IMPROVEMENT OF IAQ BY COATING OF ADSORPTIVE POLYMER: THE DEVELOPMENT OF MATERIAL, EVALUATION AND ITS APPLICATION

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ABSTRACT
A coating material of adsorptive polymer by graft polymerization was developed for the purpose of improving IAQ to decrease formaldehyde and VOC concentrations. The material was evaluated by a simple method with a small glass chamber of a circulation system. The ability of sealing of both of formaldehyde and VOC and adsorption, respectively, was performed by emission rate test and adsorption test. The polymer with three kinds of function group of sulfonic, amino and carboxyl was relatively effective to sealing and adsorption. The material was superior to the other materials on market in Japan. The material was applied to improve IAQ in two kinds of new multi-family house, and was evaluated by concentrations of indoor air and emission rate from individual parts. It was shown that formaldehyde concentration and TVOC, respectively, decrease to one fifth or one sixth and a half in the room treated with the coating material.

INDEX TERMS
VOC, Formaldehyde, Adsorptive polymer, Improvement of IAQ, Coating

INTRODUCTION
Improvement of IAQ by coatings is required when VOCs and formaldehyde concentrations can not be decreased to use selected materials. The required conditions of coating material are follows: Strength of coating membrane; Adsorbent of both of VOC and formaldehyde; To be coated easily with brash, roller or spray; Water soluble; Non-color; Economical. A coating material with Graft polymerization was developed by Ohkawara in 1996. In this paper it was studied to apply the material with graft polymerization to coating material for chemicals emission control. Sealing effect test for emission control and adsorption test for removal from indoor air was performed to evaluate the coating materials with a simple method of circulation system, and in addition to the material test field test was performed.

MATERIAL AND METHODS
Material: Coating material was prepared to add some kinds of functional groups to base of carbohydrade such as glucose in 6 h exposure of radiation in the graft polymerization. Acrylate of carboxyl group forms coating film, and urea of amino group, styrene sulfonic acid and ethanol as a polymerization adjustor was also mixed. The functional groups were also added on a seat such as cell rose with graft polymerization.

Evaluation of the ability to seal formaldehyde and VOCs in a board: Emission test was performed in a small glass chamber of 6.5L with a circulation system shown in Figure 1(1).

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One or 3 pieces of sample veneer boards and control of 20cm ×10cm was set, and volatile compounds emitted for 3h to 24h were collected with a DNPH cartridge or an active carbon tube (Figure 1). Formaldehyde and VOCs in the sample respectively were determined with HPLC and GC method. The chamber was set in an experimental room controlled at 23 to 25°C and on the other hand the humidity was not controlled. The temperature and humidity were monitored when necessary. The sample was prepared by coating of a material at a fixed weight per unit surface area of boards. Sealing efficiency is estimated by (B – A) /B, provided that the emission weight from a sample and control board is A and B.

Evaluation of the ability of the material to adsorb formaldehyde and VOCs in surrounding air: Adsorption test was performed with a chamber of 6L shown in Figure 1(2). A sample was prepared to coat the material on a glass plate or a veneer board that the emission had been controlled enough of 20cm ×10cm. The chamber system has a stirring fan and an injector of formaldehyde or VOCs and a monitor inserted to the circulation line. After the sample or control board was inserted in the chamber, formaldehyde or VOCs was injected. Formaldehyde was prepared by vaporization from formarine and monitored with a potential-controlled gas sensor. A VOC was prepared by injection of the vapor with a syringe and monitored with a gas sensor on semiconductor. When concentrations of monitor became constant, the concentrations for the sample and control (A and B) were read. Removal efficiency was estimated by (B – A) / B.

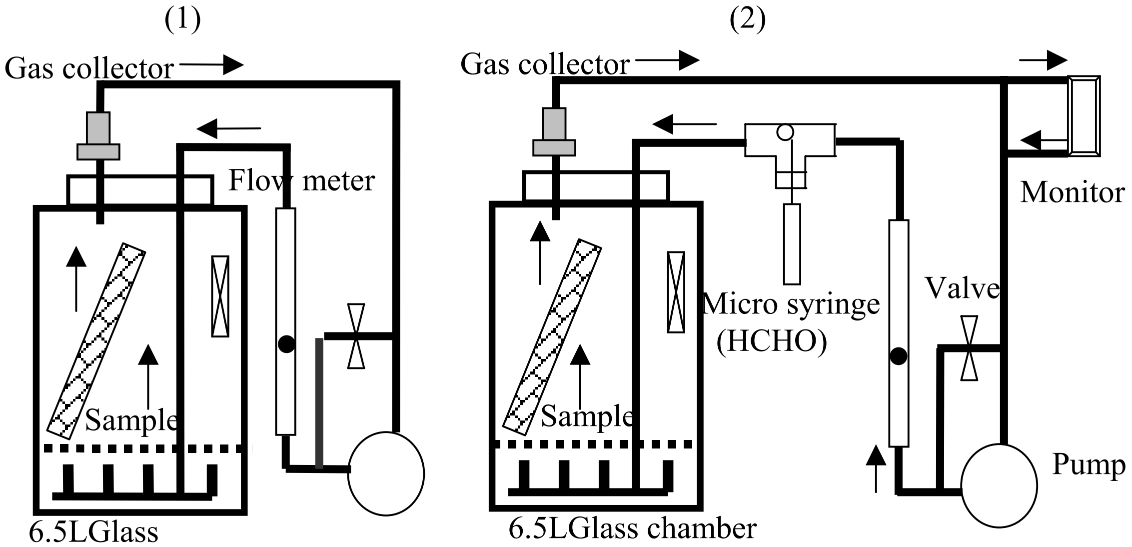

Figure 1. Simple chamber system for emission test (1) and adsorption test (2).

The concentrations of formaldehyde and VOCs in fields, respectively, were measured according to determination method of ISO 16000-3 and 6. The sampling was performed for 30 minutes after elapse of 5 hours from time when doors and windows had been shut. Emission rate of formaldehyde in field: TEA-Dish method developed by Hori et al was applied to the measurement. It is a simple method for measurement of formaldehyde emission rate parallel to many points in field. The procedure is as follows: A filter of cell rose permeated with 10 % triethanolamine(TEA) fixed on inner surface of a dish of aluminum of 20 cm in diameter, which was put on surface of parts such as ceiling and wall for 24h. Formaldehyde collected with the filter was determined with AHMT absorption method after abstraction to water.

RESULTS AND DISCUSSION

Effect of function groups of material on sealing efficiency.

Sealing efficiency of kinds of function groups added to a base of glucose on emission rate from coated veneer boards was as follows: Carboxyl group 52%; Carboxyl and amino group 72%, Carboxyl, amino and sulfonic group(sulfonic 0.5) 82%, Carboxyl, amino and sulfonic group (sulfonic 1.4) 85%. Emission rate of formaldehyde from control veneer board was approximately 20 μg /m^2 h. Addition of amino and sulfonic group was effective for formaldehyde, and that of carboxyl group was slightly effective. It is assumed that amino(NH_2-) and sulfonic(-$C_6H_4SO_3H$) groups bring about chemical adsorption of formaldehyde, and coating of carboxyl group and urea bring about only physical sealing effect. Material of amino, sulfonic and carboxyl group addition was used in this study.

Comparison with the other kinds of coating material

Examples of sealing efficiency and adsorption efficiency in some kinds of material are shown in Table 1. Sealing test was performed, and subsequently adsorption test was performed. When the sealing efficiency of a sample is low in the sealing test, the adsorption efficiency was estimated to correct the concentration of formaldehyde emitted in the sealing test. Therefore it is presumed that the measurement values are low in precision. The result shows that the coating material of No.9 is superior to the others on market in Japan for sealing and adsorption of formaldehyde. Adsorption test of this material is going to be performed in the concentration of 0.1 to 0.2 ppm

Table 1. Examples of sealing efficiency and adsorption efficiency of formaldehyde in some kinds of material.

Sample		Non-coating (μg/h)	Emission rate (μg/h)	Sealing (%)	Adsorption (%)
1	Natural organic	14	0.47	82	25
2	Synthetic paint(1)	14	0.42	97	47
3	Synthetic paint(2)	14	0.58	96	70
4	Synthetic paint(3)	14	2.7	5.5	20
5	Ceramic paint	14	5.5	61	40
6	Synthetic coating (1 time)	31	20	35	-
7	Synthetic coating (2 times)	31	10	67	-
8	Natural inorganic	14	0.79	98	89
9	Present material	13	0.31	98	94
10	Cell rose sheet*				97

Control(non- coating): veneer board of 20×10×9 cm

* Function group was added directly on seats of Cell rose with graft polymerization.

Mount of formaldehyde injected in adsorption test was 9.9 μg(1.2ppm).

Samples of No.2,3,4 were measured with a potential-controlled monitor, and the others with DNPH method because of interference of VOC .

The sealing of formaldehyde is assumed to result from decrease of diffusion area on coating membrane. This effect also affects for VOCs emitted from inner building materials. Concentrations of formaldehyde in the chamber decreased when the material was inserted in the chamber. The result means that formaldehyde adsorbed to surface of the coating material. Formaldehyde is assumed to adsorb on the amino group because of high polarity of formaldehyde, but it is not clear for the adsorption to be followed by dehydration from HCHO and NH_2- such as polymerization of urea resin. It has a limited adsorption amount of formaldehyde and VOCs. Therefore this material is presumed to be effective for improvement of IAQ as amount of them emitted to an indoor air is limited, and it is necessary to evaluate the effect again after 1 or 2 years.

Field test

This coating material was applied in new multi-family houses of 38 m^2 in area. One of them was treated with the coating material which was 2.4 L in volume of undiluted solution and about 2 g/m^2 in dry weight in the surface. In addition the sheets of No.10 in Table 1 and 18 m^2 in total area were inserted under wall and flooring. After two weeks sampling of air in both of the room and the other that had not been treated was performed. The measurement values is shown in Figure 2. The concentration of formaldehyde decreased to one fifth. Some kinds of VOC except ethanol that the concentration decreased more than the other VOCs in this field test is shown. The ethanol comes from a polymerization adjustor. The concentration of ethanol is presumed to decrease rapidly because of vaporization from the surface.

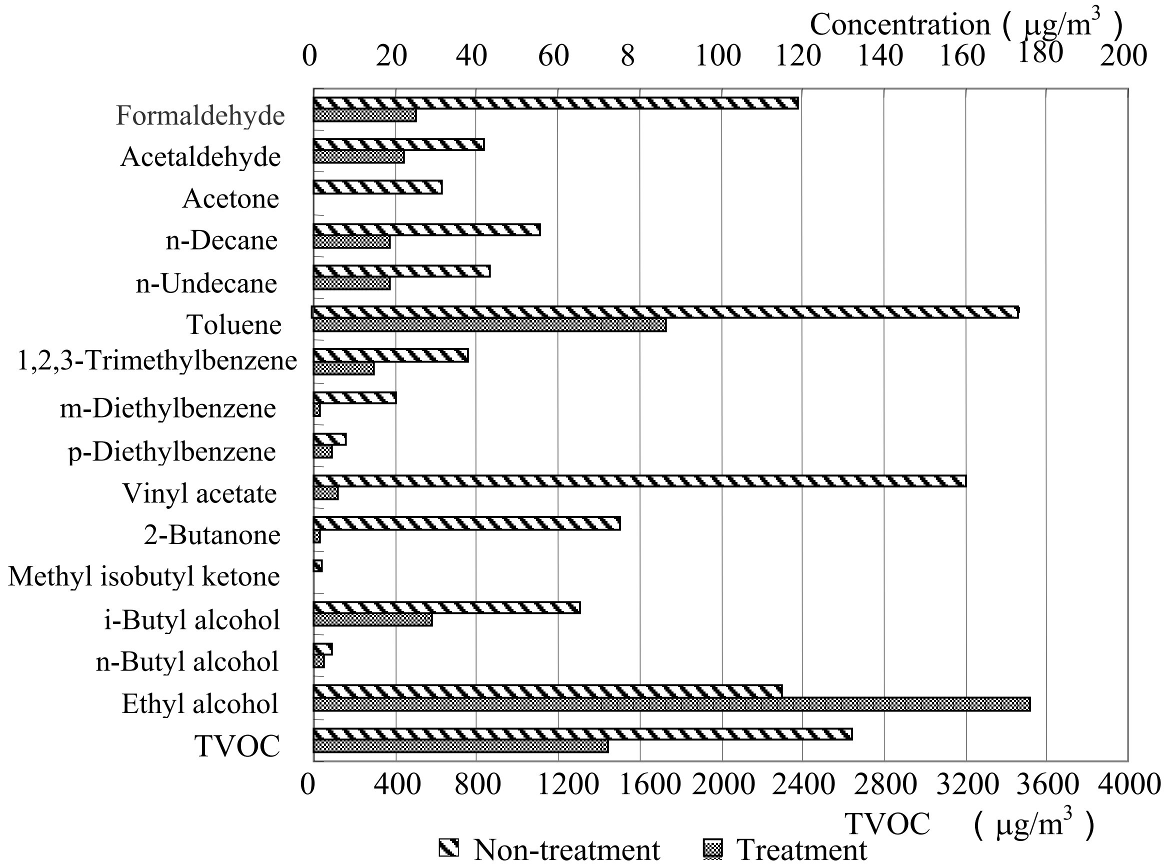

Figure 2. Comparison of the concentration of formaldehyde and VOCs in a room treated with the coating material with that in a non-treated room.

The room has two ventilation fans only in a bathroom, a toilet and a kitchen and does not air supply holes. These fans are operated in use time. Ventilation rates of the room with and without operation of the fans of bathroom and a toilet, respectively, were 0.17 and 0.4 (1/h). The concentration was measured after elapse of 5 h without operation of the fan from when windows and doors had been shut. We ordinary dwell in the conditions. If HVAC of 0.5 in ventilation rate is applied, the concentration of formaldehyde would be estimated to be 40 $\mu g/m^3$. In resent years new residential houses of a full time ventilation has increased in Japan, but the great portion of new houses does not have it, even if airtight houses. Therefore the improvement of IAQ with the building materials is considered to be valid

Emission rate of formaldehyde from individual parts of building material used in the other new multi-family house was measured with TEA-Dish method. The effect of treatment by the coating material was evaluated to compare emission rate of a part in a treated room with that of the same part in non-treated room. Amount emitted from a part was estimated by product of surface area of the part and the measured emission rate. Contribution(%) of a part such as wall is shown as ratio of amount emitted from the part to total amount. The results are shown in Figure 3 and 4. The sampling was performed for 24h after 3 days. Total amount of formaldehyde emitted decreased one sixth. The result shows that coating to both of wall and ceiling was effective, and that of flooring was not effective. After treatment both of door and

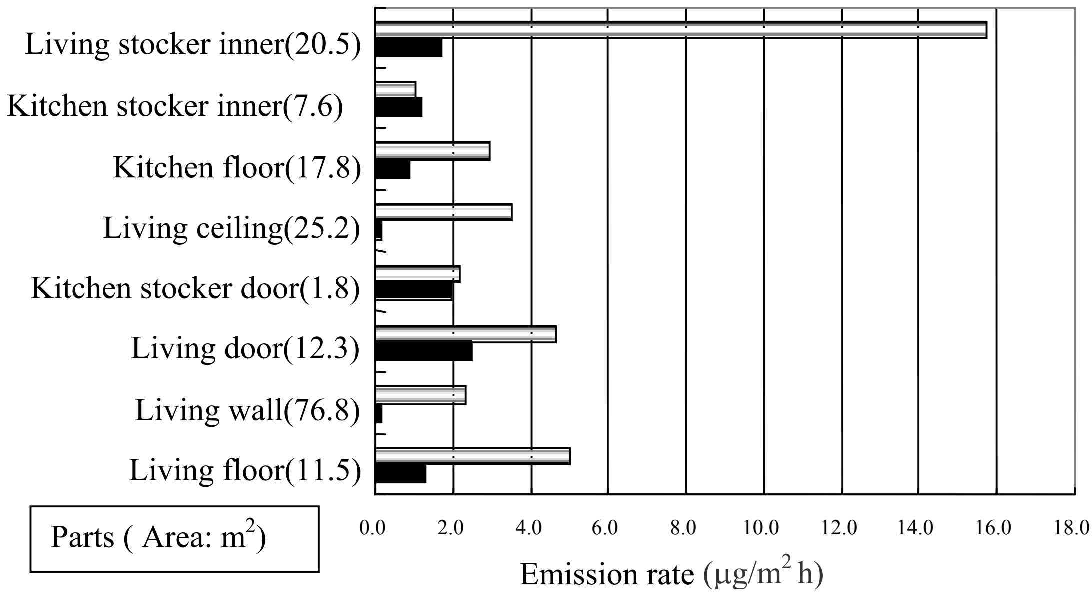

Figure 3. Emission rate of formaldehyde emitted from individual parts; Comparison of non-treatment with treatment. The surface area of each parts was described in parentheses. Upper bar: Non-treatment; Lower bar: Treatment. Surface of the kitchen stocker was not treated.

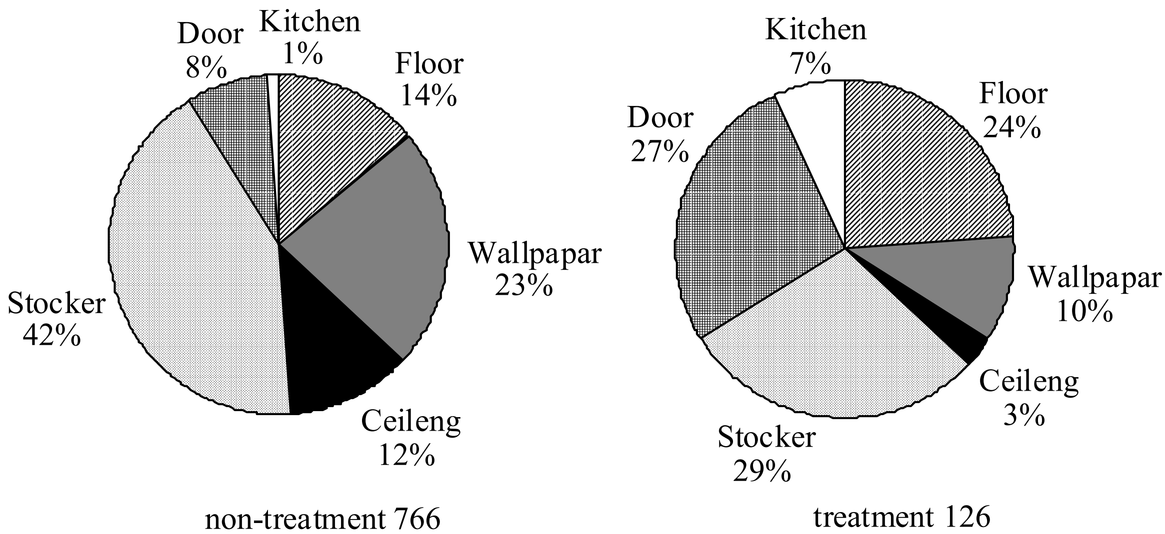

Figure 4. Contribution of individual parts for emission of formaldehyde in treatment and non-treatment room. Number of bottom is total emission amounts (µg/h) in the room calculated by $\sum$ RA; R: Emission rate of parts constructed with a material and A: Total area of the part. They are described in Figure 3.

Surface of stocker made relatively large contributions to emission of formaldehyde. It is necessary to study how to coat effectively to surface of melamine resin of stocker and flooring. This coating material is valid to improve IAQ in not only new houses but also established sick houses on formaldehyde and some kinds of VOCs.

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