

Passive parallel VOCs and ventilation rate sampler

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ABSTRACT

Ventilation is the most effective procedure to reduce indoor air pollutant. Volatile organic compounds (VOCs), which cause health related symptoms, are often detected in the indoor environment. The way of ventilation should be decided depending on the level of VOCs. The level of VOCs and ventilation rate are usually measured individually. This study will propose a simple method to measure both the ventilation rate, by perfluorocarbon tracer gas technique (PFT), and VOCs concentration immediately by using a single sampler. A glass vial with a diffusion cap on top was selected as a tracer source, filled with perfluorocarbon (PFC). A thermal desorption (TD) tube packed with carbon adsorbent was used as a sampler. TD and a gas chromatograph–mass spectrometer (GC–MS) was employed for injection and analysis, respectively. Selected analysis conditions enable to separate VOCs and PFC. According to this method, low cost, less complexity and shorter time for analysis are made possible.

INDEX TERMS

VOCs; Ventilation rate; PFT; Passive sampler; GC–MS

INTRODUCTION

Exposure to indoor air pollutant, which has a potential effect on health, is of much concern. Ventilation is one of the most effective ways to reduce the pollutant concentration. Measurement of ventilation rate and indoor pollutant concentration is necessary to calculate the rest of the factors that contribute to increasing and decreasing indoor contamination concentration. To know the appropriate ventilation, the simple method is to measure ventilation rate, and measuring period of more than 1 week could be required to reflect the lifecycle of the resident. A passive simple method commonly known as perfluorocarbon tracer gas technique (PFT) has been used for the measurement of ventilation rates (Dietz and Cote, 1982). In this method, tracer gas is emitted by small passive sources and collected by passive samplers.

The objective of this study was to develop a simple passive method, based on the PFT method, to measure both VOCs and air exchange rate at the same time.

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METHODS

Equipment

Passive tracer source

A 4 ml glass vial with diffusion cap filled with tracer gas, as shown in Figure 1, was selected as a tracer source. The size of the diffusion cap is 8.0 mm in length and 1.0 mm in internal diameter. We used perfluoromethylcyclohexane (PMCH) as the tracer gas.

To estimate the emission rates, the sources were kept in a constant temperature bath (10, 20 and 30°C) and weight loss was measured for 3 days. Five to 10 data points were collected for each temperature. Twenty sources were tested to evaluate the standard deviation of emission rates.

The emission rate was calculated also according to the following equation:

$$M = C_d \times S_d \times k_d \quad (1)$$

where M is the emission rate (g/h), C_d the concentration in glass vial (g/m³), S_d the cross-sectional area of diffusion cap (m²) and k_d the mass transfer coefficient of diffusion cap (m/h).

To prevent the weight loss during the transportation, we considered using a set of Teflon septum instead of the diffusion cap (Figure 1, right). We measured the weight loss of tracer sources.

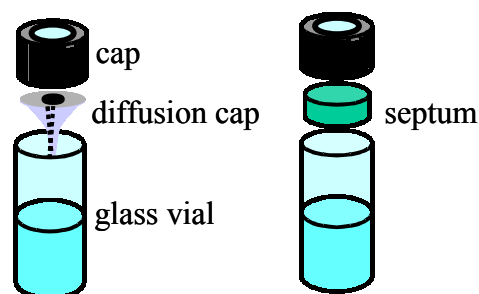


Figure 1 Passive tracer source.

Passive sampler

Thermal desorption (TD) tube with adsorbents, as shown in Figure 2, was selected as a tracer sampler. The tracer gas is collected passively into the tubes by adsorption. The diffusion length and diameter of the sampler were 0.0136 m and 0.00480 m, respectively. CarboxpackB (Supelco, USA) was chosen as adsorbent because it is possible to adsorb VOCs as well as PMCH.

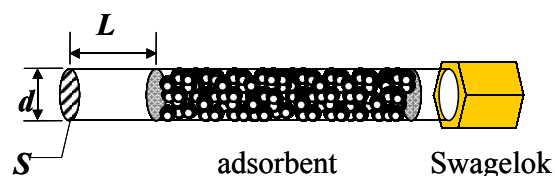


Figure 2 Passive sampler.

The sampling rate was calculated by comparing active sampling to passive samplings. Active and passive samplings were done simultaneously for 26 h at 2 different locations in the laboratory. The sampling rate was calculated according to the following equation.

$$v = S_s \times k_s \quad (2)$$

where v is the sampling rate (m³/h), S_s is the cross-sectional area of sampler (m²) and k_s the mass transfer coefficient (m/h). The precision of the sampler was investigated by eight duplicate samplings of the tracer at different locations in a house.

Analysis

The sampled tracer gas and VOCs were injected to a gas chromatograph (HP6980, Hewlett Packard) by thermal desorption system (ATD 400, PerkinElmer, Inc.). The advantage of using thermal desorption method is that 100% of trapped gas can be injected into GC and, as a

result, the sensitivity is much higher than liquid extraction.

For calibration, we performed gas dilution for PMCH, and liquid dilution for VOC. PMCH was diluted by N₂ and induced into a sampler by a gastight syringe after 1 min into a tube purging with N₂. VOC standard solution was diluted by methanol and induced into a sampler by a syringe with N₂ flow. Japanese Indoor Air Standards Mix (cat. #47537-U, Supelco, USA), a mixture of 52 compounds for VOC standard solution was used in this current study.

Field application

This method was employed for several indoor air quality studies. The sources and the samplers were sent separately to prevent contamination during transportation.

Measurements at two residential houses in Japan for one week in winter were carried out. Room volumes and number of tracer sources and sampling points are shown in Table 1. We took duplicate sampler at every sampling point.

Table 1 Room volumes, number of tracer source and sampling point [HOUSE 1]

Room.No	1	2	3	4	5	6	7	8
volume(m ³)	18.77	19.87	44.95	37.76	19.87	27.82	27.82	35.77
tracer source	1	1	2	2	1	2	2	2
sampling point	1	1	1	1	1	1	1	1

[HOUSE 2]

Room.No	1	2	3	4
volume (m ³)	18.77	20.98	18.77	18.77
tracer source	1	1	1	1
sampling point	1	1	1	1

RESULTS AND DISCUSSION

Equipment

Passive tracer source

Experimental emission rates of tracer sources at 10, 20 and 30°C were 2.44 ± 0.26 , 4.66 ± 0.51 and 8.12 ± 1.11 mg/h, respectively. Results of each source are shown in Table 2. Each correlation coefficient of time-weight for each vial was 0.99–1.00. Theoretical emission rates were 3.29, 5.58 and 8.92 mg/h at 10, 20 and 30°C, respectively. These results show that (1) the emission rate was widely dependent on temperature, (2) theoretical rates were higher than experimental rates and (3) although the rate of each vial was steady, individual vial had wide range of the rates.

Since the emission rate is highly dependent on temperature, it is difficult to predict the emitted amounts by calculation during field measurement. Therefore, we decided to measure the weights of tracer source before and after the measurement and calculate the emission rates by the weight loss and emission time.

The weight loss during transportation was 0.13 ± 0.032 mg/h in the case of the Teflon septum cap. It was small enough compared to total emission for 1 week (410–1400 mg).

Table 2 Emission Rates (mg/hr) of 20 sources

temperature (°C)	10	20	30
vial 1	2.5	4.5	7.7
vial 2	2.4	4.2	7.3
vial 3	2.9	5.5	9.7
vial 4	2.3	4.3	7.3
vial 5	2.5	4.9	8.3
vial 6	2.5	4.7	7.9
vial 7	2.5	4.9	8.8
vial 8	2.4	4.6	7.9
vial 9	2.6	4.8	8.2
vial 10	2.7	5.3	9.5
vial 11	2.4	4.3	7.3
vial 12	2.3	4.3	7.3
vial 13	2.1	4.0	7.0
vial 14	2.2	4.3	7.3
vial 15	2.5	4.8	10
vial 16	3.2	6.1	11
vial 17	2.2	4.4	7.2
vial 18	2.3	4.6	8.4
vial 19	2.2	4.4	7.3
vial 20	2.2	4.3	7.4

Passive sampler

The sampling rate of the passive sampler was acquired by comparing active and passive samplings. Experiment showed that the rate was 0.84 ml/min. The result from the theory (Eqn (1)) is 0.34 ml/min. The precision of the sampler was ensured by measuring eight duplicates during sampling of tracer at different locations in a house and the mean RSD was 1.88% (0.34–4.56%).

Analysis

The analytical instruments and its conditions are shown in Table 3. The ranges of quantitation for PMCH are 0.02–4.5 µg. Moreover according to this condition shown in Table 3, PMCH and VOCs were successfully separated as the chromatogram shown in Figure 3.

Table 3 Analysis conditions

Compounds	VOCs and PMCH
Desorption meth.	ATD400(Perkin Elmer)
Primary Desorption	300°C 10min
Secondary Desorption	5°C→40min→300°C(10min)
Analytical meth.	GC-MS/HP6890-HP5973
Column	HP5ms 30m×0.25mm×0.25mm
Carrier gas	He
Flow Rate	1ml/min
Column temp.	40°C(4min)→10°C/min→280°C

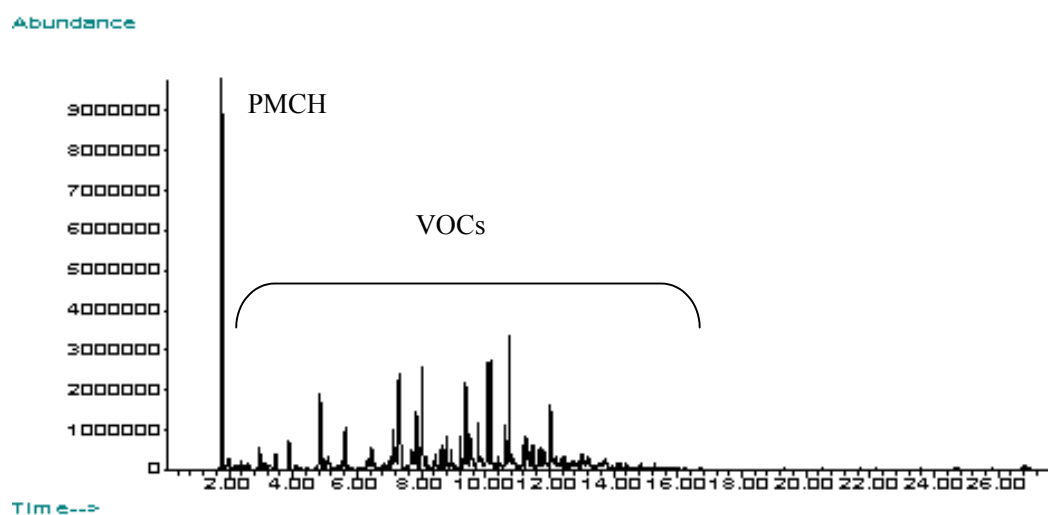


Figure.3 Total Ion Chromatography of a sample.

Field Application

Results of field experiments held in Japanese houses are shown in Tables 4 and 5.

Table 4 House 1 - Ventilation rate (1/h) and VOCs concentrations (µg/m³)

Room No.	1	2	3	4	5	6	7	8	outdoor
Ventilation Rate (1/hr)	0.57	1.3	1.0	0.69	0.52	0.56	0.66	0.60	-
Benzene	3.9	3.8	4.2	3.2	4.2	3.9	3.9	4.0	1.9
Heptane	20	21	23	13	21	18	17	20	0.79
Toluene	25	25	29	20	25	24	22	23	22
Ethylbenzene	11	10	11	6.4	10	8.5	8.1	8.8	1.0
m,p-Xylene	16	15	16	9	15	12	12	12	0.83
o-Xylene	16	15	17	9	14	12	12	12.3	0.68
alpha-Pinene	1.2	1.1	1.3	0.8	1.2	1.2	1.1	0.86	0.21
1,2,4-Trimethylbenzene	27	21	24	12	22	19	18	19	0.87
Decane	63	50	55	29	52	45	42	47	1.1
p-Dichlorobenzene	1.6	1.5	1.7	4.0	1.8	1.9	1.9	1.8	0.31
Limonene	30	38	43	19	26	20	21	18	0.17

SUMMARY

This method enables to collect tracer and VOCs in the same sampler and separate and determine the quantity with only 28 min of analysis. Therefore, not only ventilation rate but also VOC concentrations are acquired. Emission rate of pollutant source is calculated from the pollutant concentration (C (g/m^3)) and the average ventilation (Q (m^3/h)).

$$M = C \cdot Q \quad (3)$$

Our proposed method makes it possible to know the ventilation requirement to reduce the VOCs to a planned level.

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Table 5 House 2

Ventilation rate (1/h) and VOCs concentrations ($\mu\text{g}/\text{m}^3$)

Room No.	1	2	3	4	outdoor
Ventilation Rate (1/h)	1.5	- *	1.8	1.9	-
Benzene	4.0	3.7	3.2	2.7	1.5
Heptane	25	20	13	9.3	1.1
Toluene	98	87	54	40	2.8
Ethylbenzene	8.8	8.1	5.9	4.4	0.88
m,p-Xylene	12	11	7.6	5.6	1.1
o-Xylene	13	11	7.8	5.7	1.1
alpha-Pinene	0.61	0.55	0.59	0.56	0.19
1,2,4-Trimethylbenzene	18	17	11	9	1.8
Decane	57	54	36	26	4.6
p-Dichlorobenzene	110	100	97	48	0.29
Limonene	13	9.8	8.7	9.7	<0.27

* data lost