Survey on the VOCs concentration in hospitals using a passive sampler method

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ABSTRACT
VOCs concentration measurements in six hospitals were conducted, using passive samplers, in order to get outlined information on the IAQ. Most of the toluene, xylene, ethel benzene and styrene concentrations obtained from 158 points were lower than the detected limit. Concentrations of formaldehyde and toluene measured at each point exceeded the guideline values. Concentration of xylene obtained from two points also exceeded it's guideline value. TVOC concentrations by in-depth measurements obtained from 53 points out of 55 were lower than the determination limit, 200μg/m³.

INDEX TERMS
Hospital; Indoor air quality; VOCs; Passive sampler; Ventilation

INTRODUCTION
The indoor air pollution caused by volatile organic compounds (VOCs) is one of the serious problems in Japan. Many measurements in various buildings are now being conducted in order to know the actual status of the problems. Especially, very few measurements have been conducted in medical institutions even when the relevant literature was looked into (Damiani *et al.,* 1997; Volpe *et al.,* 1997). The air pollution problem in the medical institution might be caused by emissions from many sources, such as, disinfection and the medical practices along with construction material, furniture and so forth, which were also to be the likely pollution sources in other buildings. Indoor air pollutions from sources that do not exist in a building other than a medical institution are matter of concern. We, therefore, conducted the concentration measurements on VOCs in six medical institutions.

PURPOSE
The major objective of the measurements was to understand the VOC concentrations of indoor air in medical institutions.

OUTLINE OF INVESTIGATIONS
About the Investigation Building
Table 1 shows the outline of medical installations measured. The investigation was conducted from the beginning of March, to the beginning of April 2002.

Measurement Item
Table 2 shows the measurement items.

Concentrations of Formaldehyde and VOCs
Indoor air for testing the formaldehyde and the VOC concentrations was sampled by diffusive sampler for exposure time of 24 h. Samplers used are products of the Advance Chemical Company.

Temperature, Humidity, Carbon monoxide, and Carbon dioxide
The measurements of temperature, humidity and concentration of carbon monoxide and dioxide were conducted by a grab sampling method during set-up and on recovery of the samplers for VOCs and formaldehyde. Sampling points of these measurements were located in the center of each room, 1.2m above the floor.

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Table 1 The outline of medical installations measured

Hospital name	Number of beds	Investigation period (2002)	Names of Buildings	Number of stories		Structure	Bulding area(m²)	Total floor space(m²)	Construction fiscal year
				above ground	beneath ground				
A	360	4th - 5th in March	Main building	8	2	SRC	8179	48259	July, 1999
B	610	7th - 8th in March	New building	7		SRC	3915	22220	May, 2000
			Management & treatment building	5		RC	600	3000	1963
			Old administration building	1		RC	60	60	1965
			Treatment building	2		RC	1120	2100	1981
			Day care building	1		RC	900	900	1984
			Radiation building	2		RC	845	920	October, 2001
			Central diagnosis and treatment building	2		RC	2500	4100	October, 2001 and unused
C	1000	22nd - 23rd in March	Main building	17	3	SRC	5702	62180	1993
			The second Building	12	1	SRC	1419	14514	1972 and reform in 1996
D	700	25th - 26th in March	Main building	10	2	RC	13000	71834	March, 1994
E	253	3rd - 4th in April	Main building	6		RC	7138	18385	1987
			The second building	4		RC	6103	19086	September, 1999
F	215	11st - 12nd in April	Main building	10		RC	1184	7222	2001
6 Hospitals			**14 Buildings**						

Table 2 The measurement items.

Factors measured	Sampling method	Measuring items	Analysis method
Formaldehyde	sampled by diffusive sampler exposure time of 24 hours,	F-50	HPLC, Analysis by Ibaraki environmental analysis center
Toluene, Styrene, Xylene, Ethyl benzene		0V-09	GC-MS, Analysis by Ibaraki analysis center
Temperature, humidity, carbon monoxide, and carbon dioxide	When setting up and collecting passive sanpmlers, all Sampling points of these measurements were located in the center of each room 1.2m above the floor.	Q-TRACK Model.2351	temperature(thermistor), humidity(polymer thin film element), CO(low voltage electrolytic method), CO_2(nondispersive type infrared rays method)

Questionnaire

Questionnaire survey on the outdoor air intake rates in ACH (air change par hour) and operation patterns of ventilation and the air-conditioning systems was conducted for the facility managers or maintenance engineers of HVAC systems.

Sampling locations

Table 3 shows the number of installation points finally located. A total 158 points for indoors selected from 31 sections out of 7 divisions, and 6 points for outdoors were selected for the sampling locations. The measurement points were selected 20-40 points from each facility and/or room of each hospital building. About 30-40 % of the points were allocated for the rooms in the Ward Section. The other points were located for administrative departments, outpatient section, inspection section, operation section, intensive cure section, and supply section of the seven divisions. At least one sampling point was set in outdoor of each hospital.

A total of 158 Sampling points were basically selected from the rooms of similar usage. They were selected as many types of place as possible and were selected from the place where cooperation of the staffs were available. However in Hospital A, sampling points for VOC samplers were located in as many kind of rooms as possible since the hospital was relatively huge and needed more points than the other hospitals. Average of exposure time of the samplers for all points was 23 h.

Setting up of the Sampler

The installation of sampler was conducted in the afternoon of the first day, and was recovered in the afternoon of next day roughly, i.e. roughly 24 h after. The installation location is carefully selected so that it might not be an obstacle for medical activities. Therefore, we could not always locate the sampling points in the center of each room, but we could keep the principle to set them up 1.2 m above the floor.

Table 3 The number of installation points finally located

Hospital name	Names of Buildings	Number of installation rooms							
		Departments of management *	Outpatient Section	Inspection section	Operation section	Concentrated treatment	Ward section	Supply section **	**Toatal**
A	Main building	2	8	6	0	3	17	3	**39**
B	New building						12	1	**13**
	Management & treatment building	1		1					**2**
	Old administration building	1							**1**
	Treatment building			1					**1**
	Day care building		4						**4**
	Radiation building			1					**1**
	Central diagnosis and treatment building					1			**1**
C	Main building	1	6	2	2	2	16	3	**32**
	The second Building				2	1	1		**4**
D	Main building	2	5	3		1	12	1	**24**
E	Main building	1	4	4			6		**15**
	The second building						4		**4**
F	Main building	1	3	3		1	9		**17**
	14 Buildings	**9**	**30**	**21**	**4**	**9**	**77**	**8**	**158**

*Clerical work sections of general affairs, accounting, and medical affairs, etc.

**Central material, drugstore, nourishment, article management, and electricity and machine, etc.

MEASUREMENT RESULT AND CONSIDERATION

Results of the Basic Investigations and their Consideration

The outlined results were shown in Table 4 and concentration distributions were shown in Figure 1. The detailed data of each individual measurement point is omitted because of shortage of the space.

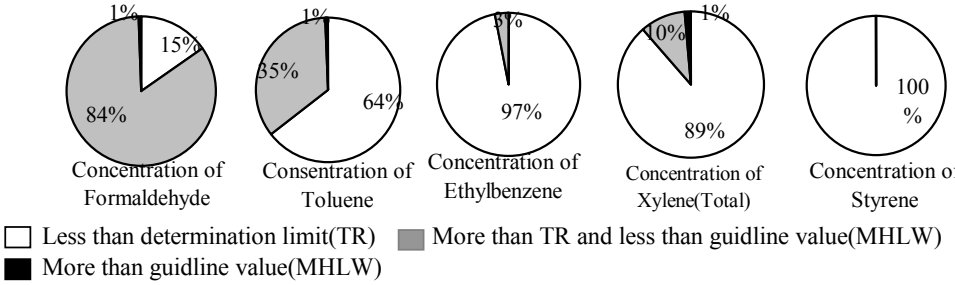

Figure 1 Classification of the results

Table 4@ The outlined results

			Hospital						all rooms	all outdoor
			A	**B**	**C**	**D**	**E**	**F**		
sampling points		points	39	23	36	24	19	17	158	6
Average of exposure time		hr	23.2	23.0	23.3	23.6	23.7	23.2	23.3	22.0
Average of temperature(*)		°C	24.7	23.5	23.2	25.7	25.5	23.1	24.3	12.3
Formaldehyd	Average (**)	μg/m³	25	<12	17	15	19	21	19	<13
	Number of less than the TR	points	1	17	3	3	0	0	24	5
Toluene	Average (**)	μg/m³	60	61	<38	<38	<38	<38	38	<40
	Number of less than the TR	points	0	18	24	24	19	16	101	4
Ethylbenzene	Average (**)	μg/m³	<43	57	<43	<43	<43	<43	<43	<46
	Number of less than the TR	points	38	20	36	22	19	17	152	6
Xylene	Average (**)	μg/m³	61	193	<43	60	<43	<43	61	<46
	Number of less than the TR	points	32	19	36	16	19	17	139	6
Styrene	Average (**)	μg/m³	<43	<43	<43	<43	<43	<43	<43	<45
	Number of less than the TR	points	39	22	36	24	19	17	157	6

TR is the determination limit (*) Average of when setting up and collecting it

(**)In the caluculation of statistical values half of TR-value of each cpmpound was used.

Formaldehyde concentrations obtained for all sampling points were above the detection level of the analyzer and only one datum (0.1% of the entire data) exceeded the guideline level set by the Ministry of Health, Labor and Welfare (MHLW) of Japanese government. Almost all data of styrene concentration were not less than determination limit (<43μg/m³).

A total of 88% of xylene concentration data was less than determination limit (<43μg/m³). Two data of xylene concentrations were more than the guideline value of the MHLW.

For ethyl benzene, 97% of the concentration data were less than determination limit (<43μg/m³).

Table 4 shows the number of points for which the data exceeded the guidelines values for each VOC set by the Japanese MHLW.

Table 5 shows that of the number of points that exceeded the MHLW guidelines, three points of data were obtained at the inspection section. The xylene concentration data obtained at point number 'A-20' and 'B-10' at inspection section were 1.4 and 4.3 times as high as MHLW's guidelines, respectively. There is a chance to use the chemicals, such as xylene and formaldehyde, in these rooms, and this influences concentration levels of the chemicals. The central medical care building of Hospital B, where point 'B-12' was located, was not used on October, 2001 because the construction was just over.

Table 5 The number of points of where data were exceeded the guidelines for each VOCs set by the Japanese MHLW

Hospitals	Point number		μg/m³				
			Formaldehyde	Toluene	Ethyl benzene	Xylene	Styrene
A	A-20	3F: Pathology inspection room usage: Banking Inspection Department and pathology inspection	122	*56*	*265*	1249	*<43*
B	B-10	Inspection department (treatment building 2F) usage: Inspection and specimen material inspection	92	*<38*	*784*	3704	*<43*
	B-12	ICU nurse station(central diagnosis and treatment building 2F) Usage: Unused	*22*	650	*<43*	*<43*	*<43*
Guidelines for each VOCs set by Japanese MHLW			*100*	*260*	*3800*	*870*	*225*

Result of Grab Sampling Measurements and their Consideration

The concentration distributions of carbon monoxide and carbon dioxide are shown in Figure 3 and 4, respectively.

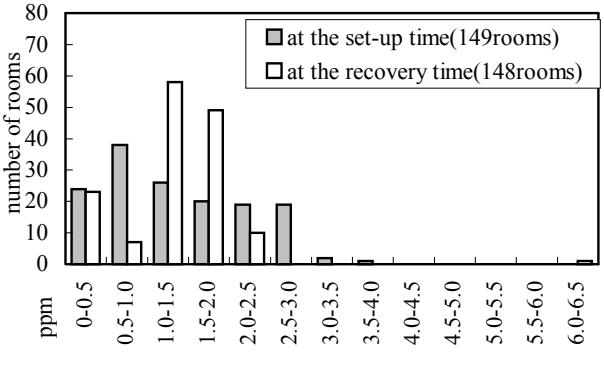

Figure 3. The concentration distributions of the carbon monoxide

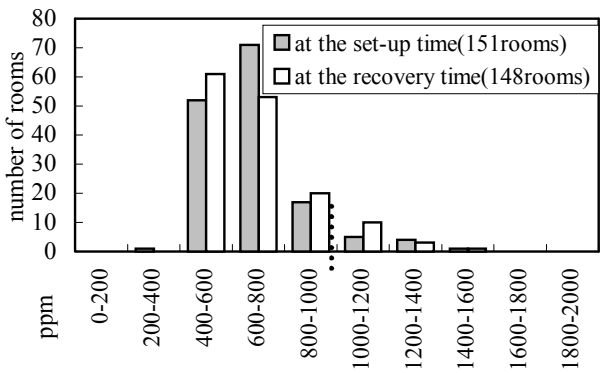

Figure 4. The concentration distributions of the carbon dioxide

Average of carbon monoxide concentrations obtained from both cases, on setting-up and on recovery of the passive samplers, was 1.3ppm. All the carbon monoxide concentration data were below a standard level (10 ppm) of the Building Management Law, which was set by the Japanese MHLW. Those of carbon dioxide were, on the other hand, 687 ppm during setting up

and 686 on recovery of the passive samplers. They are both below the standard level, 1000 ppm set by the Japanese MHLW. However if we take look at the data individually, the data obtained from 10 out of 151 rooms (7%), on the occasion of setting-up, and from 14 of 148 rooms (9%), on the occasion of recovery, exceeded the standard level of 1000ppm. Facilities where the standard value 1000ppm had been exceeded were often seen in Hospital A. There were four such rooms on setting-up and 10 rooms on recovery. The points where the carbon dioxide concentrations were found in Hospital A, four data for the setting-up and 10 data for the recovery were over the standard. There were relatively more data in administrative division and outpatients section where the concentrations exceeded the standard value. These are the sections where a lot of people were going in and coming out.

Carbon dioxide is one of the indexes, which evaluate the indoor air quality level. Correlation between 'Mean values of the carbon dioxide concentrations obtained at setting-up and recovery' and '24 average formaldehyde concentration' was not clearly seen. (Such correlations for the other chemicals were not examined because their concentrations were below the detection level.)

Consideration of Pollutant Concentration and Ventilation Operation

The condition of the ventilation operation of each facility was different, according to the response to the questionnaire. The mechanical ventilation system in Hospital E and F was 24 h in the operation throughout the buildings. Mechanical ventilation systems were operated 24 h in the occupied areas of hospital A-D. But in the areas, such as outpatients and inspection section which were occupied only in daytime, mechanical ventilation systems were operated only from 7 a.m. to 6 p.m. The ventilation equipment of every facility was very much complicated.

Three rooms, where TVOC concentration exceeded the guideline value, were not same rooms, where carbon dioxide concentrations exceeded standard value.

Xylene concentrations were high in the rooms, such as pathology laboratory and inspection room, where alcohol, formaldehyde and xylene were frequently used. They were possible sources of the VOCs in these rooms. Therefore, locally high pollutant concentrations appeared. The outdoor air intake rates of the measured rooms were about 5 ACH. Although it is preferable to increase the rates, introduction of local ventilation system is very much effective to in prevent dispersion of the pollutants and also reduces the changes of exposure.

There were not many person in coming from outside since it was an evening time when the carbon dioxide concentration measurements were conducted. However, the predicted concentration is much more than this because more patients were coming during morning and early afternoon. There is a necessity to increase the rate of outdoor air intake on such occasions. A lot of people also work in the administrative section of the hospital. It is necessary to increase the outdoor air intake rates to such places because carbon dioxide concentrations exceeded the standard value in three hospitals.

On the Odor of the Hospitals

Questionnaire form on the odor in hospitals was distributed and collected by all the investigators including authors. In some of the rooms, where the VOC concentrations measured by diffusive samplers were higher than the guideline value, strong odor impressions were reported by the investigators. However, strong impressions were also reported in the room where the VOC concentrations were pretty much lower than the guideline level.

Although overall measurement results of this study were low except for some cases, levels of the perceived air qualities were not necessarily satisfactory.

SUMMARY

1. Only three out of 158 points were exceeded the Japanese guidelines for VOCs. Overall tendency of the all data obtained at measuring points were considerably low.
2. Most of the rooms, where the VOC concentrations were over the guidelines, were found in the inspection section.
3. However, there were several points with a strong impression of unpleasant smell although concentrations there were not necessarily above the guideline value. The odor impression was different from the VOC concentration.

ACKNOWLEDGEMENT
This research was conducted by the research found, 'Development of counter measures for so-called sick House Syndrome', prepared by Ministry of Land, Infrastructure and Transport of the Japanese government. We express our gratitude to director of each medical institution who understands and cooperated in the investigation, managers, person in charge of the facilities management, air-conditioning equipment managers, and staff' and in-patients. We also thank to Y.Itamura, H.Koshimizu, M.Bando and special thanks to M.Hayashi of the project secretariat.

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