

Field survey of indoor chemical pollution and health hazards in sick houses

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ABSTRACT

In order to determine the a etiological factor of Sick House Syndrome (SHS), indoor air quality of 35 houses in Miyagi prefecture of Japan, where occupants are suspected of suffering from SHS, had been investigated during the summers in 2000–2002. The investigation included the measurement of indoor chemical substance concentration and a questionnaire regarding residential environment and subjective symptoms.

As a result, the formaldehyde concentrations in 71% of all houses exceeded the guideline of Japan. While the VOCs concentrations had reduced, the formaldehyde concentration had hardly changed across the ages. Concerning health conditions, many residents have suffered from airway/mucous membrane symptoms such as eye irritation and coughing. The relationship between the measurement result of indoor chemical substance concentration and the symptoms obtained from questionnaires suggested that the symptoms became more serious not only in the houses that recorded higher concentrations of TVOC, but also in the houses with lower concentrations.

INDEX TERMES

Field survey; Sick house; Formaldehyde; VOCs; Health hazard

INTRODUCTION

Polluted indoor air quality from chemical substances, which may cause a hazardous influence on human being such as Sick Building/Sick House Syndrome (SBS/SHS), has become a serious problem in our daily life. Despite investigations of this problem have been looked into for several years in Japan, there are still a lot of uncertainties that have not yet been clarified. Especially, data about the actual living conditions in houses, where the residents have SHS, are still lacking.

This survey was conducted to understand the state of indoor air pollution and residents' health conditions in dwelling, which was suspected as a Sick House.

METHODS

In this study, the air quality of houses in the Miyagi prefecture of Japan, where residents worry about indoor air pollution, had been investigated during the summers from 2000 to 2002.

The present paper provides a summary of the results from 35 houses selected by the aspect of sick house problems. After moving in or retrofitting in these houses, symptoms such as irritation of eyes, coughing and headache were reported by residents, and the health condition of residents, in terms of allergy, also got worse. These houses include 13 houses investigated more than twice as continuous surveys.

The measurements of chemical concentrations (carbonyl compounds and VOCs), ventilation rate and airtight performance, together with questionnaire survey about indoor air

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quality, were carried out in 35 selected houses. In addition, a survey of the health conditions based on the Quick Environmental Exposure and Sensitivity Inventory (QEESI) (Miller and Prihoda, 1999) was also conducted on the residents.

The Measurement of Chemical Substance Concentration

A few typical rooms of each house (total 93 rooms) were chosen for the measurements. The chemical substance concentrations (carbonyl compounds and VOCs) were measured at a height of 1.2 m above the floor. Table 1 shows the measuring methods for the chemical substance concentration. The openings of the rooms were closed as much as possible at the time of measurement. The measurement was recorded for a period of 24 hours.

Contents of Questionnaire Survey

Two types of questionnaires regarding residential environmental conditions and residents' health conditions were distributed. The former contained building attributes (building age, structure, building materials, etc.), indoor environment (use of pesticides, use of cleaners, frequency of ventilation, etc.) and consciousness of life (awareness of Sick House, provision of indoor pollution, etc.), as indicated in Table 2. The latter was QEESI, as shown Table 3.

Table 1 Outline of measuring methods of chemical substance concentrations

Items	Carbonyl compounds	Volatile Organic Compounds
Sampler	DNPH-Silica cartridge	Charcoal absorption tube
Sampling Method	Passive sampling (24 hours)	Active sampling (500ml/min, 24 hours)
Measuring Point	1.2m above the floor in 2 or 3 typical rooms	
Analyze Method	HPLC	GC (FID)

Table 2 Contents of questionnaire about house, occupants and environment

items	contents
1. Information about residents' attribution	1) Personal attribution 2) Personal habit
2. Information about house	1) Environment around building 2) Specification about building and equipment 3) Situation of use indoors
3. Information about consciousness of life	1) consciousness of life
	A family type (The number of person, age) etc. The existence of smokers etc. Institutions around building, use of pesticides etc. Structure, scale, materials, ventilation system etc. Use of chemicals, life style etc. Knowledge of sick house, provision etc.

Table 3 Contents and risk criteria of QEESI

items	contents	degree to which MCI is suggested		
		Very suggestive	Somewhat suggestive	Pobleumatic
1. Chemical Intolerance	Intolerance of chemical substances like insecticides, paints etc. (0-100)	≥40	≥40	<40
2. Other Intolerance	Intolerance of substances like pollen, foods, house-dust etc. (0-100)	-	-	-
3. Symptom Severity	Degree of symptoms on residents' bodies like headache, cough, eczema etc. (0-100)	≥40	<40	≥40
4. Life Impact	Relation with daily lives of residents (0-100)	-	-	-
5. Masking	Being camouflaged of residents' symptoms by chemical substances (0-10)	≥4 or <4	≥4	≥4 or <4

(Items 1-4 ; 0 : Not in particular, 50 : Middle level, 100 : Serious case)

RESULTS

Results of the Questionnaire Survey of Residential Environment

There were 30 detached houses and five multi-family houses investigated in this survey, in which six of the houses had retrofitting. The mean building age of the period of initial survey was 4.36 years, and more than half were less than 3 years. The mean age after retrofitting was 2.79 years.

Figure 1 shows the ventilation system and the frequency of opening windows. Nearly half of the houses had mechanical ventilation. The percentage of the houses whose residents often open the window to ventilate the room was 60%.

Results of the Questionnaire Survey of Health Hazard

As a result of the investigation, 80 (31 males; 49 females) out of 149 residents were suspected of having sick house syndrome (the symptoms begin or become worse after moving in the house). QEESI was distributed to 80 SHS patients with 69 (29 males; 40 females) answers received.

As shown in Figure 2, the most frequent symptom was airway/mucous membrane symptoms (e.g. coughing, irritation of eyes, a lot of mucus), followed by skin symptoms (e.g. rash, hives, dry skin), gastrointestinal symptoms (e.g. abdominal pain, nausea, diarrhoea). There were 39 patients (57%) having a history of allergic disease. Multiple Chemical Intolerance was suggested in 33 patients (48%) according to the risk criteria of QEESI.

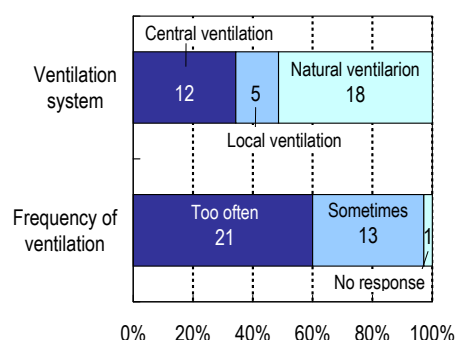


Figure 1 Questionnaire results of ventilation system and frequency of ventilation.

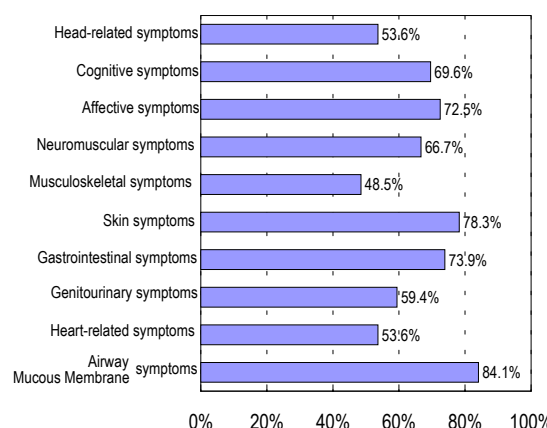


Figure 2 Questionnaire results about the prevalence rate of SHS symptoms in 69 patients.

Results of the Measurements

The number of rooms from which data were obtained regarding the availability of formaldehyde was 91, that of acetaldehyde 83 and that of VOCs 93. Table 4 shows the results of typical indoor chemical substance concentrations. Figure 3 shows the cumulative frequency of the formaldehyde, toluene and TVOC concentrations. These values were obtained in the initial measurement (35 houses) and were detected in over 70% rooms. The formaldehyde concentrations in 65 rooms (71% of the total rooms) exceed the criterion of the guideline (0.08 ppm) from the Ministry of Health, Labour and Welfare of Japan. These formaldehyde concentrations are found higher than that in ordinary houses (residents with no SHS symptoms) of Miyagi prefecture. The toluene concentrations in 10 rooms (8% of the total rooms) exceed the criterion of guideline (260 $\mu\text{g}/\text{m}^3$). The *p*-dichlorobenzene concentrations in 14 rooms (15% of the total rooms) exceed the criterion of the guideline (240 $\mu\text{g}/\text{m}^3$). The ethyl benzene and xylene concentrations in all rooms were below the guideline. TVOC concentrations in 61 rooms (66% of the total rooms) exceed the advisable value (400 $\mu\text{g}/\text{m}^3$).

Table 4 Results of measurement of indoor concentration about chemical substances compared with the guidelines from the Ministry of Health, Labour and Welfare of Japan

Substance	Unit	Indoor concentration			Guideline	The number of detected data	The number of detected data (over guideline)
		Average	Median	Max			
Formaldehyde	ppm	0.124	0.111	0.315	0.08	87/91	65/91
Acetaldehyde	ppm	0.128	0.112	0.412	0.03	80/83	72/83
Toluene	$\mu\text{g}/\text{m}^3$	138.4	43.2	2530.0	260	93/93	10/93
Ethylbenzene	$\mu\text{g}/\text{m}^3$	15.9	10.1	140.0	3800	68/93	0/93
Xylene	$\mu\text{g}/\text{m}^3$	28.0	17.0	196.1	870	78/93	0/93
p-Dichlorobenzene	$\mu\text{g}/\text{m}^3$	452.9	38.5	16065.5	240	68/93	14/93
α -pinene	$\mu\text{g}/\text{m}^3$	178.1	12.5	3350.0		67/93	
TVOC	$\mu\text{g}/\text{m}^3$	1556.5	701.7	16815.8	400		61/93

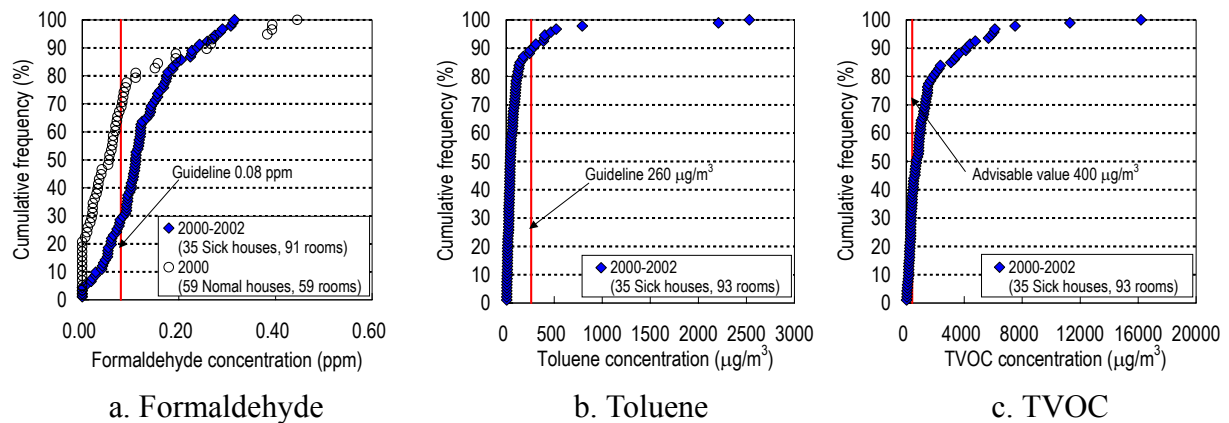


Figure 3 The cumulative frequency of chemical substance concentrations.

Figure 4 shows the relationship between chemical substance concentrations and building age. These data include the houses where a follow-up survey was conducted (total 51 houses). The formaldehyde concentration does not show much decrease, even with an increase of building age. But the toluene concentration decreases as building age increases. TVOC concentration is similar to the behaviour of the toluene concentration, but high concentration was detected in houses using moth crystals (shown by * in the figure). In retrofitted houses, the formaldehyde concentration value is higher.

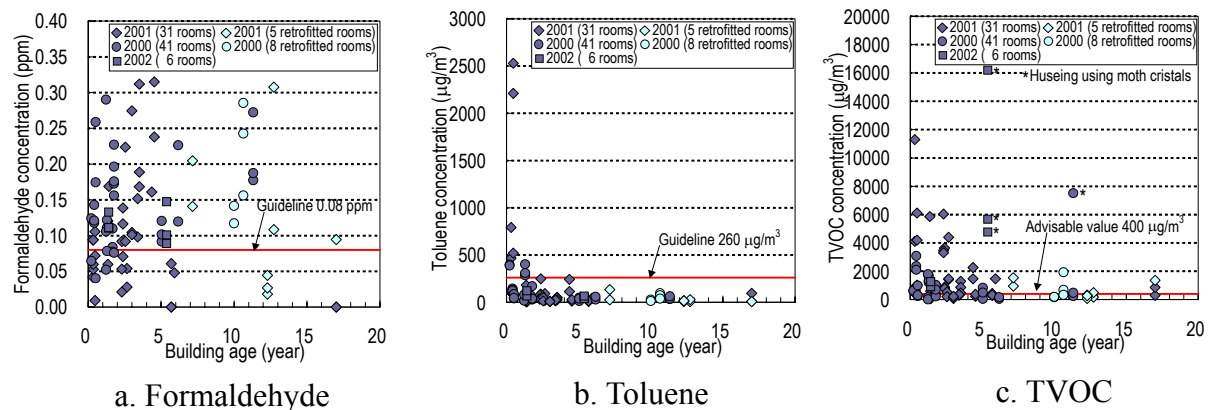


Figure 4 The relation between chemical substances concentration and building age.

Figure 5 shows the concentrations of indoor chemical substances in 13 houses (having 30 rooms in total) in which a follow-up survey was conducted. The VOCs concentrations in the second measurement markedly decreased. In contrast, the carbonyl compound concentrations

hardly changed, and the formaldehyde and acetaldehyde concentrations in the second measurement were found higher than those in initial measurement in half the rooms.

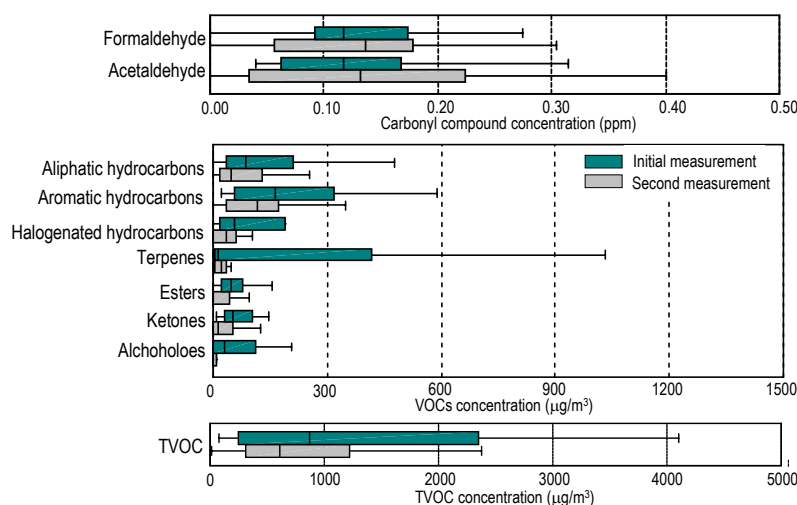


Figure 5 The chemical substance concentration in 13 houses.

Figure 6 shows the changes of indoor chemical concentration and severity of subjective symptoms by QEESI in the two houses, which had been investigated over a period of three years. It was found that the formaldehyde concentration had not shown obviously changes and TVOC concentration had shown more than 40% decrease from the initial measurement in both houses. However, the resident's health condition was different in two houses. House A reported various symptoms in the initial investigation, but no report was received by the time of third investigation. In contrast, House B had shown a progressive worsening of symptoms with the focus on the central nerve system. The scores of the neuromuscular symptoms (lightheadedness, difficulty focusing eyes) and gastrointestinal symptoms (abdominal bloating, diarrhoea) were shown to be high followed by cognitive, affective, musculoskeletal and airway/mucous membrane symptoms.

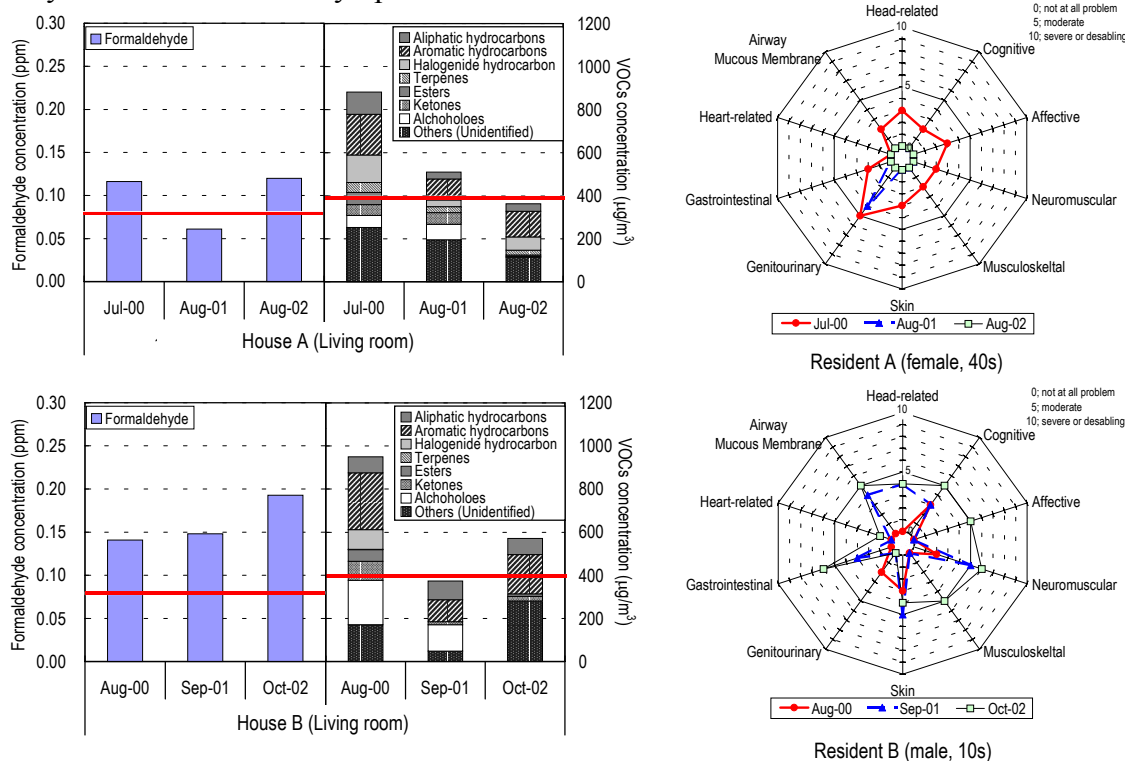


Figure 6 The changes of chemical substance concentrations and symptoms in two houses.

Figure 7 shows the relationship between TVOC concentration and the score of symptoms by QEESI. TVOC concentration was not clearly correlated to the scores of symptom. There were some patients with high score of symptoms severity in spite of relatively low concentration. And their score of chemical intolerance was also high.

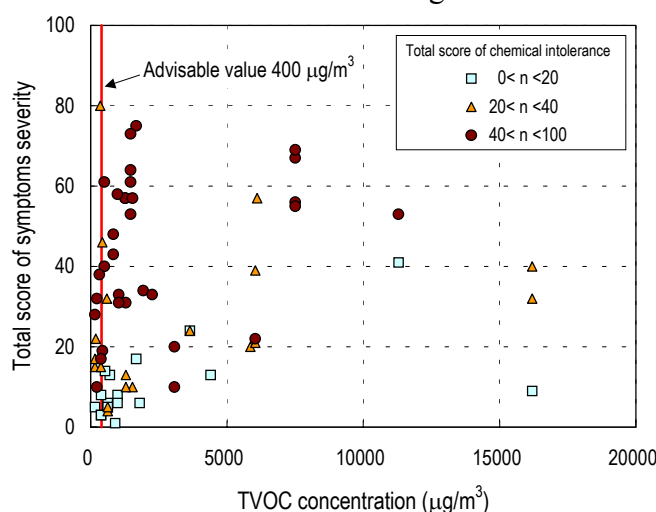


Figure 7 Relationship between the score of symptom by QEESI and TVOC concentration.

CONCLUSIONS

1. The average values of formaldehyde concentration and TVOC of the 35 investigated houses from this study are 0.124 ppm and 1557 $\mu\text{g}/\text{m}^3$, respectively. The formaldehyde concentration in 71% of the total rooms exceeds the guideline from the Ministry of Health, Labour and Welfare of Japan.
2. The most frequently described symptoms are airway/mucous membrane symptoms (coughing, irritation of eyes, mucus in nose). In addition, many patients had allergic diseases.
3. Suspicion of MCI was found in 48% of the patients by the QEESI.
4. TVOC concentration is not clearly correlated to the scores of symptom. There were some patients with high score of symptoms severity in spite of relatively low concentration. And their score of chemical intolerance was also high.

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