Chemical pollution of indoor air in Japan

Kanagawa environmental research center
Ogawa, Takehiko

Abstruct

Recently, indoor air pollution from chemical compounds has been attracting attention. Sick-house syndrome and hypersensitivity to chemical compounds are also being recognized as health problems.

In this presentation, the situation of indoor air pollution by chemical compounds in Japan will be explained.

1. Introduction

In recent years, houses are being built with very little ventilation, and many are almost air-tight. In addition, the buildings and interiors are often constructed with materials that emit chemical vapors. It is known that people who live in such houses sometimes suffer from various physical disorders caused by indoor air pollution due to chemicals. These conditions are collectively termed "sick house syndrome", on the grounds that the symptoms are diverse, that there are many unresolved questions concerning these symptoms, and that multiple factors seem to cause them.

The author has recently had the opportunity to take part in a survey of the living environment in Japanese houses. The results of this survey will be outlined here, on the basis of a report published by the Ministry of Health and Welfare.

2. Survey method

The survey was conducted for 2 years (1997 and 1998). During the survey, samples of indoor air and air from the outdoor vicinity of the target houses were collected and checked for volatile organic compounds. At the same time, a questionnaire survey was conducted to investigate the indoor and outdoor environments, styles of living and the health situation of the residents. In 1998, the level of exposure of individual subjects to certain chemicals (i.e., the level of these substances contained in the indoor air inhaled by the subjects) was examined as well. The survey was conducted on a total of 385 houses nationwide.

3. Summarized results of the survey

3-1. Indoor contamination levels

1) Mean, median, maximum and distribution of the amount of each compound

Tables 1 and 2 show the parameters examined. As shown in Figures 1 and 2, the results were similar in both of the two surveys. For each parameter, there were large clusters of data in the low level area, and some points were sporadically distributed in the high level area (a non-normal distribution). In each parameter, the sporadic distribution of high level points increased the mean value, so that the mean value significantly exceeded the median.

P-dichlorobenzene and toluene were found to have high mean, median and maximum levels. The mean alpha-pinene level also tended to be high. The causes of these peak levels remain to be clarified in order to suggest countermeasures. Fig. 3 graphically represents the summarized results.

2) Comparison between the indoor and outdoor levels

Tables 3 and 4 show the level of the substances found indoors.

As an indicator of the source of these chemicals, the ratio of the indoor level (I) to the outdoor level (O) was calculated (I/O ratio). This ratio was high for limonene, p-dichlorobenzene and styrene (Table 8 and Fig. 4). Most of the other chemicals examined had an I/O ratio of 3 or more. A high I/O ratio indicates that the substance in question originates indoors. The I/O ratio for hexadecane and some other substances was close to 1, suggesting that their source is located outdoors.

3) Comparison with data from other countries

Table 6 compares these data with findings in other countries. The mean level of p-dichlorobenzene in the present study was about twice or three times as high as that in other countries. The levels of all other chemicals were comparable to or lower than those in foreign countries.

The WHO has formulated guidelines concerning toluene, xylene, tetrachloroethylene, 1,2-dichloroethane, dichloromethane, chloroform, ethylbenzene and styrene. The levels of these chemicals in the present survey were lower than the WHO tolerances. However, the levels of toluene, chloroform and xylene, which were very high at some points, exceeded the WHO tolerance levels.

The Japanese Ministry of Health and Welfare (MHW) has set a mean for a tolerable level of p-dichlorobenzene (0.1 ppm; 590 mg/m3) in indoor air. The amount of this chemical was higher than the MHW level in about 5% of all houses examined.

3-2. Exposure levels for individuals

Each subject carried a compact air collecting tube for 24 hours to measure the mean exposure level during his/her total activity (indoor + outdoor activity) for 24 hours.

1) Mean, median, maximum and distribution of levels

Table 7 shows the exposure levels for individuals. Like the data for indoors, the total indoor + outdoor exposure level had clusters in the low level area and several points sporadically distributed in the high level area (a non-normal distribution), as shown in Fig. 5. The points in the high level area again increased the average. For this reason, the average of each parameter was much higher than its median.

All of the mean, median and maximum value were high for p-dichlorobenzene, toluene, and other substances.

2) Comparison of individual exposure with indoor levels

The ratio of personal exposure (P) to the indoor level (I) for each chemical (the P/I ratio) was close to 1 for most substances (Table 5). Thus, there was a close correlation between their indoor concentration and the corresponding personal exposure levels (Table 8, Fig. 6).

3-3. Correlation to house type

Fig. 7 shows the ratio of the indoor concentrations and the personal exposure level in new houses (N) to those in old houses (O) (N/O ratio). For both indoor and personal exposure levels, this ratio was over 2 for some chemicals such as toluene. These results indicate that toluene and certain other chemicals are very likely to be emitted in new houses.

It is unknown whether there are significant differences in these values between separate and apartment houses, between wood and reinforced concrete or steel skeleton houses or between air-tight and ordinary houses. When the floor material was evaluated, the indoor levels of toluene, xylene, styrene, and alpha-pinene tended to be higher in houses with wooden floors than in houses with other floors.

3-4. Correlation to environments and living style

The levels of heptane, and limonene tended to be higher in winter than in any other season. The levels of p-dichlorobenzene, and alpha-pinene tended to be higher in summer.

The levels of some chemicals such as aromatic hydrocarbons tended to be slightly higher in the Hokkaido and Tohoku districts than in other districts of Japan. Overall, the levels of chemicals tended to be low in Kyushu. The levels of some chemicals such as aromatic hydrocarbons were higher in houses using oil stoves than in houses using other types of room heating.

3-5. Questionnaire survey of health status

The questionnaire survey of the health condition of the people who lived in the target houses revealed that a total of 28 people had some complaints. Their predominant complaints were pain in the eyes or throat, headache, and coughing.

4. Conclusion

The indoor concentration of chemical substances varies not only depending on the house type but also depending on ventilation, airing habits, temperature, and other factors. Furniture can also affect the indoor concentration of chemicals substantially. Further studies must collect data on these topics in order to carry out more detailed analyses.

Toxicological evaluation of indoor pollution and personal exposure to these substances, evaluation of health hazards and risks, and measures to reduce the use of pollutants in living areas and to control their indoor concentration are desirable goals of further research.

Table 1 Indoor air (1997)

Compound	Max.	Min.	Ave.	Med.
Hexane	138	0.5	7.4	3.6
Heptane	427	0.4	7.7	2
Octane	478	0.4	11.5	1.6
Nonane	591	0.4	20.9	3.3
Decane	572	0.4	23.1	4.2
Undecane	268	0.4	14.6	2.9
Dodecane	232	0.4	9.5	2.6
Tridecane	182	0.4	7.3	1.9
Tetradecane	75	0.4	5.7	2.8
Pentadecane	42	0.4	2	0.5
Hexadecane	60	0.3	1.3	0.3
2,4-Dimethylpentane	62	0.3	1.2	0.3
2,2,4-Trimetylpentane	38	0.3	0.9	0.3
Benzene	66	0.4	5.9	3.1
Toluene	2,375	0.3	93.3	26.9
Ethylbenzene	723	0.2	21.6	6.8
m, p-Xylene	717	0.2	26.7	9.6
o-Xylene	380	0.2	11.5	4.2
Styrene	184	0.1	4.5	0.6
1,3,5-Trimethylbenzene	1,086	0.1	9.6	1.3
1,2,4-Trimethylbenzene	2,989	0.1	29	4.1
1,2,3-Trimethylbenzene	156	0.1	5.8	1
1,2,4,5-Tetramethylbenzene	122	0.1	1.5	0.1
α-Pinene	297	0.1	12.9	3.6
Limonene	691	0.1	26.5	6.1
Dichloromethane	154	0.4	7.5	2.6
Trichloroethylene	1,864	0.2	7.9	0.2
Tetrachloroethylene	84	0.2	1.8	0.4
Chloroform	155	0.4	2.1	0.4
1,1,1-Trichloroethane	58	0.2	1.7	0.3
1,2-Dichloroethane	61	0.2	1.2	0.2
1,2-Dichloropropane	37	0.2	1.1	0.2
p-Dichlorobenzene	6,059	0.3	128.4	12.3
Carbon Tetrachloride	284	0.4	3.6	0.4
Chlorodibromomethane	490	0.2	5.3	0.2
Ethyl Acetate	149	0.5	9	3.8
Buthyl Acetate	442	0.3	10.3	2.1
Acetone	361	2.6	32.3	18.3
Metyl Etyl Ketone	130	0.7	6.6	2.3
Metyl Isobutyl Ketone	474	0.3	7.3	0.8
Ethanol	2,477	5	281.2	84.7
n-Butanol	83	0.5	5.1	1.9
Nonanal	74	0.7	5.9	3.4
Decanal	47	0.7	3.1	1

Expressed in ug/m^3

Table 2 Indoor air (1998)

Compound	Max.	Min.	Ave.	Med.
Hexane	98	0.100	7.0	2.9
Heptane	163	0.100	7.8	2.5
Octane	258	0.085	12.7	1.8
Nonane	347	0.120	20.8	4.8
Decane	343	0.124	21.0	7.4
Undecane	229	0.138	13.0	4.6
Dodecane	142	0.099	10.2	4.8
Tridecane	453	0.007	13.1	5.7
Tetradecane	1,115	0.036	18.7	4.4
Pentadecane	316	0.027	5.3	1.4
Hexadecane	78	0.012	2.3	0.8
2,4-Dimethylpentane	13	0.032	0.5	0.2
2,2,4-Trimetylpentane	1,096	0.022	7.1	0.2
Benzene	434	0.092	7.2	2.6
Toluene	3,390	0.200	98.3	25.4
m, p-Xylene	425	0.200	24.3	10.2
o-Xylene	144	0.072	10.0	3.8
Styrene	133	0.002	4.9	0.2
1,2,3-Trimethylbenzene	53	0.023	3.1	1.3
1,2,4-Trimethylbenzene	577	0.069	12.8	4.8
1,3,5-Trimethylbenzene	231	0.032	4.2	1.2
1,2,4,5-Tetramethylbenzene	17	0.004	0.7	0.2
Ethylbenzene	502	0.100	22.5	6.8
Chloroform	13	0.033	1.0	0.3
1,1,1-Trichloroethane	65	0.056	3.0	0.4
Carbon Tetrachloride	19	0.033	1.5	0.6
Trichloroethylene	105	0.060	2.4	0.3
Tetrachloroethylene	43	0.034	1.9	0.3
1,2-Dichloroethane	12	0.041	0.5	0.2
1,2-Dichloropropane	20	0.006	0.5	0.2
Dibromochloromethane	313	0.032	2.0	0.2
p-Dichlorobenzene	2,247	0.059	123.3	16.1
Ethyl Acetate	288	0.186	11.9	3.7
Buthyl Acetate	341	0.018	11.7	1.9
Nonanal	421	0.176	15.8	6.8
Decanal	169	0.180	9.7	2.5
Metyl Etyl Ketone	101	0.041	5.8	1.6
Metyl Isobutyl Ketone	179	0.018	4.8	0.8
n-Butanol	175	0.127	6.8	1.4
α-Pinene	2,232	0.042	77.6	4.7
Limonene	555	0.200	42.1	12.8

Expressed in ug/m^3.

Table 3 Outdoor air (1997)

Compound	Max.	Min.	Ave.	Med.
Hexane	14.3	0.5	2.2	1.4
Heptane	13.8	0.4	1.1	0.6
Octane	14.0	0.4	0.8	0.4
Nonane	9.4	0.4	1.2	0.5
Decane	26.2	0.4	1.9	0.8
Undecane	7.4	0.4	1.1	0.6
Dodecane	38.7	0.4	1.1	0.4
Tridecane	48.2	0.4	1.4	0.4
Tetradecane	58.9	0.4	1.5	0.4
Pentadecane	56.6	0.4	2.4	0.4
Hexadecane	85.2	0.3	3.6	0.3
2,4-Dimetylpentane	4.2	0.3	0.4	0.3
2,2,4-Trimetylpentane	9.6	0.3	0.5	0.3
Benzene	45.8	0.4	2.9	1.7
Toluene	536.7	0.3	20.3	8.5
Ethylbenzene	216.5	0.2	7.3	2.2
m, p-Xylene	79.4	0.2	4.7	2.7
o-Xylene	24.0	0.2	1.8	1.1
Styrene	3.4	0.1	0.3	1.0
1,3,5-Trimethylbenzene	93.7	0.1	1.8	0.4
1,2,4-Trimethylbenzene	34.8	0.1	2.5	1.1
1,2,3-Trimethylbenzene	7.4	0.1	0.9	0.3
1,2,4,5-Tetramethylbenzene	20.2	0.1	0.4	0.1
α-Pinene	41.1	0.1	2.0	0.9
Limonene	80.5	0.1	2.6	0.1
Dichloromethane	14.7	0.4	2.8	1.4
Trichloroethylene	4.8	0.2	0.7	0.2
Tetrachloroethylene	4.7	0.2	0.5	0.2
Chloroform	2.2	0.4	0.4	0.4
1,1,1-Trichloroethane	1.6	0.2	0.3	0.2
1,2-Dichloroethane	1.1	0.2	0.3	0.2
1,2-Dichloropropane	0.5	0.2	0.2	0.2
p-Dichlorobenzene	44.3	0.3	2.7	1.0
Carbon Tetrachloride	47.7	0.4	1.5	0.4
Chlorodibromomethane	1.0	0.2	0.3	0.2
Ethyl Acetate	50.6	0.5	2.3	0.5
Buthyl Acetate	24.7	0.3	1.3	0.3
Acetone	22.3	2.6	5.6	2.6
Metyl Etyl Ketone	23.9	0.7	1.6	0.7
Metyl Isobutyl Ketone	6.5	0.3	0.7	0.3
Ethanol	18.3	5.0	6.2	5.0
n-Butanol	9.1	0.5	0.8	0.5
Nonanal	28.8	0.7	1.5	0.7
Decanal	26.3	0.7	1.3	0.7

Expressed in ug/m^3.

Table 4 Outdoor air (1998)

Compound	Max.	Min.	Ave.	Med.
Hexane	110.6	0.10	3.4	1.0
Heptane	25.8	0.01	0.9	0.3
Octane	63.2	0.04	1.2	0.2
Nonane	62.4	0.08	2.2	0.8
Decane	109.0	0.04	3.5	0.9
Undecane	74.2	0.04	2.1	0.5
Dodecane	43.9	0.03	1.8	0.5
Tridecane	87.8	0.01	5.0	1.2
Tetradecane	56.5	0.00	2.1	0.7
Pentadecane	5.1	0.00	0.4	0.2
Hexadecane	161.7	0.02	1.3	0.2
2,4-Dimetylpentane	3.6	0.03	0.3	0.2
2,2,4-Trimetylpentane	20.2	0.03	0.6	0.2
Benzene	45.8	0.01	3.3	2.0
Toluene	444.7	0.20	21.2	10.1
m, p-Xylene	65.9	0.03	4.3	2.3
o-Xylene	26.9	0.07	2.2	1.1
Styrene	6.7	0.00	0.2	0.1
1,2,3-Trimethylbenzene	12.2	0.02	0.6	0.2
1,2,4-Trimethylbenzene	31.8	0.05	2.4	1.3
1,3,5-Trimethylbenzene	34.2	0.03	0.8	0.4
1,2,4,5-Tetramethylbenzene	3.5	0.00	0.2	0.1
Ethylbenzene	90.1	0.10	4.9	2.0
Chloroform	8.2	0.01	0.4	0.2
1,1,1-Trichloroethane	8.8	0.04	0.5	0.2
Carbon Tetrachloride	14.3	0.04	1.0	0.5
Trichloroethylene	14.4	0.06	1.1	0.2
Tetrachloroethylene	10.8	0.04	0.7	0.2
1,2-Dichloroethane	17.1	0.05	0.5	0.2
1,2-Dichloropropane	4.7	0.10	0.3	0.2
Dibromochloromethane	0.2	0.09	0.2	0.2
p-Dichlorobenzene	129.3	0.04	4.9	1.4
Ethyl Acetate	44.0	0.10	2.8	0.4
Buthyl Acetate	22.7	0.01	1.4	0.2
Nonanal	32.9	0.03	1.4	0.4
Decanal	106.1	0.12	2.7	0.4
Metyl Etyl Ketone	30.3	0.03	1.6	0.4
Metyl Isobutyl Ketone	20.5	0.01	1.0	0.2
n-Butanol	42.4	0.01	0.9	0.2
α-Pinene	575.2	0.01	5.7	0.2
Limonene	23.4	0.00	1.1	0.2

Expressed in ug/m^3.

Table 5 Comparison of Indoor air, Outdoor air, and Individual disclosure (1998)

Compound	Indoor Air		Outdoor Air		Individual		I/O	P/I
	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ratio	Ratio
Hexane	7.0	97.5	3.4	110.6	12.9	450.9	2.1	1.8
Heptane	7.8	163.2	0.9	25.8	7.6	100.0	8.6	1.0
Octane	12.7	257.7	1.2	63.2	10.8	181.4	10.3	0.9
Nonane	20.8	346.9	2.2	62.4	17.8	293.9	9.6	0.9
Decane	21.0	342.7	3.5	109.0	19.0	368.8	6.0	0.9
Undecane	13.0	228.6	2.1	74.2	12.0	149.4	6.3	0.9
Dodecane	10.2	141.6	1.8	43.9	10.5	118.6	5.7	1.0
Tridecane	13.1	453.1	5.0	87.8	13.7	353.8	2.6	1.0
Tetradecane	18.7	1114.8	2.1	56.5	15.4	483.3	8.9	0.8
Pentadecane	5.3	316.3	0.4	5.1	4.4	133.9	12.2	0.8
Hexadecane	2.3	77.5	1.3	161.7	3.1	144.4	1.8	1.4
2,4-Dimetylpentane	0.5	13.0	0.3	3.6	0.6	9.2	1.6	1.3
2,2,4-Trimetylpentane	7.1	1095.6	0.6	20.2	1.7	86.8	12.0	0.2
Benzene	7.2	433.6	3.3	45.8	6.9	167.8	2.2	1.0
Toluene	98.3	3389.8	21.2	444.7	110.8	2534.5	4.6	1.1
m, p-Xylene	24.3	424.8	4.3	65.9	22.9	377.4	5.6	0.9
o-Xylene	10.0	144.4	2.2	26.9	10.3	112.7	4.5	1.0
Styrene	4.9	132.6	0.2	6.7	5.5	218.8	25.1	1.1
1,2,3-Trimethylbenzene	3.1	53.2	0.6	12.2	3.1	43.2	5.3	1.0
1,2,4-Trimethylbenzene	12.8	577.2	2.4	31.8	13.3	628.9	5.4	1.0
1,3,5-Trimethylbenzene	4.2	231.3	0.8	34.2	4.9	276.2	4.9	1.2
1,2,4,5-Tetramethylbenzen	0.7	16.8	0.2	3.5	0.8	20.2	2.9	1.1
Ethylbenzene	22.5	501.9	4.9	90.1	21.2	352.4	4.6	0.9
Chloroform	1.0	12.8	0.4	8.2	1.5	27.7	2.6	1.6
1,1,1-Trichloroethane	3.0	65.1	0.5	8.8	3.2	122.9	6.2	1.1
Carbon Tetrachloride	1.5	18.5	1.0	14.3	1.3	15.0	1.5	0.9
Trichloroethylene	2.4	104.7	1.1	14.4	1.8	28.0	2.1	0.8
Tetrachloroethylene	1.9	43.4	0.7	10.8	1.8	52.5	2.9	1.0
1,2-Dichloroethane	0.5	11.5	0.5	17.1	0.8	75.0	0.9	1.8
1,2-Dichloropropane	0.5	19.9	0.3	4.7	0.6	17.1	1.6	1.2
Chlorodibromomethane	2.0	313.0	0.2	0.2	0.2	2.1	10.0	1.0
p-Dichlorobenzene	123.3	2246.9	4.9	129.3	170.7	2782.7	25.1	1.4
Ethyl Acetate	11.9	288.0	2.8	44.0	13.3	233.8	4.3	1.1
Buthyl Acetate	11.7	340.9	1.4	22.7	10.8	218.0	8.6	0.9
Nonanal	15.8	421.2	1.4	32.9	18.0	248.9	11.3	1.1
Decanal	9.7	169.0	2.7	106.1	9.2	130.3	3.6	1.0
Metyl Etyl Ketone	5.8	101.0	1.6	30.3	5.4	64.2	3.7	0.9
Metyl Isobutyl Ketone	4.8	179.1	1.0	20.5	4.5	74.5	4.8	0.9
n-Butanol	6.8	174.5	0.9	42.4	8.4	168.5	7.8	1.2
α-Pinene	77.6	2231.8	5.7	575.2	92.5	2239.6	13.6	1.2
Limonene	42.1	554.8	1.1	23.4	40.2	542.1	39.3	1.0

Expressed in ug/m^3.

I/O ratio: Indoor / Outdoor (average)

P/I ratio: Individual / Indoor (average)

Table 6 Comparison of foreign countries

Compound	Report	Min.	Med.	Max.
Hexane	WHO		10	
	Japan		3.6, 2.9	
Heptane	WHO		5	
	Report*[1]	0	1.02	
	Japan		2.0, 2.5	
Decane	WHO		10	
	Report*[1]	0.39	2.25	
	Report*[2]		0.28	
	Japan		4.2, 7.4	
Benzene	WHO		10	
	Report*[1]	0.21	3.11	38.6
	Report*[2]		3.14	
	Japan		3.1, 2.6	
Pinene	Report*[1]	1.05	7.7	36.4
	Report*[2]		0.23	
	Japan		3.6, 4.7	
1,1,1-Trichloroethan	WHO		5	
	Report*[1]	0	1.03	7.76
	Japan		0.3, 0.4	
Tetrachloroethylene	WHO		5	
	Report*[1]	0	0.3	5.65
	Report*[2]		0.74	
	Japan		0.4, 0.3	
Toluene	WHO		65	
	Report*[1]	0.6	20.2	70.4
	Report*[2]		1.66	
	Japan		26.9, 25.4	
Xylene	WHO		25	
	Report*[1]	2.04	7.57	28.63
	Japan		4.2+9.6, 3.8+10.2	
p-Dichlorobenzene	WHO		5	
	Report*[1]	0	0.08	8.94
	Report*[2]		0.28	
	Japan		12.3, 16.1	

Expressed in ug/m^3.

WHO: WHO working group (1989)

Report*[1]: Kostiainen

Report*[2]: Shaha et al.

Japan: Median value (1997, 1998)

Table 7 Individual disclosure (1998)

Compound	Max.	Min.	Ave.	Med.
Hexane	450.9	0.100	12.9	3.6
Heptane	100.0	0.100	7.6	2.6
Octane	181.4	0.058	10.8	2.0
Nonane	293.9	0.107	17.8	4.9
Decane	368.8	0.189	19.0	7.4
Undecane	149.4	0.156	12.0	4.8
Dodecane	118.6	0.124	10.5	5.3
Tridecane	353.8	0.015	13.7	6.7
Tetradecane	483.3	0.046	15.4	5.5
Pentadecane	133.9	0.033	4.4	1.9
Hexadecane	144.4	0.029	3.1	1.2
2,4-Dimetylpentane	9.2	0.014	0.6	0.2
2,2,4-Trimetylpentane	86.8	0.019	1.7	0.2
Benzene	167.8	0.200	6.9	3.3
Toluene	2534.5	0.200	110.8	34.2
m, p-Xylene	377.4	0.200	22.9	10.3
o-Xylene	112.7	0.068	10.3	4.6
Styrene	218.8	0.001	5.5	0.4
1,2,3-Trimethylbenzene	43.2	0.010	3.1	1.3
1,2,4-Trimethylbenzene	628.9	0.100	13.3	6.0
1,3,5-Trimethylbenzene	276.2	0.035	4.9	1.5
1,2,4,5-Tetramethylbenzene	20.2	0.006	0.8	0.4
Ethylbenzene	352.4	0.095	21.2	7.6
Chloroform	27.7	0.049	1.5	0.5
1,1,1-Trichloroethane	122.9	0.042	3.2	0.7
Carbon Tetrachloride	15.0	0.028	1.3	0.7
Trichloroethylene	28.0	0.100	1.8	0.4
Tetrachloroethylene	52.5	0.070	1.8	0.5
1,2-Dichloroethane	75.0	0.050	0.8	0.2
1,2-Dichloropropane	17.1	0.008	0.6	0.2
Dibromochloromethane	2.1	0.031	0.2	0.2
p-Dichlorobenzene	2782.7	0.068	170.7	23.3
Ethyl Acetate	233.8	0.200	13.3	4.5
Buthyl Acetate	218.0	0.035	10.8	2.3
Nonanal	248.9	0.157	18.0	9.2
Decanal	130.3	0.182	9.2	3.5
Metyl Etyl Ketone	64.2	0.077	5.4	2.1
Metyl Isobutyl Ketone	74.5	0.015	4.5	0.9
n-Butanol	168.5	0.058	8.4	2.1
α-Pinene	2239.6	0.099	92.5	5.0
Limonene	542.1	0.200	40.2	14.0

Expressed in ug/m^3.

Table 8 Co-relationship between indoor air and individual disclosure

Compounds	Co-relation	P-Value
Hexane	0.247	0.0007
Heptane	0.806	<0.0001
Octane	0.839	<0.0001
Nonane	0.806	<0.0001
Decane	0.872	<0.0001
Undecane	0.841	<0.0001
Dodecane	0.841	<0.0001
Tridecane	0.915	<0.0001
Tetradecane	0.948	<0.0001
Pentadecane	0.919	<0.0001
Hexadecane	0.781	<0.0001
2,4-Dimetylpentane	0.678	<0.0001
2,2,4-Trimetylpentane	0.002	0.9779
Benzene	0.905	<0.0001
Toluene	0.792	<0.0001
m, p-Xylene	0.922	<0.0001
o-Xylene	0.884	<0.0001
Styrene	0.899	<0.0001
1,2,3-Trimethylbenzene	0.671	<0.0001
1,2,4-Trimethylbenzene	0.967	<0.0001
1,3,5-Trimethylbenzene	0.960	<0.0001
1,2,4,5-Tetramethylbenzen(	0.366	<0.0001
Ethylbenzene	0.906	<0.0001
Chloroform	0.663	<0.0001
1,1,1-Trichloroethane	0.770	<0.0001
Carbon Tetrachloride	0.706	<0.0001
Trichloroethylene	0.404	<0.0001
Tetrachloroethylene	0.287	<0.0001
1, 2-Dichloroethane	0.073	0.3321
1, 2-Dichloropropane	0.929	<0.0001
Dibromochloromethane	0.778	<0.0001
p-Dichlorobenzene	0.753	<0.0001
Ethyl Acetate	0.722	<0.0001
Buthyl Acetate	0.790	<0.0001
Nonanal	0.776	<0.0001
Decanal	0.893	<0.0001
Metyl Etyl Ketone	0.621	<0.0001
Metyl Isobutyl Ketone	0.415	<0.0001
Butanol	0.691	<0.0001
α-Pinene	0.691	<0.0001
Limonene	0.805	<0.0001

Co-relation: higher value means effective relationship between indoor air and individual disclosure.

P-value: lower value means effective relationship between indoor air and individual disclosure.

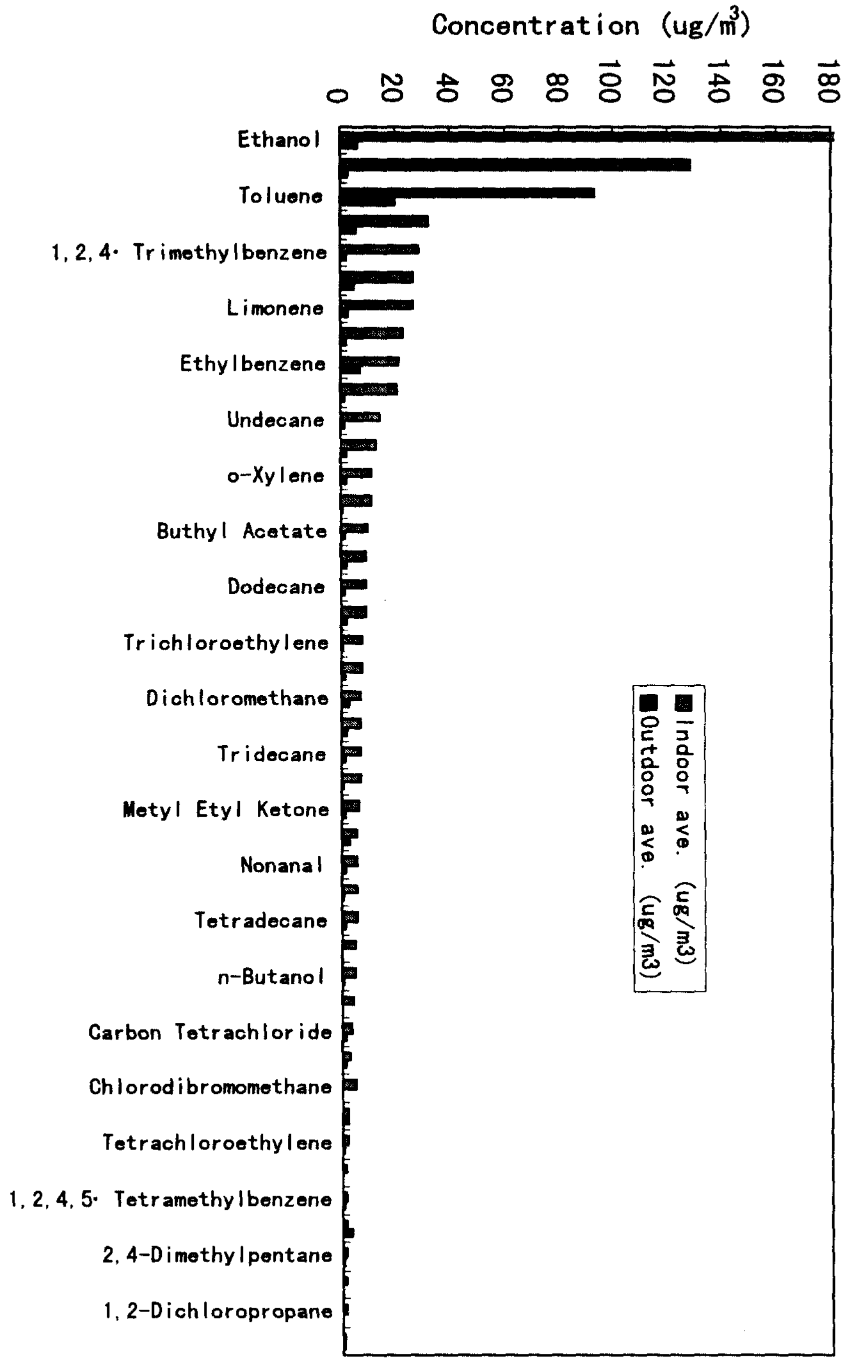

Fig. 1 Comparison of indoor and outdoor air (average, 1997)

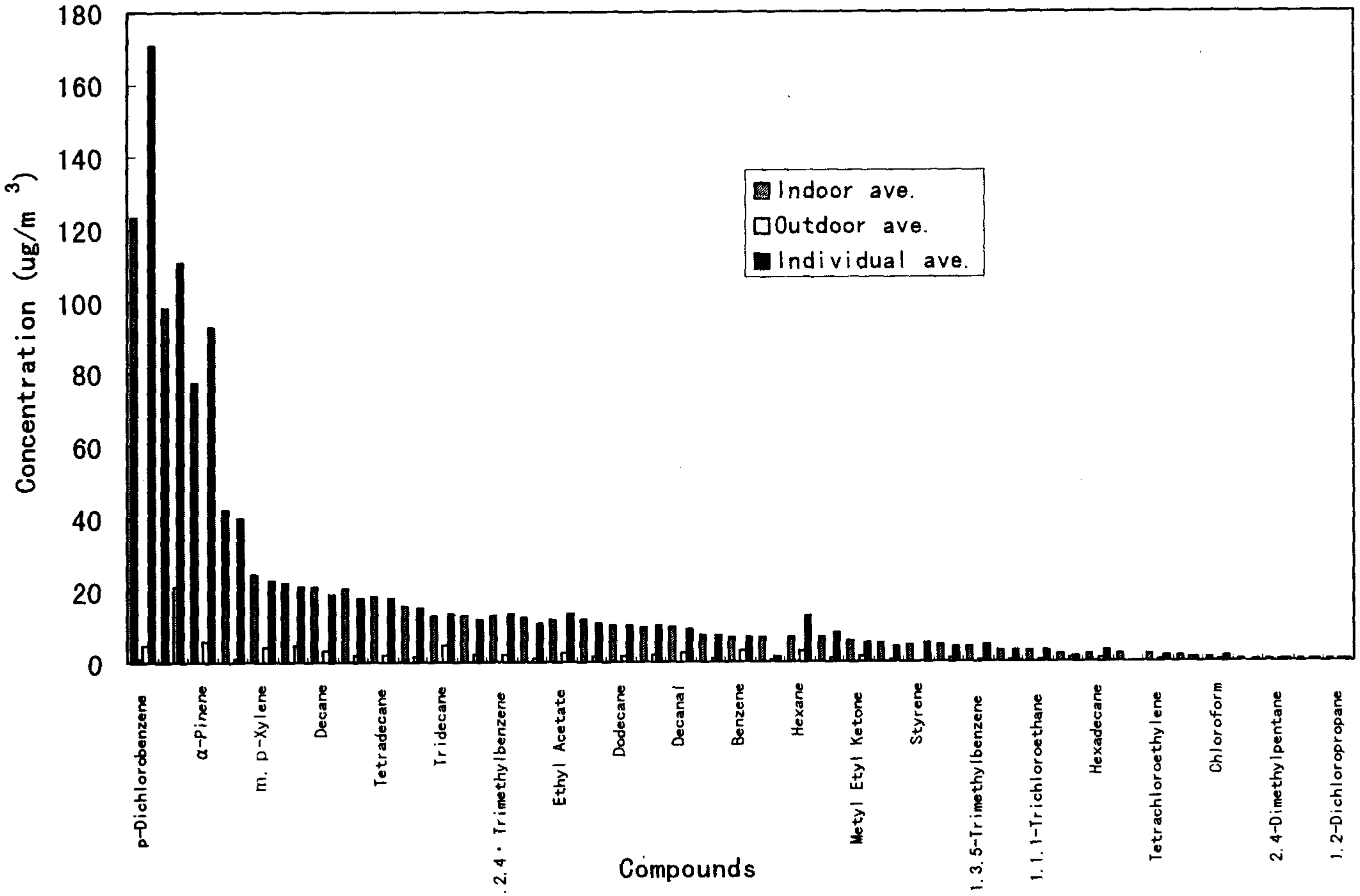

Fig. 2 Comparison of indoor, outdoor air, and individual exposure (average)

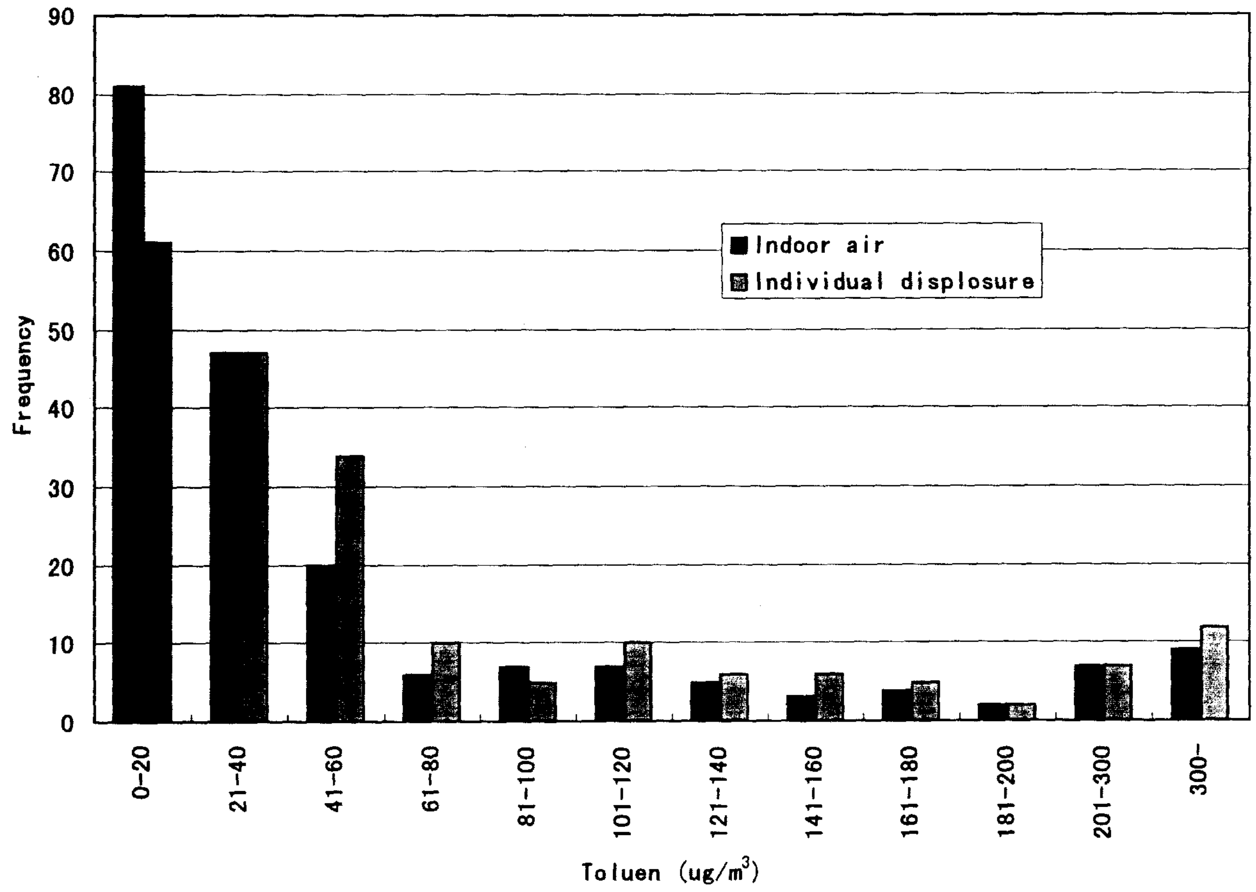

Fig. 3 Concentration of Toluen

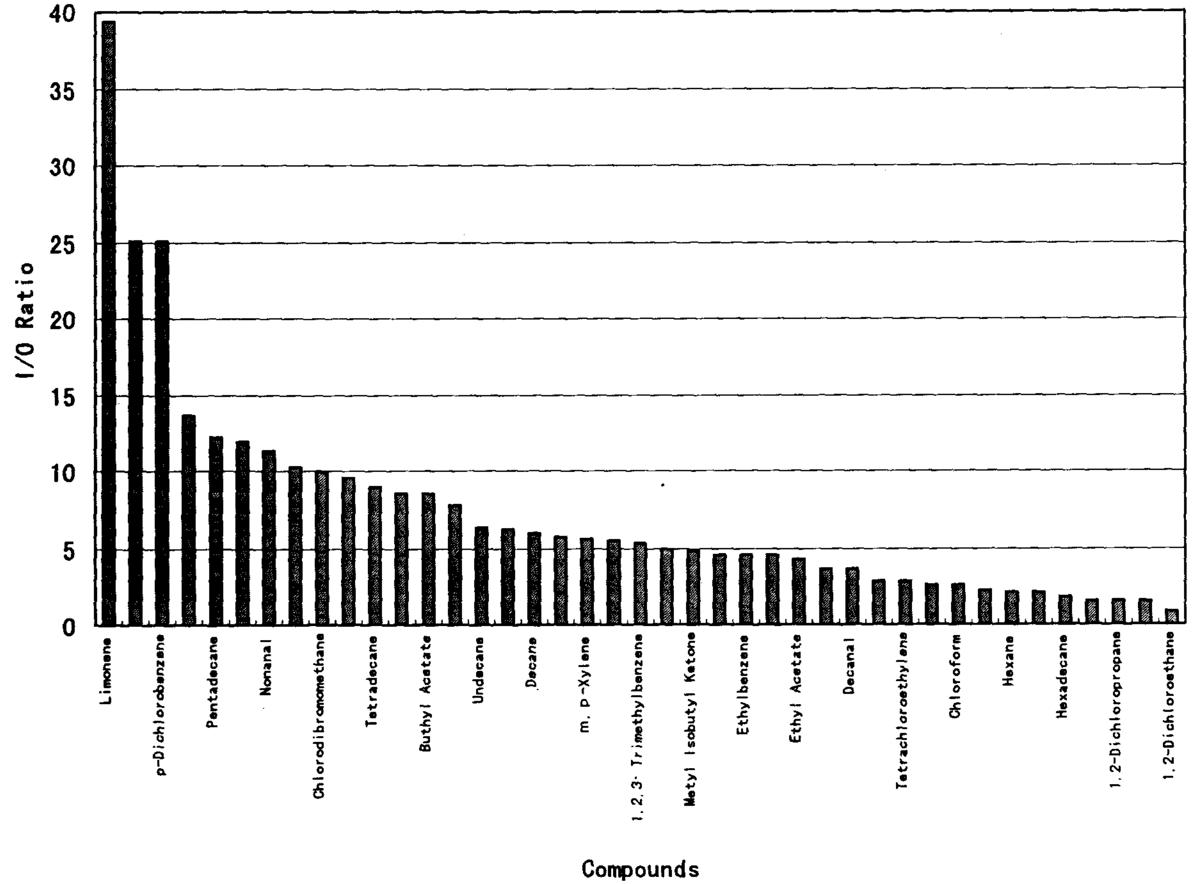

Fig. 4 Indoor/Outdoor concentration ratio (Average)

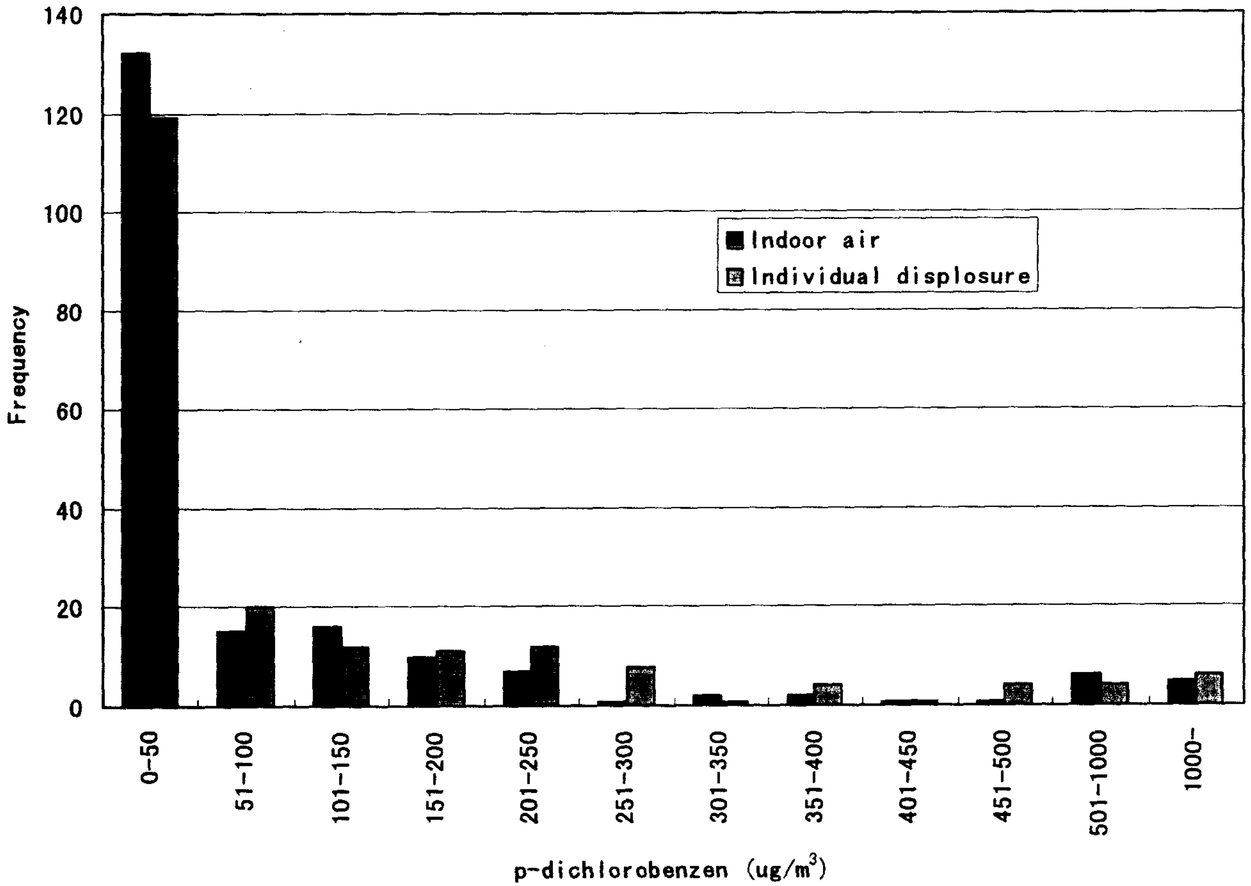

Fig. 5 Concentration of p-Dichlorobenzene

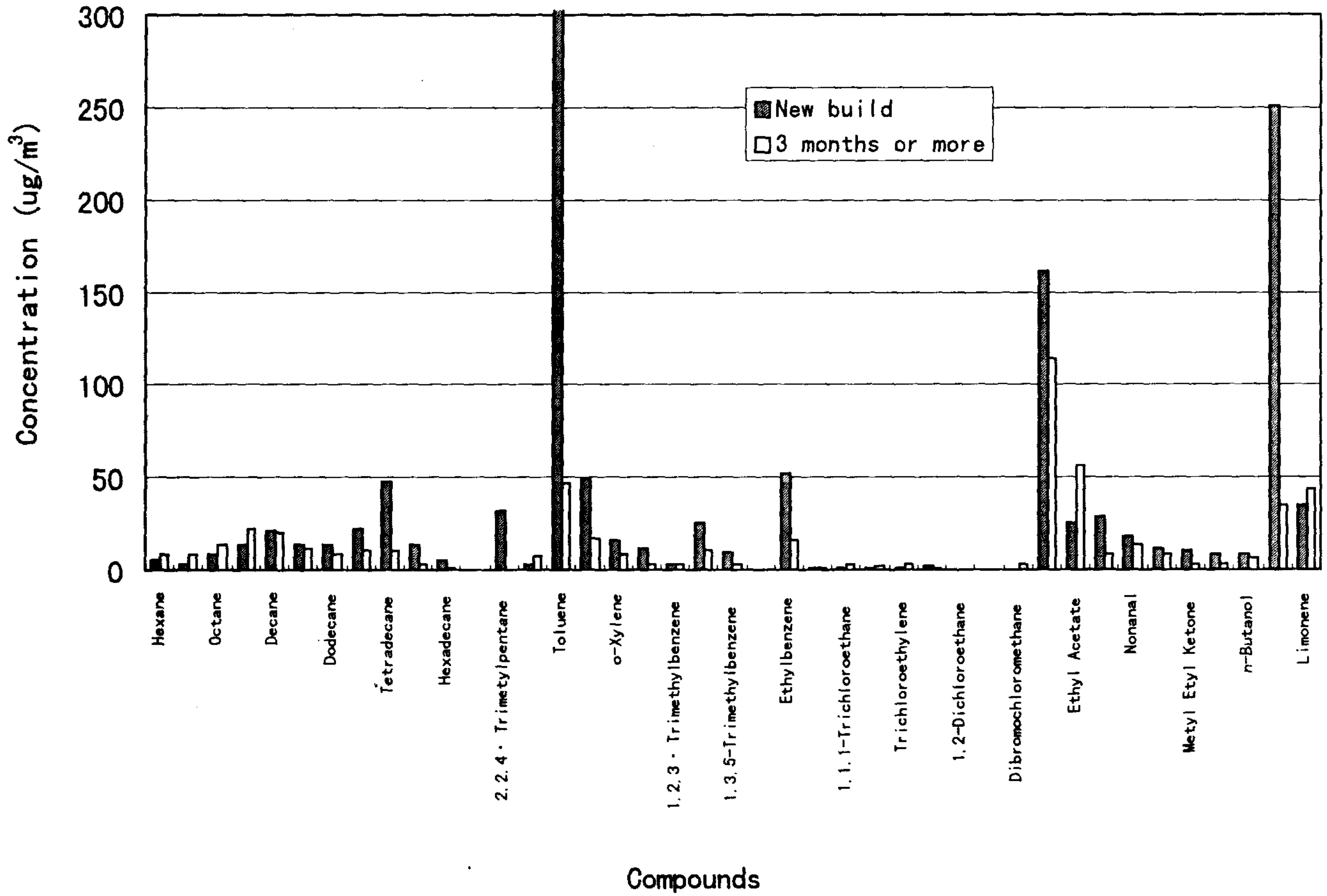

Fig. 6 Indoor air of new and old households

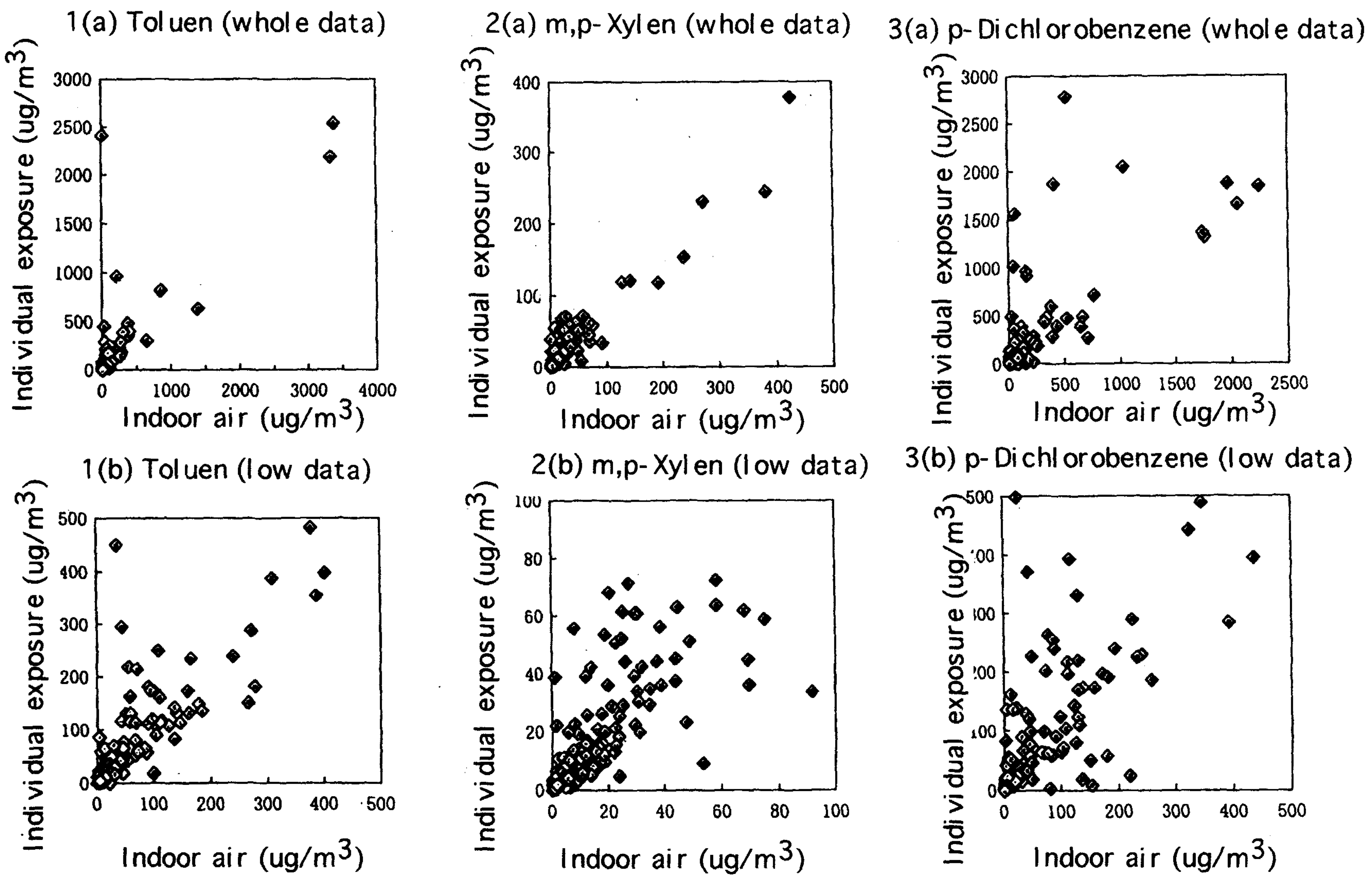

Fig. 7 Relatiomship between indoor air and individual exposure