture manufacturing processes and the research and development of healthy new furniture products, but also has important practical significance for improving enterprise production levels and maintaining the physical and mental health of the public.

2. The types of VOCs in furniture

Volatile organic compounds (VOCs) are a class of small-molecule organic compounds with low boiling points (50 ℃-260 ℃) under normal pressure and easy volatilization at room temperature. They can be released by indoor furniture under the action of various factors such as temperature and humidity [3]. At present, more than 400 kinds of VOCs have been identified in the industry. According to their chemical structures, they can be divided into aliphatic hydrocarbons, aromatic hydrocarbons, chlorinated hydrocarbons, alcohols-aldehydes-ketones, acids-esters and other categories. The representative substances of each category are shown in Table 1.

Table 1: The common VOCs in furniture

Category	Representative Substances
Aliphatic Hydrocarbons	Cyclohexane, 2,2-Dimethylpentane, 2-Methylhexane
Aromatic Hydrocarbons	Toluene, p-Xylene, Ethylbenzene
Halogenated Hydrocarbons	1,2-Dichloropropane, Tetrachloroethylene
Aldehydes and Ketones	Formaldehyde, Acetaldehyde, Acetone, Cyclopentanone
Acids and Esters	Formic Acid, Methyl Acetate, Butyl Acetate
Other Categories	Dimethylformamide, Methyl Bromide

Except that formaldehyde is easily soluble in water, the vast majority of VOCs are generally insoluble in water but soluble in organic solvents. The concentration of a single VOC component in indoor air is often not high, but when multiple VOCs coexist for a long time, their combined effects on the health of various human systems cannot be ignored. Therefore, the total amount of volatile organic compounds (TVOC) is commonly used to measure the impact of indoor furniture and other items on indoor air quality.

3. The Sources of VOCs in Furniture

The sources of VOCs in indoor air are extensive, mainly coming from decoration materials (wallpaper, carpets, curtains, etc.), furniture components (solid wood boards, artificial boards, paints, etc.), and daily/work supplies (disinfectants, detergents, inks, etc.). Among them, furniture is one of the important sources of indoor VOCs. Moreover, with the improvement of people's demand for living quality and personalized life, various new types of furniture have gradually been introduced into indoor environments in addition to traditional furniture.

Whether traditional furniture or new-type furniture, they are all end products made of various dry and wet materials such as boards, paints, adhesives, textile fabrics, leather, etc. through processing. Furniture made of different materials contains different types, concentrations, and emission durations of VOCs. During use, furniture boards, leather, etc., themselves will release various VOCs, and materials such as adhesives and paints added in the manufacturing process will introduce new organic substances, which remain in the furniture due to insufficient reaction and continuously volatilize a large amount of VOCs [4]. The classification composition of furniture materials and the VOCs released by them are shown in Table 2.

Table 2: Classification and Composition of Furniture Materials and Their Emitted VOCs

Classification	Composition	Representative Substances	Emitted VOCs
Dry Materials	Boards	Solid Wood Board, Plywood, Particleboard	Formaldehyde, Acetaldehyde, Styrene, Cyclopentanone, Benzaldehyde
	Upholstery Materials	Textile Fabrics, Leather	
Wet Materials	Paints	Water-based Paints, Powder Paints, UV-cured Paints	Benzene, Toluene, Xylene, Formic Acid, Acetaldehyde, Butyl Acetate, Acetone
	Adhesives	Water-based Adhesives, Solvent-free Adhesives	
	Others	Colorants, Thinners, Cleaners	

4. The Influencing Factors of VOCs Emission from Furniture

4.1. Boards of Furniture

The substrates of furniture products are mainly various boards. The types, contents and release rates of VOCs in furniture composed of different panel materials vary. For example, artificial boards such as plywood require the addition of adhesives during furniture manufacturing, and adhesives are the main source of organic compounds such as esters and ketones. Therefore, the VOCs content in furniture made of artificial boards is higher than that in solid wood furniture. In addition, the thickness and porosity of furniture boards also affect the release of VOCs.

4.2. Paint Film and Thickness of Furniture

Due to decorative needs, artificial boards require secondary surface processing such as painting. As paints contain a large amount of organic compounds like aromatic hydrocarbons, the VOCs content and emission in painted furniture are higher than those in unpainted furniture. Meanwhile, the thicker the decorative paint film, the higher the VOCs release concentration and the faster the release rate.

4.3. Loading Rate of Furniture

The loading rate of furniture generally refers to the surface loading rate, which is the ratio of the surface area of furniture to the volume of the space where the furniture is located. Studies have shown that the loading rate has a significant impact on the release of VOCs from furniture, that is, as the loading rate increases, the concentration of VOCs released by furniture also increases. This influence is more significant in the initial stage of release, gradually weakens over time, and when the concentration tends to zero, the influence of the loading rate shows no obvious difference **Error! Reference source not found.**.

4.4. Temperature and Relative Humidity

The emission of formaldehyde and other TVOCs from furniture materials increases with the rise in indoor environmental temperature and relative humidity. In an indoor environment with higher temperatures, increasing relative humidity has a more significant effect on promoting the emission of VOCs from furniture materials. When the indoor temperature is in the range of 10-38°C and the relative humidity is between 55%-85%, an increase in either temperature or relative humidity promotes the accumulation of indoor formaldehyde. Studies have shown that for every 5°Cincrease in temperature, the equilibrium concentration of formaldehyde in different furniture materials rises to nearly twice the original level; a 30% increase in relative humidity causes the equilibrium concentration of formaldehyde in different furniture materials to rise to nearly three times the original level **Error! Reference source not found.**.

4.5. Air Change Rate and Air Flow Velocity

Before the formation of furniture paint films, the release of VOCs is generally controlled by evaporation, during which the emission rate of VOCs is nearly proportional to the air change rate. After the paint film is formed, the release process may be controlled by diffusion within the paint film and furniture materials, or simultaneously controlled by both evaporation and internal diffusion. If the release of VOCs is controlled by internal diffusion, changing the air change rate has little effect on the VOCs release rate. Air flow velocity mainly affects the release rate of VOCs from furniture surfaces by changing the flow pattern of the boundary layer near the surface. Increasing air flow velocity can accelerate the evaporation of VOCs from furniture, and this influence is more significant in the initial emission stage (evaporation-controlled period) of wet materials such as furniture paint films and adhesives **Error! Reference source not found.**.

4.6. Other Influencing Factors

The adsorption effect of furniture materials on VOCs can

prolong the residence and exposure time of VOCs, thereby causing persistent pollution of indoor air. The presence of oxidants in the air (such as ozone) can accelerate the formation of aldehydes and acids, as well as damage to the furniture surface, thus affecting the emission of VOCs from furniture and promoting an increase in the release of aldehydes and TVOCs.

5. Summary

Furniture, made from various raw and auxiliary materials through processing, is an important component of the indoor environment. Furniture made from different materials contains varying types and concentrations of VOCs, which mainly originate from dry materials such as boards and leather, as well as wet materials like paints and adhesives. The release of VOCs from furniture is not a simple summation of the release from its component materials but a complex process influenced by the furniture's own physical and chemical properties (boards, paint films and thickness, loading rate, etc.) and environmental factors (temperature, relative humidity, air change rate, air flow velocity, etc.). Based on the above research foundation, comprehensive measures need to be taken across material source reduction, manufacturing process control, and indoor environmental management—such as selecting low-VOC and low-volatility materials, optimizing spraying and coloring processes, and effectively increasing indoor air change rate and air flow velocity—to minimize indoor VOCs concentration, thereby improving indoor air quality and safeguarding public health.

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