Pilot study on VOCs during indoor renovation

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ABSTRACT
The concentrations of volatile organic compounds (VOCs) were measured during renovation of a residence. In order to determine the relationship between indoor concentration and the phase of the renovation process, samplings of indoor concentrations and personal exposures were divided into 19 and 8 periods, respectively. VOCs were sampled by active charcoal and analyzed using GC-MS. Carbonyl compounds were sampled by 2,4-dinitrophenylhydrazine (DNPH) cartridges and analyzed using HPLC. It was revealed that the most causal process influencing the personal exposure during renovation was painting. The renovation in this study was conducted to reduce formaldehyde. Use of a material with less formaldehyde content was to effective for the reduction of formaldehyde concentration during renovation.

INDEX TERMS
Renovation; Personal exposure; VOCs; Carbonyl compounds

INTRODUCTION
Although many field studies have been done on the concentration of indoor volatile organic compounds (VOCs) in Japan, most of these studies focused on indoor residential environment after construction. There are few studies, however, on indoor VOC concentrations during renovation. In the course of renovation, the occupants continue to live in the residence where half-dry paints or adhesive materials release organic solvents and, as a result, VOC concentrations may become considerably high. The purpose of this study was to determine the personal exposure to VOCs including carbonyl compounds emitted from building materials, paints and so on during renovation.

METHODS
The residence of renovation was a two-floor wooden house built 22 years ago (Architectural area, 140.4 m^2, 1F: 84.9 m^2, 2F: 55.5 m^2). Most of the renovation was conducted in the living room. During the renovation, the front and kitchen doors were kept open.

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Standardized material with formaldehyde emission less than 0.5 mg/L was used as flooring. ‘Non formaldehyde bond’ was used to cover the wall with wallpaper. The paint used was left out of the consideration to reduce chemical compounds. The items measured were as follows:

- Personal exposure [Subjects A, B, C, D (Subject D is the carpenter)]
  Subject A stayed in the 1st floor for most of the time
  Subject B stayed in the 1st floor during the daytime and 2nd floor during the night.
  Subject C stayed in the 2nd floor for most of the time.
  Subject D stayed in the 1st floor for most of the time.
- Indoor air concentration [Living Room, Japanese-style Room, Bed Room (upstairs)]
- Outdoor air concentration
- Temperature and humidity.

SAMPLING

The concentrations of VOCs were measured by an active sampling method and were sampled for some periods of 24 days of renovation using charcoal tubes (SIBATA Kagaku, Japan) at a flow rate of 750 ml/min. Sampling was done separately during the daytime when the renovation was taken place and the night time when the carpenter left and the openings were closed. A passive sampling to measure the 1 week average concentration was carried out for every week until the 47th day from starting the renovation using Passive gas tubes (SIBATA Kagaku, Japan). Personal exposure was measured by passive sampling with the passive gas tubes every week (Table1).

The concentration of carbonyl compounds was measured by an active sampling and a passive sampling using 2,4-dinitrophenylhydrazine (DNPH) cartridges (Xposure, Waters Ltd, USA). The sampling period was the same as that for the VOCs. The flow rate was set at 100 ml/min. Personal exposure was measured by passive sampling using DNPH cartridges for every week.

ANALYSIS

VOCs were ultrasonically-extracted from the sampler by agitating for 10 min in 1 ml carbon disulfide (Wako Pure Chemicals Co.Ltd, Japan). Determination of the VOCs was conducted by gas chromatography/mass spectrometry (GC-MS, 6890-5973, Agilent Technologies, USA) (Table2).

The DNPH cartridge was eluted with 10 ml of HPLC-grade acetonitrile (Wako Pure Chemicals Co.Ltd, Japan), and 20 μl aliquots were injected into a High Performance Liquid Chromatograph (Hewlett-Packard 1100, U.S.A.) (Table3).

Table1 Sampling schedule

personal exposure		indoor* and outdoor concentration		method	renovation
before	2002/10/21-10/23	before**	2002/10/21day-10/23day	Active	carry the building material in
1st-week	2002/10/23-10/28	1st-D	2002/10/25day-10/26night	Active	plywood(ceil,floor),shelf
		1st-N	2002/10/26night-10/27day	Active	
		2nd-D	2002/10/27day-10/27night	Active	flooring
2nd-week	2002/10/28-11/5	5th-D	2002/10/29day-10/29night	Active	plywood (wall),
		5th-N	2002/10/29night-10/30day	Active	
		8th-D	2002/11/1day-11/1night	Active	kitchen set
		8th-N	2002/11/1night-11/2day	Active	
3rd-week	2002/11/5-11/11	12th-D	2002/11/5day-11/5night	Active	paint
		12th-N	2002/11/5night-11/6day	Active	
		14th-D	2002/11/7day-11/7night	Active	cloth
		14th-N	2002/11/7night-11/8day	Active	
		15th-D	2002/11/8day-11/8night	Active	cloth
4th-week	2002/11/11-11/18	18th(after)	2002/11/11-11/13	Active	
		20th(after)	2002/11/13-11/14	Active	paint
		21th(after)	2002/11/14-11/15	Active	
5th-week	2002/11/18-11/26	25th(after)	2002/11/18-11/26	Passive	
6th-week	2002/11/26-12/3	33th(after)	2002/11/26-12/3	Passive	
7th-week	2002/12/3-12-10	40th(after)	2002/12/3-12-10	Passive	

*D: for Daytime **N: for Nighttime

Table2 Analytical conditions of GC–MS

Instrument	Condition
Column	HP5-MS capillary column 30 m × 0.25 mm (0.25 μm)
Carrier gas	He
Flow rate	1 ml/min
Injection volume	1 μl
Split ratio	10 : 1
Injector temperature	250 ºC
Column temperature	40 ºC (4 min) - (10 ºC /min) - 280 ºC.

Table3 Analytical conditions of HPLC

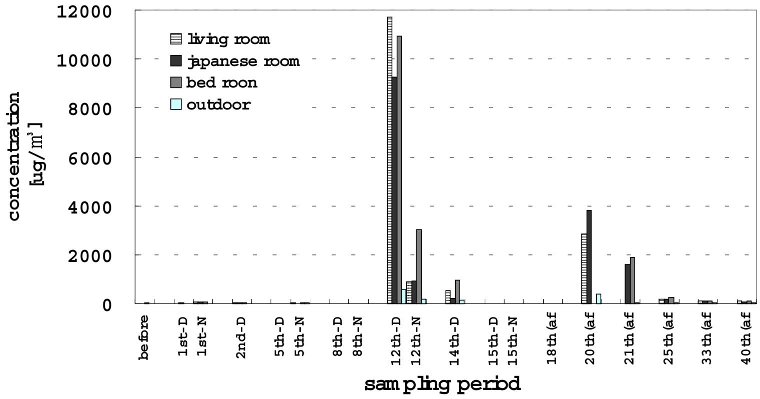
Instrument	Condition
Column	ZORBAX Eclipse XDB-C18 4.6mm × 250mm (5 mm)
Mobile phase	CH3CN : H2O = 65 : 35 (v/v)
Flow rate	1ml/min
Injection volume	20 ml
Column temperature	35 °C
Detector	Diode Array Detector (DAD) 365nm

RESULTS AND DISCUSSION

VOCs

Figure1 shows the variation of toluene concentration. Toluene concentration rose during painting. Moreover, the concentration of ethylacetate, m,p-xylene and so on. showed a similar tendency. Therefore, the source of elevation of the concentration of those compounds was assumed to be the paint but it was temporally elevated and decayed during the daytime.

Figure2 shows the personal exposure variation of toluene. For subjects A and B, personal exposure is over 1000 μg/m^3 (toluene concentration guideline in Japan is 280 μg/m^3) during the paint.



D: Daytime
N: Nighttime

Figure1 The variation of indoor air concentration—toluene.

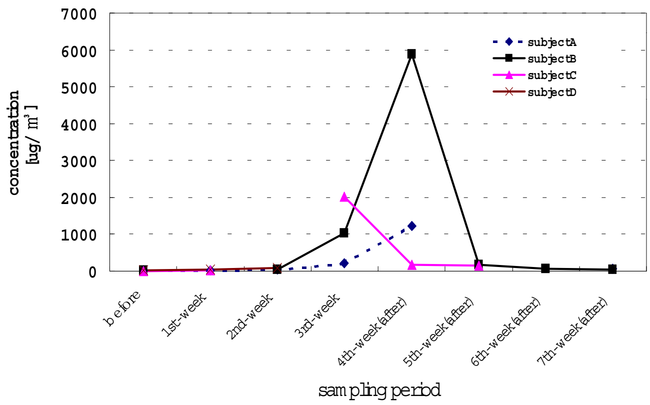


Figure2 The variation of personal exposure—toluene.

Carbonyl Compounds

Figure3 shows the variation of acetaldehyde concentration. The concentration of acetaldehyde in the living room, Japanese room and bed room exceeded the guidelines for Japan (48 μg/m^3) after the renovation. There was no remarkable change of temperature and humidity so this elevation was responsible for the ventilation rate. The highest concentration was observed on the 20–21 day. The formaldehyde concentration did not exceed the Japanese guidelines during the sampling period.

Furthermore, formaldehyde and acetaldehyde concentrations in the bedroom on the 2nd floor were higher than those in the living room, so there was a possibility of another source besides the renovation in the bedroom. There was a correlation between acetaldehyde concentrations in the living room and acetaldehyde concentrations in the Japanese room, so it is postulated that in these rooms was derived from the renovation.

Figure 4 shows the time series of personal exposure of acetaldehyde. Exposure of subjects A and C to acetaldehyde exceeded the guidelines. Subject C stayed on the 2nd floor for most of the time. The high concentration in the 2nd floor might cause the high exposure level observed in subject C. Personal exposure of formaldehyde did not exceed the guideline (100 μg/m^3).

Figure 5 shows the variation of crotonaldehyde concentration. The concentration of crontonaldehyde increased during the flooring and painting phase.

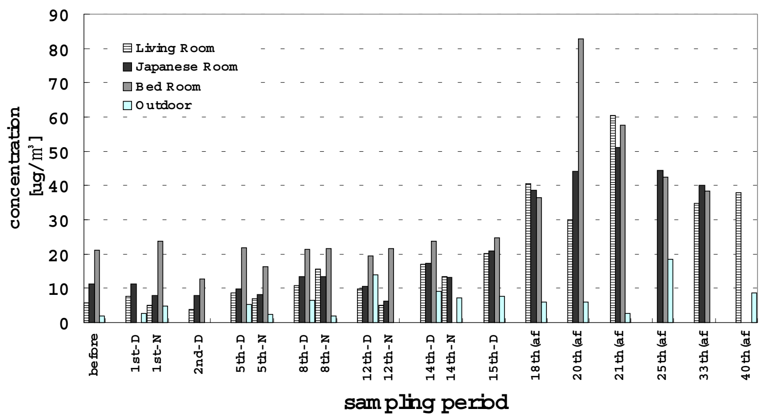


Figure3 The variation of indoor air concentration—acetaldehyde.

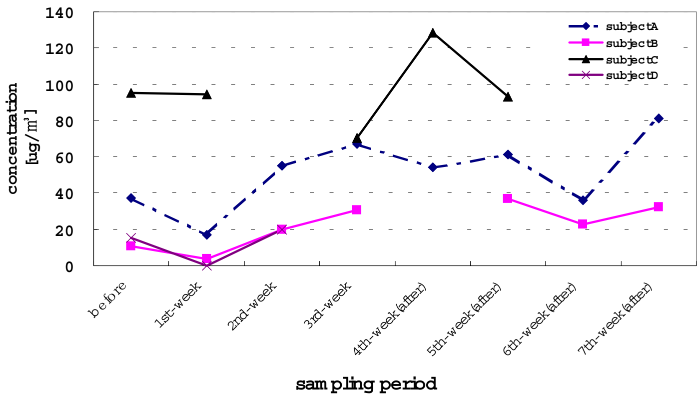


Figure4 The variation of personal exposure—acetaldehyde.

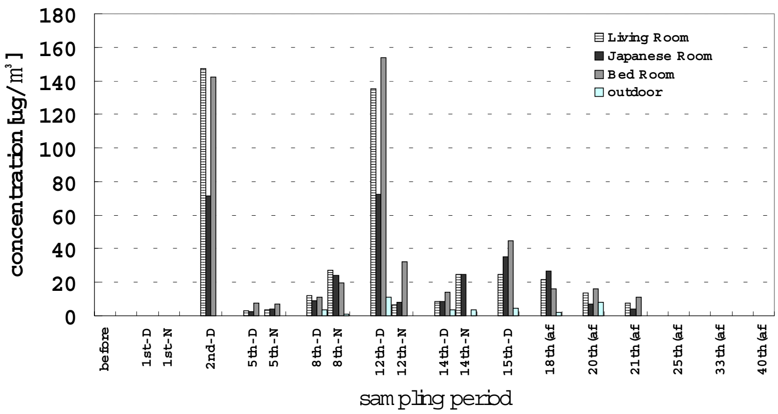


Figure5 The variation of indoor air concentration—crotonaldehyde.

CONCLUSION

- The most probable process influencing personal exposure during renovation was painting.
- Personal exposure varied widely among the occupants living in the same residence.
- The concentration did not increase remarkably during the nighttime, when the openings were closed.
- Use of material with lower formaldehyde content was actually effective for the reduction of formaldehyde concentration during renovation.

ACKNOWLEDGEMENT

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