THE HOKKAIDO HEALTHY HOUSING (H3) STUDY: STUDY DESIGN AND BASELINE FINDINGS

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ABSTRACT

In the past several years, the insulation efficiency of houses in Japan has been much improved, but new indoor environment problems (e.g., indoor air pollution emitted from building materials, condensation, etc.) have become a concern. Residents usually live in the same house for many years. It is important to investigate indoor environments longitudinally. In order to study the indoor environment and the change in pollutant levels, we formed two cohorts to follow in Hokkaido. The first cohort consists of newly constructed houses. The second cohort consists of houses built by one construction corporation in Hokkaido. This cohort is divided into three groups: newly built houses, 5-year old houses and 10-year old houses. In this paper, the study design and baseline findings of the indoor environment measurements in 2001 are presented.

INDEX TERMS

Indoor environment, House cohort, House characteristics, Energy consumption

INTRODUCTION

In the past several years, the insulation efficiency of houses in Japan has been much improved, but new indoor environment problems (e.g., indoor air pollution emitted from building materials, condensation, etc.) have become a concern. Many indoor environment studies have been conducted in the past. However, most of these were cross-sectional studies. We do not know well the longitudinal change in the indoor environment and general information about the contribution of many house characteristics on the indoor environment. Residents usually live in the same house for many years. For the sake of the residents' health and risk assessment/management, it is important to investigate the change in the efficiency and indoor pollutant levels at many houses. In order to study the indoor environment and the change in pollutant levels, we formed house cohorts in Hokkaido and followed them. We call the study the Hokkaido Healthy Housing Study (H3 study). Hokkaido is a northern island of Japan, and houses in Hokkaido are required to be better sealed and insulated than in other regions of Japan. This study should give us some suggestions for making more healthy, efficient houses. In this paper, the study design and part of the baseline study results are described.

METHODS

The study area is the city of Sapporo and its vicinity in Hokkaido. We used two house cohorts for our study.

The first cohort consists of newly constructed houses. Approximately 30 houses were

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randomly selected as the study subjects based on a local house construction register or an alternative. Indoor environments and other parameters will be longitudinally measured until the end of follow-up (for approximately 10 years from construction). During the first two years, measurements are conducted in summer and winter. As follow-up progresses, the measurement interval will be longers (every half year to every year). VOCs, aldehydes, temperature, relative humidity, air exchange rate, dust mite allergen, and house characteristics (by a questionnaire), will be the parameters of interest. A passive gas tube for organic solvents (Sibata Scientific Technology Ltd., No.8015-066) is used for analysis of VOCs and a Sep-Pak XPoSure aldehyde sampler (Waters Corporation, No.047205) is used for aldehyde sampling. Each sampler is placed both indoors and outdoors. The measurement period is one week during each measurement season. VOCs, extracted from activated charcoal by CS_2, are analyzed with GC-MS. Aldehydes are eluted with acetonitrile and analyzed by HPLC. Temperature and relative humidity during VOC and aldehydes measurement are measured using HOBO H8/H8 Pro (Onset Computer Corporation). The air exchange rate is measured by a tracer gas method, and an equivalent leakage ratio is measured by a blower door method with depressurization. Air exchange rate by tracer gas is measured for one week with aldehydes/VOC measurement. The measurement by blower door is conducted at the first aldehydes/VOC measurement. Dust is collected from the floor surface, and dust mite allergen will be analyzed by high-sensitivity ELISA. House characteristics that may be considered to influence pollutant levels, such as house structure, smoking, heater use, etc., are collected by a questionnaire. Monthly use of heater fuel as an energy consumption indicator is also investigated by the questionnaire.

The second cohort consists of the houses of one construction corporation in Hokkaido (Jose, 1999; Nakai, 1999). The corporation uses low-emission materials for their houses. This cohort is divided into three groups: newly built houses, 5-year old houses (± 2 months) and 10-year old houses. The corporation has not changed its building construction method, so we can consider the three groups of houses a quasi-historical cohort. Differences in indoor environment levels among the groups can be considered as the indoor concentration change of one cohort. Approximately ten houses for each group are randomly selected based on the register of the corporation. The same measurements as for the first cohort are conducted for the second cohort cross-sectionally. Also, a prospective follow-up study for this cohort will be planned.

In addition to environment measurements, a self-administered questionnaire and some objective tests about chemical sensitivity and other indoor related diseases such as allergy is planned for the people who are living at each cohort house. These tests may be conducted every two or three years.

RESULTS

The recruitment for the first cohort is now ongoing. The baseline survey of cohort 2 is discussed in this manuscript.

The members of the second cohort were recruited in the winter and the summer 2001. Fifteen houses (five house for each of three groups) were selected in the winter and another eleven houses were collected in the summer. Ten newly constructed houses, eight 5-year old houses, and eight 10-year old houses were recruited for the study. Indoor environment measurements have been conducted in March and August 2001. Therefore, the houses recruited in the winter have two measurements and the houses from the summer have one measurement. Average house descriptions for each group is shown in Table 1. The floor area in newly built houses is the largest, but the equivalent leakage ratio is the smallest.

Table 1. House description of cohort 2

	Newly built	5-years	10-years
Number	10	8	8
Floor area (m^2)	158.8 (128.4-184.4)	152.3 (132.5-174.7)	143.7 (125.9-159.0)
Leakage ratio (cm^2/m^2)	3.8 (2.7-4.5)	5.0 (3.9-6.2)	6.2 (4.5-7.3)

Mean (min-max)

Formaldehyde and acetaldehyde concentrations in March and August 2001 are shown in Figure 1 and Figure 2, respectively. For the March measurement, the mean indoor concentration is 24.4 ppb among newly built houses (range: 13.3-29.4 ppb), 35.0 ppb for 5-year old houses (range: 31.9-39.9 ppb), and 25.9 ppb for 10-year old houses (range: 15.7-32.0 ppb). Indoor formaldehyde levels are the highest in the 5-year old house group. Outdoor levels are less than 5 ppb for all houses. Mean acetaldehyde levels are 24.4 ppb for newly built houses (range: 11.6-25.2 ppb), 12.0 ppb for 5-year old houses (range: 7.9-11.1 ppb), and 8.6 ppb for 10-year old houses (range 4.7-11.1 ppb).

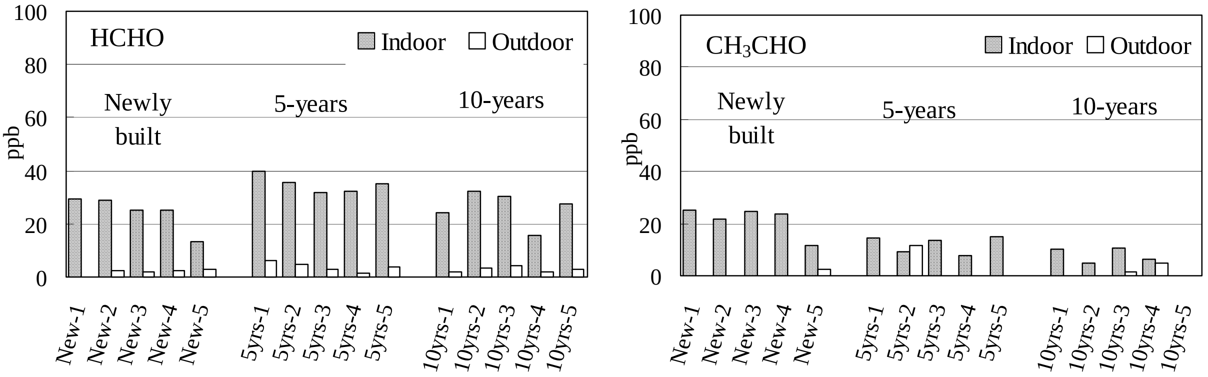

Figure 1. Indoor and outdoor aldehyde concentrations (March 2001)

Most of the acetaldehyde concentrations are less than the detection limit in the summer. Mean indoor formaldehyde concentration is 33.7 ppb among newly built houses (range: 16.0-87.9 ppb), 40.5 ppb for 5-year old houses (range: 27.5-59.0 ppb), and 44.5 ppb for 10-year old houses (range: 26.8-67.5 ppb). The mean indoor level is the lowest in newly built houses.

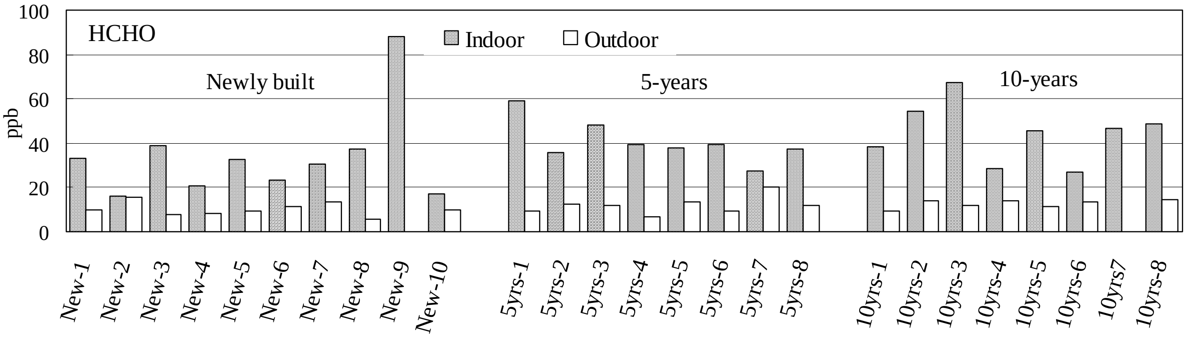

Figure 2. Indoor and outdoor aldehyde concentrations (August 2001)

The first five homes in each group were measured both in the winter and the summer, and then each concentration was compared in order to investigate the effect of season and/or aging. Indoor formaldehyde concentration in the summer is 60% higher than the winter in newly built houses, 15% higher in 5-year old houses, and 70% higher in 10-year old houses.

VOC analysis for the August 2001 measurement is still ongoing. In this paper, only the results of March measurements are shown (Table 2). Due to machine trouble, the results of four 10-year houses were missed, so we compare the levels of the newly built houses with the levels of 5-year old houses in this paper.

Guidelines for several indoor pollutants are established in Japan (Ikeda, 2001). The concentrations described in Table 2 are lower than the guidelines except *p*-dichlorobenzene. Most VOCs concentrations decrease according to the age of house based on the comparison of mean values.

Table 2. Indoor VOC concentrations (March 2001)

	Newly built	5-years old	10-years old *
Toluene	22.6 (8.8- 52.3)	18.2 (6.8- 29.7)	7.0
Ethylbenzene	6.1 (2.6- 13.0)	4.6 (3.7- 6.4)	0.0
M/p-Xylene	19.1 (4.9- 58.8)	12.2 (6.7- 17.8)	6.3
Stylene	12.8 (7.6- 18.1)	0.0 (0.0- 0.1)	0.0
o-Xylene	7.2 (2.1- 18.7)	5.2 (2.4- 7.8)	3.3
α-Pinene	181.4 (44.9- 263.5)	2.2 (0.6- 5.3)	1.9
p-Dichlorobenzene	302.1 (0.0-1403.6)	165.5 (0.0-523.0)	0.0
Limonene	153.7 (0.0- 294.9)	68.1 (0.0-206.1)	84.2
Undecane	105.8 (19.0- 195.3)	36.8 (0.0-144.3)	7.4
Nonanale	17.2 (0.0- 38.1)	1.3 (0.0- 3.5)	2.1
Tetradecane	98.3 (19.1- 175.5)	6.4 (0.0- 20.7)	1.0

$\mu g/m^3$, mean (range),
* Only one house for 10-year old houses

DISCUSSION

Some furniture or other goods, which emit VOC and/or aldehydes, might be brought into the house. In another paper, the relationship between indoor environment and house characteristics derived by a questionnaire is investigated (Kumagai, 2002). Indoor environment levels, the determinants of them, and the longitudinal change of indoor environment parameters that are related to residents' health will be clear, as we follow-up these cohorts and investigate other indoor environmental factors such as mite allergen and temperature.

This study has several shortcomings. The most important is the small number of subjects. The number of subjects is mainly determined based on study feasibility, not based on statistical power. Therefore, it may be difficult to evaluate joint contributions of house characteristics, season, life style, etc. on indoor environments in this study. A more large-scale study may be necessary. However, several new findings and suggestions on indoor environment in Japan should be expected from our study.

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