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To cite this article: Hyuntae Kim *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **609** 042046

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The emission rate of newly regulated chemical substances from building materials

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Abstract. The Japanese government mandated a mechanical ventilation system for the purposes of solving sick houses and setting the guidelines for indoor hazardous chemical substances. However, as the use of new chemical substances and alternative substances has increased, pollution in the rooms has been a major concern. Therefore, the present study measured the emission rate of new contamination chemicals from building materials through the micro-chamber. As a result, the emission of 2EHA from the adhesive was confirmed. In addition, TXIB, TEXANOL, DINP, DEHP, DBP and other chemical substances were emitted from the building materials such as carpet, PVC flooring, water paint, and insulation.

1. Introduction

Nowadays, people spend approximately more than 90% of their time indoors, so it is likely that their health is heavily affected by the air contamination inside their residences [1, 2]. Previous research has revealed that the chemical substances diffused from the building materials are one of the causal factors that influence people's health by the indoor environments [3-6]. To solve the "sick house" problems, the Japanese government stipulated guideline values for indoor air and made mechanical ventilation obligation by law [7]. However, the increasing use of substitute materials in residence settings brings the possibility of contamination from new chemical substances.

The Sick House Committee of the Ministry of Health, Labour and Welfare has been currently reviewing policies for the substances that will potentially subject to the revised guideline values. Of the 13 substances, guideline values for some substances (including ethylbenzene, xylene, di-n-butyl phthalate (DBP), and di-2-ethylhexyl phthalate (DEHP)) were revised [7]. While the value for ethylbenzene will be further examined, the guidelines of new values for xylene, DBP, and DEHP were already announced. In addition, substances including 2-ethyl-1-hexanol (2E1H), 2,2,4-Trimethyl-1,3-pentanediol monoisobutyrate (Texanol), and 2,2,4-trimethylpentane-1,3-diyl diisobutyrate (TXIB) were proposed as new restricted substances. These tentative guideline values, however, still require further examination and analysis. Although it is speculated that DBP, DEHP, Texanol, and TXIB, which are widely used as plasticizers, are diffused from the indoor finishing materials and furniture, it is unclear which chemical substances are diffused from which kinds of products.

In this present research, the emission rate of semi-volatile organic compounds (SVOCs) from building materials was measured by using a micro-chamber to determine the emission source of chemical substances contaminating indoor spaces.

2. Measurement method

Figure 1 shows Illustrations of the micro-chamber method [8]. The micro-chamber had a volume of 630 ml ($\pm 5\%$), and a vent line was set right before its entrance to block outside air that could enter from the gap between the cover and the building materials which cause contamination. Before the



measurement started, the micro-chamber was disassembled and washed with water. Then, a heat treatment was conducted at 220°C for 1 hour using a heating device to volatilize the chemical substances remaining inside it. After the heat treatment, the micro-chamber was cooled to the room temperature. The test specimen was placed between the cover and the micro-chamber to measure the SVOCs concentration from its surface. The emission test was started when the test specimen was set in the micro-chamber and lasted for 24 hours at a temperature of 28°C.

The emission test was followed by a heat desorption test. After removing the test specimen used in the emission test from the micro-chamber, the micro-chamber was installed in a heat desorption device and desorbed the SVOCs attached to the inner surface. This heat desorption test was conducted for 1 hour at 220°C. The heat-desorbed SVOCs were collected by using a Tenax TA tube. The emission rate of the SVOCs from the building materials was calculated as the sum of the results of the emission test and the heat desorption test. Table 1 shows the thermal desorption conditions of the Tenax TA, and Table 2 shows the GC/MS conditions.

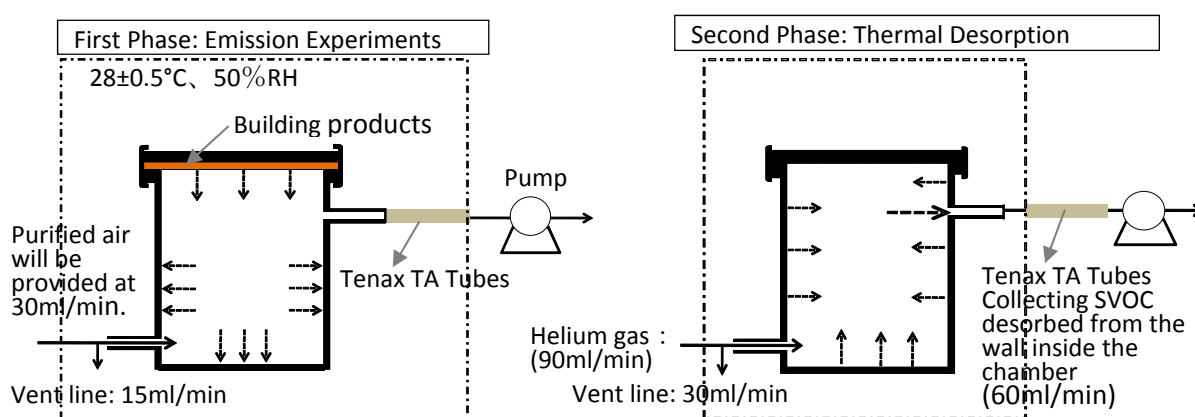


Figure 1. Illustrations of the micro-chamber method.

Table 1. Thermal Desorption Condition of Tenax TA

Instrument used	GERSTEL TDS A
Thermal Desorption Condition	280°C (10min)
Trap Temperature	-60°C
Injection Temperature	325°C (5min)

Table 2. Analysis Conditions of GC / MS

Used equipment (GC / MS)	Agilent 6890N / 5973 inert
Column	Inert Cap 1MS 30m×0.25mm×0.25μm
GC oven temperature	50°C(2min)→10°C/min→320°C(5min)
Split ratio	Low concentration : splitless High concentration : 50 : 1
Measurement mode	SCAN
SCAN parameter	m/z 29(Low)~550(High)
Detector temperature	230°C

3. Measurement outline

Tables 3 and 4, respectively, demonstrate the outline of building materials measured and the details of these materials. The building materials measured in the experiment included two types of adhesives, three types of water paints, one type of insulation material, and four types of floor materials. These materials are frequently used in conventional houses and easily purchased from building materials stores. The test specimen AF4-1 and AF4-2 are two types of adhesives combined with the carpet F-4 and a floor material. They were produced by attaching the carpet F-4 to an aluminum plate with the adhesive material applied. In the case of the test specimen with the paints P-1, P-2, and P-3, each one was applied twice to the aluminum plates according to the instruction on the respective label.

Table 3. The Overview of Measurement

Types of building materials	Item	Sampling Name
Adhesive	Adhesives for building materials	AF4-1
		AF4-2
Paint	Water-based paint used for indoor	P-1
		P-2
		P-3
Insulation	Polystyrene foam	S-1
Floor covering	PVC Sheet	F-1
		F-2
		F-3
	Carpet	F-4

Table 4. The Details of Building Materials

Types of building materials	Sampling Name	Product Details
Adhesive	AF4-1	Type: Aqueous adhesive Component: Acrylic resin (70%)、 Water(30%) Uses: PVC sheet, Carpet, Floor covering, etc.
	AF4-2	Type: Acrylic resin type Component: Acrylic resin Uses: PVC sheet, Carpet, Floor covering, etc.
Paint	P-1	Type: Synthetic resin paint Component: Synthetic resin, pigment, fungicide, water Uses: wood, iron, concrete, etc. Coated area: Approx. 0.8 m ² (once applied), Approx. 0.4 m ² (coated twice)
	P-2	Type: Synthetic resin paint Component: Synthetic resin, pigment, fungicide, water Coated area: Approx. 1.2~1.8 m ² (once applied)
	P-3	Type: Synthetic resin paint Component: Synthetic resin, pigment, water Uses: Concrete, mortar, wood, various wallpaper, indoor wall, ceiling, etc. Coated area: Approx. 0.7L/m ² (once applied)
Insulation	S-1	None Details
Floor covering	F-1	
	F-2	
	F-3	
	F-4	

The areas painted in each paint were approximately 0.8 m² (painted once) and approximately 0.4 m² (painted twice) for Paint 1, 1.2~1.8 m² (painted once) for Paint 2, and 0.7 l (painted once) for Paint 3. Therefore, the test specimens were produced by the instruction manual as explained earlier. All the test specimens produced in the laboratory were placed themselves until they were cured indoors for at least seven days before measuring the emission rates. JIS A 1904 (micro-chamber method) produced the test specimens including polystyrene foam S-1, the PVC floor materials F-1 and F-2, the vinyl chloride F-3 floor material, and the F-4 carpet.

4. Measurement results

Table 5 indicate the result of emission rate from the building materials, and twenty types of chemical substances were measured. The results of the emission rates of SVOCs with a particularly high emission frequency from the building materials are summarized below.

1) 2E1H (2-ethyl-1-hexanol)

The building material with the highest emission rates was the F-4 carpet at 86.8 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$]. In addition to this, the emission rates of 2E1H from AF4-1 and AF4-2, produced by the building material F-4 and two types of adhesive materials, were 71.0 and 87.0 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$] respectively. This result suggests that 2E1H was diffused from the carpet, not from the adhesive. The emission rates from F-2, a PVC building material, and the water paints P1, 2, and 3, were 48.9 and 0.6~11.0 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$] respectively.

2) D6 (dodecamethylcyclotrihexasiloxane)

D6 was emitted from all ten types of building materials measured in the experiment. The results show that the range of emission rate was 0.1~4.7 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$]; and average emission rate of D6 diffused from the 10 types of building materials was 0.8 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$]. The volume emitted from P-3 and water-based paint was approximately 5 to 15 times higher than those of P1 and P2.

3) DBP (di-n-butyl phthalate)

The emission range of DBP diffused from all ten types of building materials was 0.2~0.6 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$]; and the average emission rate was 0.4 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$]. The emission rates from the carpet and insulation materials were particularly higher than the others.

4) DOA (Diocetyl Adipate)

Table 5. The result of emission rate from building materials [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$]

Chemical substance	AF4-1	AF4-2	P-1	P-2	P-3	S-1	F-1	F-2	F-3	F-4
2EH	71.03	86.82	7.89	11.05	0.63	3.47	1.58	48.93	1.58	86.82
D6	0.11	0.20	0.87	0.31	4.66	0.30	0.23	0.36	0.16	0.15
DBP	0.53	0.39	0.39	0.38	0.20	0.61	0.42	0.38	0.52	0.61
DOA	0.26	0.32	0.16	0.23	0.14	0.68	0.32	0.24	0.28	0.42
DEHP	4.66	2.13	1.03	0.79	4.74	18.94	22.10	15.00	3.39	5.76
2EHA	0.38	-	-	6.95	0.14	-	-	3.00	-	-
TEXANOL	0.58	0.79		36.31	2.60	0.72	0.60	24.47	-	0.87
TXIB	1.89	-	4.81	-	1.97	0.44	0.31	0.34	0.47	-
DINP	1.03	0.95	-	-	-	2.84	1.18	1.03	0.95	0.77

-:limited detected(<5ng)

The emission rate from insulation material was the highest [0.7 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$]], among the 10 types of building materials measured: the range of emission rate was 0.1~0.7 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$]; and an average of emission rate was 0.3 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$].

5) DEHP (Di-2-ethylhexyl phthalate)

DEHP was emitted from all building materials because it is highly used as a plasticizer. The range of emission rates from PVC floor materials were 15.0~22.1 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$], and the building material, F-1, was the highest one. In addition, the emission rate of insulation material was 18.9 [$\mu\text{g}/(\text{m}^2 \cdot \text{h})$], and the

present study surprisingly found that the insulation material contained DEHP. Moreover, the emission rate of DEHP from water-based paint is lower than that of PVC building materials; however, it is considered as a potential source of contamination because it is a common product for indoor use.

6) 2EHA (2-ethylhexyl acrylate)

Of ten types of building material measured in the experiment, 2EHA was diffused from four types of materials; and among the three types of water-based paint, 2EHA was detected from the two. Specifically, the emission rate of 2EHA from P-2 was approximately 50 times higher than that of P-3. The emission rate ($3.0 [\mu\text{g}/(\text{m}^2 \cdot \text{h})]$) from the PVC floor material (F-2) was also higher than that of the other building materials. Moreover, the emission rate of 2EHA from the adhesive was also verified. Of the two types used in the experiment, 2EHA was emitted from AF4-1: the emission rate was $0.4 [\mu\text{g}/(\text{m}^2 \cdot \text{h})]$.

7) Texanol (2,2,4-Trimethyl-1,3-pentanediol monoisobutyrate)

The emission rate from the insulation material (S-1) and the carpet (F-4) were 0.7 and $0.9 [\mu\text{g}/(\text{m}^2 \cdot \text{h})]$, respectively. Texanol was also emitted from the PVC floor materials; however, while the emission rate from F-1 was $0.6 [\mu\text{g}/(\text{m}^2 \cdot \text{h})]$, the emission rate of F-2 ($24.5 [\mu\text{g}/(\text{m}^2 \cdot \text{h})]$) was more than 40 times higher. Moreover, the emission rate from the insulation material was $0.7 [\mu\text{g}/(\text{m}^2 \cdot \text{h})]$. The emission rate of Texanol was verified, and among the three types of water-based paints used, Texanol was detected from the two. The emission rate from P-2 was $36.3 [\mu\text{g}/(\text{m}^2 \cdot \text{h})]$, the highest among the products measured in the experiment.

8) TXIB (2,2,4-trimethylpentane-1,3-dily diisobutyrate)

TXIB was emitted from the insulation material, the PVC floor materials, and the PVC tiles. The range of emission rate was $0.3 \sim 0.5 [\mu\text{g}/(\text{m}^2 \cdot \text{h})]$. In addition, while TXIB was not diffused from the F-4 carpet, it was diffused from the AF4-1, which confirms that the adhesive material contains TXIB. In the case of water-based paints, TXIB was diffused from P-1 and P-3: the emission rate is 4.8 and $2.0 [\mu\text{g}/(\text{m}^2 \cdot \text{h})]$, respectively. Therefore, the two building materials are regarded as potential sources of indoor contamination.

9) DINP (diisodecyl phthalate)

DINP, diisodecyl phthalate (DIDP), and di-n-octyl phthalate (DNOP) are potential substitute materials for DBP and DEHP, but, in this measurement, only DINP was diffused from the PVC floor materials. The emission rates of PVC tiles and carpet were $0.8 \sim 1.2 [\mu\text{g}/(\text{m}^2 \cdot \text{h})]$. Specifically, the emission rate from the S-1 insulation material was $2.8 [\mu\text{g}/(\text{m}^2 \cdot \text{h})]$.

5. Discussion

In this experiment, the emission rate of SVOCs from building materials was measured by using a micro-chamber. The results showed that 2E1H, D6, DBP, DEHP, and DOA were diffused from all building materials. Also, C16, C20, 2EHA, TXIB, Texanol, and DINP were diffused from building materials used in this experiment. However, TBP, TCEP, DBA, TPP, DNOP, and DIDP were not diffused from any of the materials. This experiment also confirmed that TXIB and Texanol are contained in the water-based paints, and 2EHA and TXIB were detected from an adhesive material. Moreover, the present study showed that 2E1H, DBP, DEHP, TXIB, Texanol, and DINP were diffused from the insulation material.

6. Conclusion

In this experiment, the emission rates of 20 types of chemical substance from 10 types of building material was measured. It was confirmed that TXIB and Texanol were diffused from the water-based paints, the PVC building materials, the carpet, and the insulation material. For this reason, these substances need to be examined as potential sources of indoor contamination. In the case of TXIB and Texanol, which have the highest emission rate from water-based paint, it is necessary to carry out field surveys in educational institutions, offices, and hospitals, where water-based paint is more frequently used than in any conventional houses.

Acknowledgments

This work was supported by scientific grants from the Japanese Ministry of Health, Labor and Welfare (H30-kagaku-sitei-002).

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