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The concentration of organic compounds in indoor air after renovation and its relation to health

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ABSTRACT

Objective We aimed to investigate the pattern of the concentration of major volatile organic compounds (VOCs) in indoor air at different timepoints after renovation and its relation to health and to propose relevant measures. **Methods** We selected rooms at different timepoints after renovation to measure the concentration of formaldehyde, benzene, toluene, and xylene in the indoor air and reviewed the adverse reactions of residents. **Results** The concentration of benzene series peaked at day 30 after renovation and then gradually decreased. In particular, the mean concentrations of toluene and xylene were 10.5-fold and 7.6-fold, respectively, higher than the maximum permitted concentrations for hazardous substances in the air of residential areas in China. The benzene concentration also exceeded the maximum permitted concentration, to a relatively smaller extent. The formaldehyde concentration peaked within 1 year after renovation, and the mean concentration was 0.171 mg/m^3. More than 1 year after renovation, the mean concentration of formaldehyde in the renovated rooms was still significantly higher than that of the control ($P < 0.05$). The incidence of skin and upper respiratory tract irritation in the residents was the highest immediately after renovation and decreased over time. However, the incidence of eye irritation was the highest during the first year after renovation, and this incidence was still significantly higher than that in the control group more than 1 year after renovation. **Conclusion** These results revealed that the concentration of indoor VOCs was significantly higher after renovation, which was hazardous to the skin, upper respiratory tract, and eyes.
KEY WORDS: indoor air pollution, volatile organic compounds (VOCs), eye irritation, renovation

INTRODUCTION

As living standards improve, the demand for plywood, paints, coatings, and adhesives is increasing as people renovate their houses and apartments for more comfortable living and a more beautiful living environment. These renovation materials, however, release volatile organic compounds (VOCs), resulting in the accumulation of VOCs in rooms and the ensuing hazard to human health [1, 2]. Renovation materials mainly release VOCs such as the benzene series, including benzene, toluene, and xylene, as well as formaldehyde [3, 4]. The hazard posed by renovation materials to human health has been drawing attention and has become a social concern and a hot research topic. Residents are increasingly aware of the effect of indoor environmental quality on human health. The impact of indoor environmental pollutants on health and the relevant preventive measures are also becoming major health topics and are drawing attention from hygienists, environmental scientists, and the general public.

To investigate the pollution caused by the main VOCs in indoor air at different timepoints after renovation and the pattern in their concentration changes and to clarify the potential hazards to health, we sampled and tested the indoor air of certain renovated rooms in Guangzhou; asked the residents to complete a questionnaire survey regarding skin, upper respiratory tract, and eye irritations; analyzed the study results; and then offered professional input on measures to prevent and minimize the hazard of post-renovation VOCs to health.

1 MATERIALS AND METHODS

1.1 Site selection

We selected rooms at different timepoints after renovation: within 30 days, within 1 year, and more than 1 year after renovation. We also selected unrenovated, unoccupied rooms in the same unit of the same building as the control.

1.2 Measures

The levels of formaldehyde, benzene, toluene, and xylene of indoor air were measured.

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1.3 Sampling and testing

For each apartment, one sample each was collected from the bedroom and the center of the living room, at the level of the average breathing zone [5-7]. The samples were collected after the room windows and doors had been closed for 1 hour.

1.3.1 Determination of formaldehyde in the air

The INTERSCAN 4160-2 Formaldehyde analyzer (Windsor, NJ, USA.) was used to directly obtain the readings.

1.3.2 Determination of benzene, toluene, and xylene in the air

In accordance with the *GB/T11737 Standard Methods for Heath Inspection of Benzene, Toluene and Xylene in the Air of Residential Areas: Gas Chromatography*," an air sampler connected to activated charcoal was used to sample the air for 20 minutes at 0.5 L/minute, and then, the sample was extracted with carbon disulfide. Next, the sample was analyzed by gas chromatography using a hydrogen flame ionization detector to determine the retention time and peak height.

1.4 Evaluation criteria

The Code for Indoor Environmental Pollution Control of Civil Building Engineering (GB50325-2001) was used.

1.5 Survey of the health-related responses in residents

Four hundred thirty-four residents who lived in renovated rooms for different periods after renovation were included as the experimental subjects, and 136 residents who lived in unrenovated rooms were included as the controls. Exclusion criteria in selecting research subjects include: (a) The patients with severe chronic obstructive pulmonary disease (COPD), severe bronchial asthma, respiratory muscle; (b) Patients with conjunctiva, cornea and iris obvious lesions (c) Patients with dermatitis and eczema, urticaria and other skin disorders. The residents' eye, upper respiratory tract, and skin irritation-related symptoms and responses were recorded.

1.6 Statistical analysis

SPSS for Windows version (11th edition) statistical software package was used for the statistical analysis.

2 RESULTS

2.1 Determination of the concentration of VOCs in indoor air at different timepoints after renovation

After interior renovation, the concentration of formaldehyde peaked within 1 year after renovation, and the mean concentration was 2.1-fold higher than the indoor formaldehyde concentration (0.08 mg/m^3) set forth in the Code for Indoor Environmental Pollution Control of Civil Building Engineering (China). After more than 1 year after renovation, the formaldehyde concentration was still significantly higher than that of the control ($P < 0.05$) and exceeded the state standard in certain rooms (Table 1). The results indicated that formaldehyde was not released in a large volume from renovation materials until after a certain period after renovation.

Within 30 days after renovation, the mean concentrations of toluene and xylene in the indoor air were 10.5-fold and 7.6-fold, respectively, higher than the maximum permitted concentration (0.3 mg/m^3) for hazardous substances in the air of residential areas in China, and the concentration of benzene was 1.1-fold higher than the indoor concentration (0.09 mg/m^3) specified in the Code for Indoor Environmental Pollution Control of Civil Building Engineering (China). Thus, within 30 days after renovation, the concentrations of benzene, toluene, and xylene in indoor air were significantly higher than the control concentrations ($P < 0.01$) and then gradually decreased over time, but were still higher than the control concentrations ($P < 0.05$) (Table 1). These results suggested that interior renovation caused serious indoor VOC pollution. Moreover, after renovation, benzene series were immediately released in a large volume from the renovation materials, and then the amount released gradually decreased over time, along with the concentration of the benzene series in the air.

2.2 Survey of the residents' health-related responses at different timepoints after renovation

After renovation, the incidence of eye, skin, and upper respiratory tract irritations (such as tearing, blurred vision, runny nose, coughing, dermatitis, and difficulty breathing) was increased. The incidence of skin and upper respiratory tract irritation was the highest immediately after renovation and then gradually decreased over time. However, the incidence of eye irritation was the highest within 1 year after renovation, not shortly after renovation (Table 2). More than 1 year after renovation, the incidence of eye irritation was still significantly higher than the control value. Moreover, more than 1 year after renovation, the incidence of upper respiratory tract symptoms and skin irritations was higher in the residents living in renovated rooms than in the control residents, but this difference was not statistically significant.

Table 1. Concentration of the VOCs in indoor air at different timepoints after renovation (mg/m^3)

Time after renovation	Samples (n)	Formaldehyde	Benzene	Toluene	Xylene
		$\chi \pm S$	$\chi \pm S$	$\chi \pm S$	$\chi \pm S$
Within 30 days	52	0.064 ± 0.025**	0.101 ± 0.042**	3.136 ± 0.913**	2.265 ± 0.726**
Within 1 year	61	0.171 ± 0.048**	0.048 ± 0.020**	0.057 ± 0.021**	0.046 ± 0.021**
More than 1 year	38	0.080 ± 0.032*	0.008 ± 0.001**	0.016 ± 0.004*	0.011 ± 0.003**
Control group	43	0.033 ± 0.011	0.001 ± 0.001	0.005 ± 0.001	0.002 ± 0.001

Note: ** P<0.01 * P<0.01

Table 2. Adverse reactions of residents at different timepoints after renovation

Time after renovation	Residents surveyed (n)	Eye irritation (%)	Upper respiratory tract irritation (%)	Skin irritation (%)
Within 30 days	148	41 (27.7) **	46 (31.1) **	37 (25.0) **
Within 1 year	165	87 (52.7) **	28 (17.0) **	16 (9.7) *
More than 1 year	121	38 (31.4) *	4 (3.3)	3 (2.5)
Control group	136	6 (4.4)	1 (0.7)	1 (0.7)

Note: ** P<0.01 * P<0.01

3 DISCUSSION

During interior renovations, VOCs in the air mainly come from renovation materials, including plywood, paints, and coatings. Plywood is manufactured using a large amount of adhesives, especially urea-formaldehyde resin, which is a polymer of urea and formaldehyde, with a small amount of unpolymerized free formaldehyde [8, 9]. Coatings are mainly polyvinyl alcohol with expedient formaldehyde. Polyurethane paint, which is the most extensively and commonly used material, evaporates several VOCs, such as benzene, toluene, and xylene. Thus, once these materials containing a large amount of formaldehyde, benzene, toluene, and xylene are used in renovation, they may inevitably release some of the hazardous substances, such as organic solvents, volatile organic compounds (VOCs) mentioned above, formaldehyde and may be heavy metals[10, 11].Therefore, housing renovation has become a new source of indoor environmental pollution. In this study, the results indicate that the concentration of formaldehyde of indoor air increased in the first 30 days after renovation. Months later, the concentrations of formaldehyde increased gradually and maybe 30 times higher than that of the first 30 days. Moreover, after more than 1 year after renovation, the mean concentration of formaldehyde in the indoor air was still significantly higher than the control value ($P < 0.05$). The reason why the concentration of formaldehyde changes so dramatically might be because in addition to coatings, formaldehyde was also a main component of adhesives and was extensively used in artificial panels (furniture, etc.), sticky flooring materials, and wall materials. Specifically, in furniture panels, formaldehyde was mainly used deep within the materials, resulting in sustained release and slow evaporation. Studies have shown that indoor formaldehyde may be released for as long as 3 to 15 years; consequently, residents may experience irritation and harm while surrounded by formaldehyde for long periods.

In addition, this investigation revealed that the benzene series concentration peaked immediately after renovation and then gradually decreased over time. This concentration was related to the length of time (years) after renovation, possibly because benzene series are usually used as a solvent for paints and thus are often applied to surfaces and can be easily released and evaporated. This study showed that within 30 days after renovation, the concentration of toluene and xylene in the indoor air was far greater than the maximum permitted concentration. The benzene concentration also exceeded the maximum permitted concentration, to a relatively smaller extent. This might be because the World Health Organization has defined benzene as a potent carcinogen because of the high risk it poses to human health, and thus, GB50325-2001 has specified that benzene may not be used as a solvent for indoor coatings and adhesives. Hence, toluene or xylene, instead of benzene, is used as a solvent for commercially available coatings. However, due to purity issues, a small amount of benzene is still present in aromatic solvents such as toluene and xylene. Consequently, benzene may be detected during the monitoring of indoor air, although its concentration is lower than that of toluene and xylene.

The survey of the health status of the residents in renovated rooms revealed that the incidence of skin and upper respiratory tract irritations was highest immediately after the renovations and then gradually decreased over time, suggesting that skin and upper respiratory tract irritations may be associated with benzene, toluene, and xylene. The incidence of eye irritation was highest within 1 year after renovation and was still significantly higher than the control more than 1 year after renovation ($P < 0.01$); thus, the incidence of eye irritation was correlated with the concentration of formaldehyde in a time-dependent manner, suggesting that eye irritation may be closely associated with formaldehyde. The results of the survey are somewhat the same as the former reported[2], however, this hypothesis should be confirmed with additional experimental studies.

In addition, it is known that interior renovations may cause serious indoor VOCs pollution, posing a risk to human health. Thus, how to prevent and control VOCs pollution is an important topic to environmental scientists. Based on the results of this study and the professional knowledge of environmental health, we propose the following measures for preventing and controlling VOC pollution hazards: 1) Strengthen indoor air testing. The resident should not move in immediately after a renovation and should choose an appropriate time to move in after the indoor air has been tested by an environmental testing agency and appropriate measures are in place. 2) Improve ventilation, reduce VOC accumulation, and install air filters. The resident should open windows and doors (including cabinet doors) often to facilitate VOC evaporation and diffusion and thus reduce the accumulation of harmful indoor substances. The resident may use an air conditioning unit with air filtration to filter the indoor air. 3) Plant more trees, shrubs, and flowers in the residential area, and grow flowers in the room. Green plants absorb and purify pollutants diffused into the room, thereby promoting the outward transfer and diffusion of indoor pollutants and reducing the concentration of indoor pollutants. 4) Choose and develop green building-renovation materials. We need to actively develop green building materials, apply photocatalytic technology to novel building renovation materials, and accelerate the development and application of self-purifying materials. 5) Strengthen education, and promote knowledge regarding the hazards of indoor air pollution and the corresponding preventive measures.

Disclosure of Potential Conflicts of Interest
No potential conflicts of interest were disclosed.

REFERENCES

[1] Franck U., et al. Prenatal VOC exposure and redecoration are related to wheezing in early infancy. Environ Int. 2014;73:393-401.

[2] Sohn J., et al. Indoor air quality investigation according to age of the school buildings in Korea. J Environ Manage. 2009;90(1):348-354.

[3] Hippelein M. Analysing selected VVOCs in indoor air with solid phase microextraction (SPME): a case study. Chemosphere. 2006;65(2):271-277.

[4] Inoue M., et al. Rapid on-site air sampling with a needle extraction device for evaluating the indoor air environment in school facilities. Anal Sci. 2013;29(5):519-525.

[5] Hong YJ., et al. Assessment of volatile organic compounds and particulate matter in a dental clinic and health risks to clinic personnel. J Environ Sci Health A Tox Hazard Subst Environ Eng. 2015;50(12):1205-1214.

[6] Liu B., et al. Distribution of volatile organic compounds (VOCs) in surface water, soil, and groundwater within a chemical industry park in Eastern China. Water Sci Technol. 2015;71(2):259-267.

[7] Macey GP., et al. Air concentrations of volatile compounds near oil and gas production: a community-based exploratory study. Environ Health. 2014;13:82.

[8] Kim S., et al. TVOC and formaldehyde emission behaviors from flooring materials bonded with environmental-friendly MF/PVAc hybrid resins. Indoor Air. 2007;17(5):404-415.

[9] Wiglusz R., et al. Hygienic aspects of the use of pressed-wood products in residential buildings. Part I. The effect of particleboards ageing on release of formaldehyde. Bull Inst Marit Trop Med Gdynia. 1990;41(1-4):73-78.

[10] Ewers L CC., et al. Lead levels in new residential enamel paints in Taipei, Taiwan and comparison with those in mainland China. Environ Res. 2011;111(6):757-760.

[11] Zhang N ZD, Xue M. Research on the indoor air quality of dwelling house in rural area of Changzhou city. J Anhui Agri Sci (chin). 2008;25(3):1968-1969.