

EXPERIMENTAL STUDY CONCERNING THE REDUCTION OF VOC CONCENTRATION IN APARTMENT BUILDINGS

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ABSTRACT

Indoor air pollution in residential environments caused by chemicals, such as formaldehyde and volatile organic compounds, which are resulting from the reduction in air exchange rates by the increase of air-tightness in building envelopes aiming at improving the energy efficiency for heating and air-conditioning, and from the introduction of new type building materials like plywood and finishing materials has been drawing public attention in Japan recently. Many field and laboratory test have been conducted in the past year, although the results from those two kinds of test have not reached to combine to each other. In this study we have tested emission rates of building materials in a test chamber, and also conducted a field measurement where the tested materials were used. As a conclusion, we could not find a relationship between the chamber test and the indoor VOC concentration, and could not establish to a mass balance equation. Though as a counterplan at this point continuous ventilation was effective to reduce indoor VOC concentration. Also from the calculation, the target air exchange rate 0.5 (1/h) for air tight residence were to low to control VOC concentration under 300 $\mu\text{g}/\text{m}^3$ which Seifert has proposed as target guideline value.

KEYWORDS

VOC, Field Measurement, Materials, Construction, Chamber Test, Mass Balance, Guideline, Air Exchange Rate

INTRODUCTION

In Japan VOC concentration including formaldehyde are still very high comparing to the European countries. There are many occupants suffering from these sick buildings or sick residences. As a counterplan for this, studies on field measurement and emission from materials in a test chamber have been reported on VOCs. However from these 2 kinds of studies, we can not design the concentration of VOCs before the buildings are occupied. Buildings are made of many material and fixed to a component. The results of the chamber tests should not just be used to compare the emission rate but to predict the VOCs concentration which the occupants are exposed. In this study we have conducted chamber test³⁾ and installed the materials in a full size apartment house and monitored the change of standings of VOCs by the materials installed.

METHODS

Emission Rate Measurement Of Building Materials Using a Large And Small Chamber

The materials test in the large chamber were underlayment finishing and furnitures (shoebox, door and etc.) The quantity of the test materials were 1/10 of a regular apartment (70m²) of underlayment and the equal amount of furniture use in one apartment house. The samples measured in the small chamber were adhesives for direct flooring materials to slab. Adhesive was plastered 0.6 to 0.65 (kg/m²) on a acrylic board to equalize the loading factor to 0.4 (m²/m³) which is a particular area of flooring in a living room.

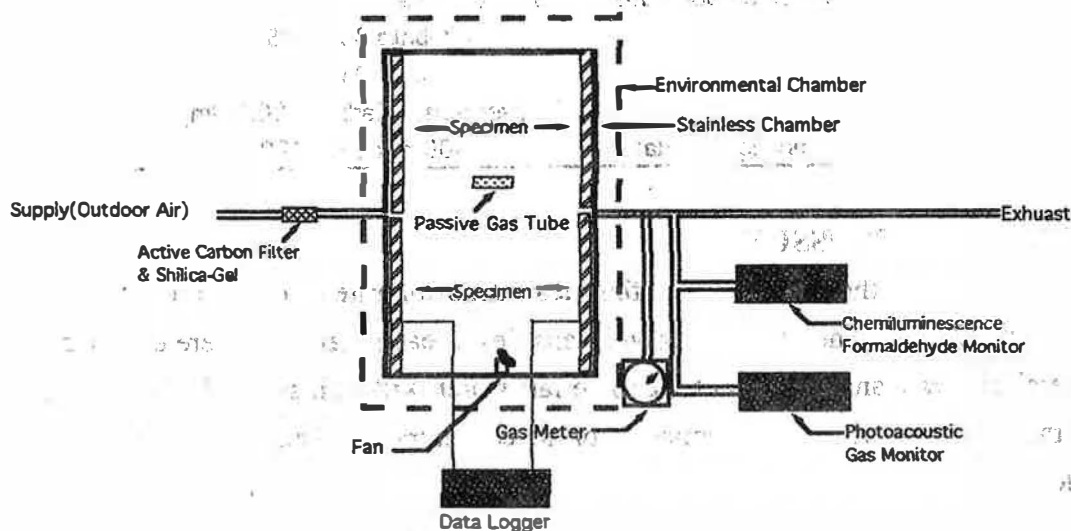


Figure 1 Diagram of The Test Chamber

The test chamber made of 3 components, the environmental chamber (5.45m x 5.45m x 3.4m), the large chamber (2.5m x 2.5m x 2.5m) and the small scale test chamber (0.4m x 0.4m x 0.745m)(Figure 1). The air of the environmental chamber is filtered through a charcoal filter and passed to the large or small chamber. The air inside the chambers are exhausted to the outside. The ventilation rates are measured by concentration decay technique using SF₆ as a tracer gas.

The sample is passed through a teflon tube into the analyzer. Formaldehyde is measured continuously using chemiluminescence method¹⁾, and is also sampled 24 hours by a passive typed sampler and analyzed by AHMT method. TVOC is measured continuously using hydrocarbon monitor²⁾ and also

VOCs were sampled to a charcoal tube sampler and analyzed by GC/FID method (Table 1). The condition of the test chamber was set to 0.5 (1/h) on ventilation rate, temperature to 23°C and relative humidity to 50%. Measurement were taken place continuously for 3 days and the 24 hours average of the 3rd day was sampled in general. Though when the concentration does not become stabled we have extended the time of the measurement.

Field Measurement in An Apartment House

2 rooms of an apartment house were measured for 4 months during “after the fixture were finished” to “before occupancy”. VOC concentration were sampled on a active carbon gas tube and analyzed by GC/FID (Table 1) and converted to toluene equivalent value. Ventilation rate was measured by concentration decay technique using SF₆ as a tracer gas. Photoacoustic gas analyzer (B&K 1302) was used to monitor the change of standing of TVOC, SF₆ and HCHO concentration.

Table 1 Conditions of GC and Sampling Devices

Gas Chromatography	
GC:	GL Science (GC-353)
Column:	CP-Sil8cb 100m*0.53 40-230°C Heat Desorption
Injection:	250°C
Carrier Gas:	N ₂
Ditector:	FID
Sampler	
Active Carbon Tube for Volatitic Gases (Shibata 8015-053) 20-40 Mesh 2 Layer Active Carbon 100/50mg)	
Sampling Flow Rate:	500ml x 14h=420L

RESULTS and DISCUSSION

From the results of the chamber test, the mean emission rate of each kind of materials were calculated (Table 2). Then the emission intensities of each materials were estimated from the mean emission rate and the area of the materials which will be installed in the room measured. From this estimation the highest emission or the concentration is expected when the finishing is completed.

The change of standings of VOCs concentration will be shown in Figure 2. After fixtures were

Table 2 Materials Installed

Product	Numbers of Samples	Average (μg/m ² h)	Area (m ²)			Emission Intensity (μg/h)		
			Inclination	Fitting	Finishing	Inclination	Fitting	Finishing
Carpet	7	14896	0	0	20.2	0	0	300899
Vinyl Flooring	5	3425	0	0	11.2	0	0	38360
Particleboard	1	114	252.7	0	0	28808	0	0
Composite Wood Product Assemblies	4	737	4.3	27.22	8.1	3169	20061	5970
Cellular Plastic Insulation	2	57	29.4	0	0	1676	0	0
Structural Composite Wood Products	3	228	0.081	0	0	18	0	0
Interior Plywood	1	170	0	0	0	0	0	0
Carpet Underpad	2	445	0	0	20.2	0	0	8989
MDF	4	340	0	18.86	52	0	6412	17680
General Interior Finishing Materials	4	219	0	0	19.9	0	0	4358
Total						33671	26474	376256

installed, TVOC concentration was highest over 7,000 $\mu\text{g}/\text{m}^3$ and decreased as the construction progressed. When the construction have finished and ready for occupancy, TVOC concentration was 3,000 $\mu\text{g}/\text{m}^3$ half of the concentration of when the fixture was finished. The trend of TVOC concentration in these 2 rooms in each period were the same, which means TVOC concentration is related with the materials installed.

Comparing between the groups, terpenes was the highest which was caused from α -Pinene. After fixture, the ratio of α -Pinene was 81% the highest and decreased as the construction progressed. The decrease rate of the α -Pinene's concentration was higher than it of TVOC concentration. This can be explained that α -Pinene emits from wood and when it is covered, e.g. by wall paper, carpets and etc., the emission of α -Pinene will be sealed by those finishing materials.

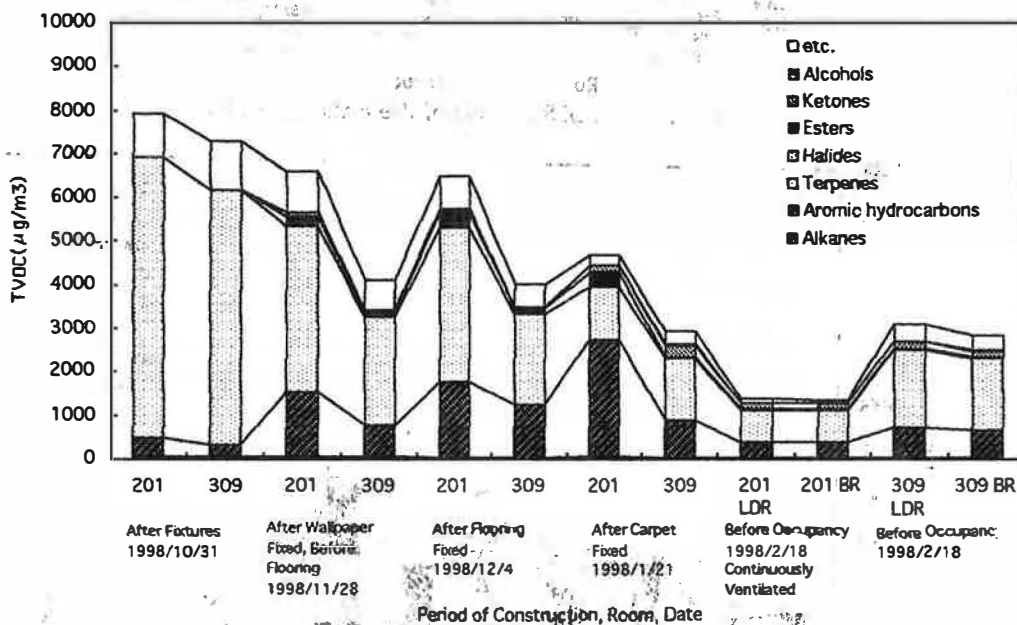


Figure 2 Change of Standing of VOCs Concentration

Table 3 Statistics of α -Pinene

average	standard deviation	maximum	minimum
2634.3	1901.9	6441.0	707.0

In Figure 4 is the change of standings of TVOC concentration excluding α -Pinene. From this the period of the highest TVOC concentration was when the construction was finished. Between the groups, aromatic hydrocarbon was highest. The adhesives used in each construction were in the same order so it is possible to compare the concentration only by the materials. The individual compound in aromatic hydrocarbon which the concentration were high were Toluene, 1,2,3-Trimethylbenzene and 1,2,4-Trimethylbenzene. In these 3 compounds Toluene were especially high.

Ventilation was effective to reduce VOC concentration³⁾. From equation (1) and (2) we have calculated the demanded air exchange rate to keep TVOC concentration bellow 300 $\mu\text{g}/\text{m}^3$ (Table 4). First the emission intensity was calculated in equation (1), then the concentration was set to 300 $\mu\text{g}/\text{m}^3$ and the demanded ventilation rate was figured in equation (2).

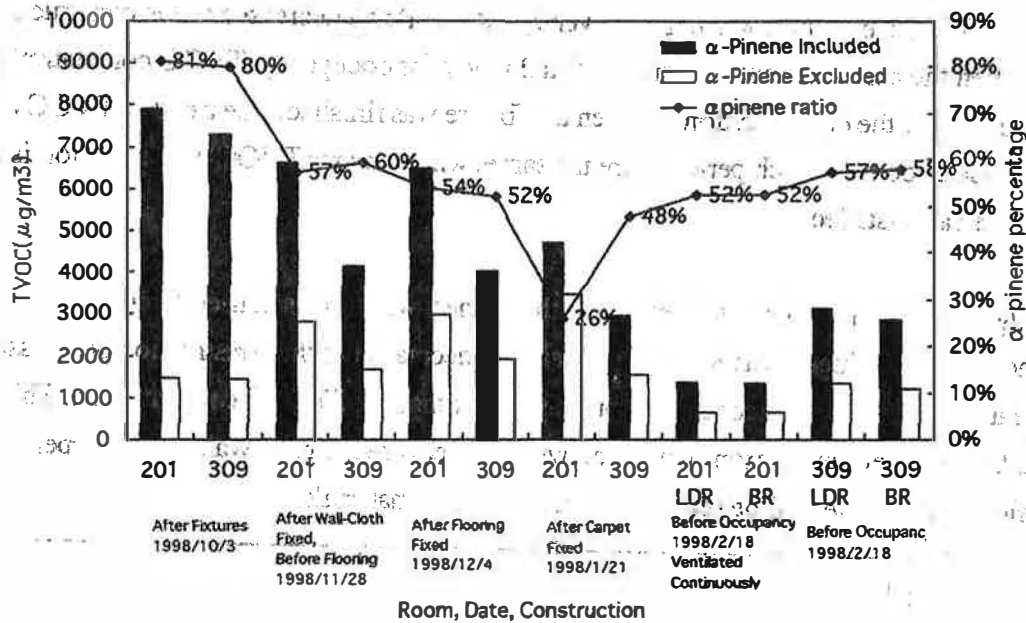


Figure 3 Change of Standing of The Ratio of α-Pinene

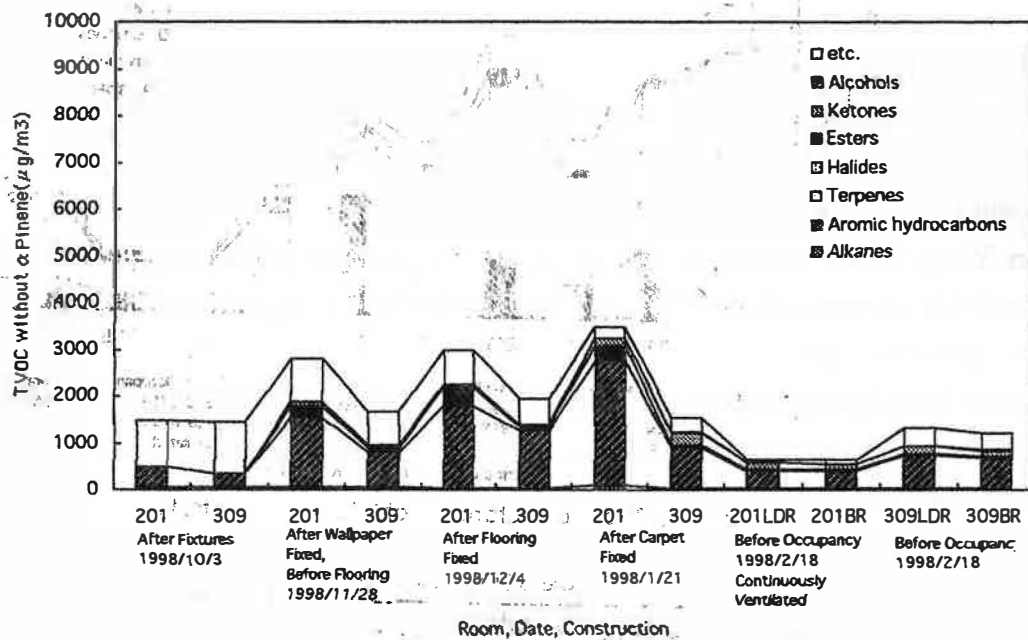


Figure 4 Change of Standing of VOCs Concentration Excluding α-Pinene

$$M = (C_m - C_o) n_m * V \quad (1)$$

$$n_d = M * \{(C_d - C_o) V\}^{-1} \quad (2)$$

C_d : Designed TVOC Concentration ($\mu\text{g}/\text{m}^3$)

C_m : Measured TVOC Concentration ($\mu\text{g}/\text{m}^3$)

C_o : Outdoor TVOC Concentration ($\mu\text{g}/\text{m}^3$)

M : Emission Intensity ($\mu\text{g}/\text{h}$)

n_d : Designed Air Change Rate (1/h)

n_m : Measured Air Change Rate (1/h)

V : Volume of The Room (m^3)

The air change rate differed 2.7 times when including and excluding α-Pinene and also by the difference of the air tightness. However if we take the safer amount, the air exchange rate should more than 1(1/h).

Table 4 Estimation of Demanded Ventilation Rate

Room Number	n-measured(1/h)		V:(m ³)		C : (μg/m ³)		M:(μg/h)		n-design(1/h)	
	201	309	201	309	201	309	201	309	201	309
α-pinene included	0.27	0.05	168.00	168.00	1363	2977.5	61826	25011	1.23	0.50
α-pinene excluded	0.27	0.05	168.00	168.00	648.5	1262.5	29416	10605	0.58	0.21

CONCLUSION

1. VOC concentration is related with the materials installs. However The diffusion coefficient must be concerned when the indoor VOC concentration is designed from the emission rates of each materials tested in a test chamber.
2. a-Pinene concentration was the highest in the individual compounds of VOCs and next was toluene.
3. Proper ventilation is needed to keep VOC concentration low.
4. TVOC is a indicator of indoor concentration, so health risk must also be concerned when indoor VOC is discussed.

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