Hedge A. and Erickson WA. (1999); Associations between sick building syndrome, indoor climate and office ergonomics, Proceedings of Indoor Air 99, Vol.1, 155~160

Jarke FH., Dravnieks A. and Gordon SM. (1981); Organic contaminants in indoor air and their relation to outdoor contaminants. ASHRAE Trans. 87(Part 1), 153~166

Popa M. and Ionut C. (1999); The assessment of housing conditions in relation with the respiratory status in children, Proceeding of Indoor Air 99, Vol.4, 501~506

Repace JL. (1982); Indoor air pollution, Environ. Internat., 8, 21-36.

Investigation of Air Pollution in Various Large-Scale Buildings and of Employees' Personal Exposure Level

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ABSTRACT

We investigated the condition of air pollution in various kinds of buildings such as university office, university library, barber shop and beauty parlor in university hospital, book store, department store, pachinko parlor, bowling alley and hotel. We also investigated the personal exposure level of employees at the above-mentioned buildings. The measured chemicals were 31 kinds of volatile organic compounds (VOCs), formaldehyde, acetaldehyde and nitrogen dioxide (NO_2). The chemicals were collected by a personal passive sampler. Generally speaking, ethyl acetate, toluene and decane showed high concentration (> 5 ppb). At bowling alley, 1,2,4-trimethylbenzene was found to be more than 150 ppb. At pachinko parlor and department store, methylethylketone was higher than other buildings. Bookstore showed highest concentration of toluene among all buildings investigated. As to aldehydes, the concentration of formaldehyde was between 10 and 55 ppb. Pachinko parlor showed the highest value. Acetaldehyde concentration was between 5 and 63 ppb. The highest was also given by pachinko parlor. NO_2 concentration was between 5 and 59 ppb. Among the buildings, department store and pachinko parlor gave higher values. The level of personal exposure generally had the same tendency with indoor air pollution level. The possible source of the characteristic chemicals at each building will be discussed.

INTRODUCTION

Recently, a big change in indoor air environment has been recognized. This new

problem is caused by high air tightness, high adiabatic and newly building material, and has been the cause of health problems. The resident in a newly-built home appealed for bodily bad condition and indisposition for this problem in around 1970. These symptoms are called Sick Building Syndrome and it has been paid attention. Afterwards, the symptom of the irregularity, and it is distinguished from a sick building syndrome and socially becomes a big problem. Approximately 80% of our life time is spent in an indoor air environment,[1] either in homes, work place etc. Especially, the indoor air quality is often worse than outdoor air and contains many pollutants. Jarke and co-workers[2] indicated that 118 chemicals were identified in the indoor air of new buildings, and the indoor pollutants arise probably from many parts, such as the carpeting, clothing furniture etc. Many researches on indoor air pollution[3] and the influence on health[4,5] have been performed. The investigations of air pollution in large-scale buildings to be open for public people such as university, department store and amusement facilities are not so many. However, it is necessary to investigate the indoor air quality of those buildings because many people may use them for the purpose of study, shopping and amusement etc. This study is aimed at grasping the realities of the conditions of the air environment of various large-scale buildings in Japan and of the chemical exposure of the employees.

METHOD

Studied Buildings

We investigated indoor and outdoor air quality at university office, university library, barber shop and beauty parlor in university hospital, book store, department store, pachinko parlor, bowling alley, hotel and museum in Japan. The sampling sites, the number of employees investigated and the characteristics of each building are listed in Table 1.

Collection and analysis of chemicals

The concentrations of the VOCs, aldehydes and NO_2 were measured. The collection of chemicals was carried out by a passive sampler. Passive samplers were used in all cases (Personal exposure, indoor air and outdoor air). To evaluate exposure level of workers to chemicals, the personal sampler was hooked on to a worker's breast. The samplers for collection of the chemicals were set up in each sampling site. After sampling, the VOCs and NO_2 samples were stored in a freezer and aldehyde samples were stored in a refrigerator. The analysis of VOCs is as

Table 1. Sampling site

Building	Site	Number of sampling places
University	Office	5
	Employees	10
	Library	5
	Employees	7
	Barber Shop	2
	Employees	2
	Beauty Parlor	2
	Employees	2
Book Store	1F	7
	Employees	5
Department Store	1F (Food Corner)	7
	Employees	5
	2F	6
	Employees	3
	6F	6
	Employees	3
	7F (Chinese Restaurant)	6
	Employees	5
Pachinko Parlor	1F	10
	Employees	12
Bowling Alley	1F	12
	Employees	5

For each buildings, outdoor air quality was also measured.

follows.[6] An activated charcoal (Pittsburgh PCB) in a sampling tube (Sibata, Japan) was moved to a test tube, 2 ml of carbon disulphide was added and then VOCs were extracted. The VOCs in extracted solution were analyzed by using a capillary gas chromatograph-mass spectrometer-apparatus (Hewlett Packard, USA) with auto sampler. The collection of aldehydes was carried out in a passive gas tube (Sibata, Japan) silica gel that is impregnated with 2,4-dinitrophenyl hydrazine. The aldehydes observed on the silica gel was extracted with the 3 ml acetonitril. The separation and determination were done by using HPLC apparatus (Shimadzu LC-10 AD, Japan).

The NO_2 that absorbs filter (Toyo Roshi, Japan) was extracted with a coloring solution. A coloring solution was prepared with a solution of sulfanilic acid, phosphoric acid and 0.1 wt% N-(1-naphthy) ethylenediamine dihydrochloride. NO_2 in the extracted solution was determined by using UV-VIS spectrophotometer (Shimadzu UV-2200A, Japan)

RESULTS

University office

As shown in Table 1, we performed the investigation at university office, university library, and barber shop and beauty parlor in university hospital. The 8-stories university was built 28 years ago. Table 2 shows the results of measurements of VOCs in university office (8 m x 38 m), and Table 3 shows those of aldehydes and NO_2.

Twenty-six kinds of VOCs were detected. Decane and 1,2,3-trimethylbenzene were in relatively high concentration (>10 ppb). Personal exposure level of university office workers to VOCs was less than 3 ppb during working time, whereas some VOCs such as toluene and p-dichlorobenzene gave higher value during non-working time suggesting that they may experience exposure at home.

The concentrations of NO_2 in indoor air during working time and of personal exposure were low (<20 ppb).

The concentrations of formaldehyde and acetaldehyde in indoor air during working time and of personal exposure were approximately 25 ppb and 6 ppb, respectively.

University library

Table 4 shows the three highest VOCs detected in university library and other settings. Aldehyde and NO_2 concentration in all sampling sites are shown in Table 4. Twenty-two kinds of VOCs were detected from university library. Except for decane, other VOCs during working time were in low concentration (<4 ppb) and were in similar concentrations as those of outdoor air. Exposure level of employees was in the same level as that of indoor air except for ethyl acetate. Toluene and p-dichlorobenzene showed high value during non-working time, suggesting that there were strong influence of living environment.

The concentration of NO_2 was less than 20 ppb in all situations.

Outdoor concentration of formaldehyde was approximately 10 ppb, whereas indoor concentration was 20-30 ppb. As to acetaldehyde, it was 2 ppb in outdoor air and ca. 10 ppb in indoor air and personal exposure.

Table 2. Concentration of VOCs in University Office

Compounds (ppb)	Working time	Non-working time	Employee (Working time)	Employee (Non-working time)
2,4-Dimethylpentane	0.89	0.41	0	0
MEK	0.94	0.91	0	0
Ethyl acetate	4.34	1.11	0.8	2.8
Chloroform	0.43	0	0.1	0
1,1,1-Trichloroethane	0.05	0.1	0.14	0.16
Carbon tetrachloride	0	0	0.23	0.18
Heptane	1.11	0.36	0.26	0.53
1-Butanol	1.17	0.6	0.27	0.65
1,2-Dichloroethane	0.03	0.02	0	0.09
Benzene	3.56	0.59	0.53	0.47
Trichloroethylene	0.19	0.03	0.07	0.07
1,2-Dichloropropane	0	0	0	0
MIBK	0.71	0.2	0.28	0.55
Octane	1.06	0.29	0.31	1.28
Toluene	6.5	2.85	2.36	10.55
Tetrachloroethylene	0.39	0.02	0.05	0.05
Acetic acid, butyl ester	0	0	0.15	1.10
Dibromochloromethane	0	0	0	0
Nonane	0.56	0.16	0.25	2.40
Ethylbenzene	3.36	1.64	2.38	2.05
m/p-Xylene	2.32	0.83	1.69	1.68
o-Xylene	2.32	1.11	1.19	1.49
Stylene	0.21	0.03	0	0
Alpha-pinene	0.22	0.03	0.23	3.22
Decane	23.34	0.59	2.73	7.27
1,3,5-Trimethylbenzene	0.38	0.2	0.35	1.15
1,2,4-Trimethylbenzene	0.85	0.5	0.98	2.75
Limonene	0.33	0.16	0.38	9.35
1,2,3-Trimethylbenzene	13.63	8.91	0.32	0.94
p-Dichlorobenzene	1.23	0.5	0.89	41.95
Undecane	0	0	2.32	6.75

Table 3. Concentrations of aldehydes and NO_2

Sampling Site	Formaldehyde (ppb)	Acetaldehyde (ppb)	NO_2 (ppb)
University office (W)	25.7	5.4	19.8
University office employee (W)	18.6	6.9	20.2
Library (W)	28.1	11.4	6.7
Library employee (W)	21.3	8.7	16.8
Barber shop (W)	32.6	16.9	9.8
Barber shop employee (W)	36.5	13.6	8.3
Beauty parlor (W)	27.0	7.3	8.9
Beauty parlor employee (W)	39.0	10.2	5.9
Book store, book corner (W)	40.5	20.5	7.8
Book store employee (W)	32.7	19.0	5.4
Department store 1F (W)	19.2	14.5	33.0
Department store employee (W)	20.7	9.5	ND
Chinese restaurant (W)	43.6	21.8	59.0
Pachinko parlor (W)	55.4	62.8	32.6
Pachinko parlor employee (W)	51.4	54.6	35.5
Bowling alley (W)	13.0	6.5	7.2
Bowling alley employee (W)	25.5	12.3	24.4

W: Working time, NW: Non-working time

Barber shop and beauty parlor in university hospital

In both barber shop and beauty parlor in university hospital, ethyl acetate, toluene and decane were detected in relatively high concentration (>10 ppb), whereas other VOCs were in the level of <5 ppb. Personal exposure level was dependent of indoor air quality, suggesting the influence of hairdressings.

The concentration of NO_2 in barber shop and beauty parlor was low (<15 ppb).

Compared to acetaldehyde (<15 ppb), formaldehyde concentration was relatively high. Indoor air concentration and personal exposure were both ca. 35 ppb.

Book store

We performed the investigation in 4-stories book store which was built 40 years ago

Table 4. Three most highest VOCs in various buildings

Sampling Site	The highest compounds (ppb)	Second highest compound (ppb)	Third highest compound (ppb)
University library (W)	Decane (3.32)	Ethyl acetate (3.32)	Undecane (2.04)
Library employee (W)	Decane (17.85)	Ethyl acetate (10.43)	Undecane (3.02)
Library employee (NW)	p-Dichlorobenzene (29.37)	Decane (11.55)	Toluene (10.06)
Barber shop (W)	Decane (23.10)	Toluene (22.08)	Limonene (3.85)
Barber shop employee (W)	Ethyl acetate (14.9)	Decane (13.87)	Toluene (12.14)
Barber shop employee (NW)	Decane (15.91)	Ethyl acetate (14.07)	Toluene (2.66)
Beauty parlor (W)	Decane (72.27)	Toluene (15.70)	p-Dichlorobenzene (11.21)
Beauty parlor employee (W)	Toluene (11.52)	Decane (9.82)	Ethyl acetate (5.41)
Beauty parlor employee (NW)	Alpha-pinene (16.20)	Decane (15.73)	Toluene (11.26)
Book store (W)	Toluene (81.82)	Undecane (12.43)	Decane (6.79)
Book store employee (W)	Toluene (99.03)	Undecane (20.20)	Decane (17.27)
Department store 1F (W)	Benzene (16.41)	Toluene (16.06)	MEK (11.12)
Department store employee (W)	Toluene (11.24)	Decane (10.62)	Ethyl acetate (8.45)
Pachinko parlor (W)	MEK (5.69)	Benzene (3.77)	Toluene (2.16)
Pachinko parlor employee (W)	Toluene (8.50)	MEK (7.39)	Benzene (5.56)
Bowling alley (W)	1,2,4-Trimethylbenzne (167.41)	1,3,5-Trimethylbenzene (49.17)	Undecane (31.77)
Bowling alley employee (W)	1,2,4-Trimethylbenzne (177.40)	1,3,5-Trimethylbenzene (56.07)	Undecane (38.03)

W: Working time, NW: Non-working time

with total floor area of 3900 m^2. Twenty-seven kinds of VOCs were detected as

shown in Table 2. Compared to other VOCs, toluene was detected in very high concentration (>80 ppb).

NO_2 concentration was 10-20 ppb in all measurements.

As to aldehydes, formaldehyde concentration was 30-40 ppb and was twice as high as that of acetaldehyde (10-20 ppb).

Department store

We measured air quality at a department store which is 7-stories building and with total floor area of 25,000 m^2. Different VOCs were detected in each floor. From 1st floor (food corner), 26 kinds of VOCs were found. Methylethylketone, benzene and toluene gave the value of >10 ppb during working time. In personal exposure, toluene and decane were in the level of >10 ppb during working time. Other VOCs were in lower concentrations than these two chemicals and most of them were in <5 ppb.

NO_2 concentration was 20-30 ppb which was the same level with that of outdoor air. Only the floor with Chinese restaurant gave 59 ppb.

Aldehyde concentration of indoor air was higher than that of outdoor air. Formaldehyde was in the range of 10-30 ppb and acetaldehyde was of 5-15 ppb. Chinese restaurant gave 44 ppb of formaldehyde and 22 ppb of acetaldehyde during working time.

Pachinko parlor

We measured air quality of a pachinko parlor (amusement facility) which has floor area of 450 m^2. The parlor was 50% full when we investigated (ca. 150 customers played). As to VOCs, compared to non-working time, methylethylketone, benzene and toluene were in relatively high concentration during working time. Personal exposure level was relatively low (<10 ppb).

NO_2 for indoor air and personal exposure was < 40 ppb.

Formaldehyde and acetaldehyde were in a similar concentration. Indoor air and personal exposure concentrations during working time were relatively high (50-60 ppb), which was much higher than that of non-working time and of outdoor air.

Bowling alley

We measured air quality of bowling alley which has floor area of 1000 m^2. Fifty-five people were on the floor when we measured. As to VOCs, concentrations

of benzene, toluene and xylene were all <5 ppb, whereas nonanoe, decane and undecane were in relatively high concentration (10-30 ppb) and especially 1,2,4-trimethylbenzene was found to be in very high concentration (>150 ppb). Personal exposure level was in a same trend with indoor air, and the level during working time was higher than that during non-working time.

NO_2 during working time, non-working time and of personal exposure were <10 ppb, <10ppb and 30 ppb, respectively.

As to aldehydes, formaldehyde was twice as high as acetaldehyde in all measurements. Personal exposure to these two aldehydes was twice as high as indoor air level, and 6 times as high as outdoor level.

Hotel

The results of hotel will be reported in a separate paper.

DISCUSSION

Sick Building Syndrome, the sickness related to indoor air pollution, has become a major social problem. Reports that have investigated the environment of large-scale buildings where many people go in and out and the health effect of the employees are quite a few. We have been investing indoor air quality of many large-scale buildings in Japan. This paper presents the results of university, book store, department store, and amusement facilities.

By using passive samplers, we were able to measure 31 kinds of VOCs, formaldehyde, acetaldehyde and NO_2. Depending on the nature of the buildings, the kind and concentration of VOCs were different. Table 4 lists three representative VOCs from each building which showed high concentration. Toluene in book store may come from printing ink of the books. 1,2,4-Trimethylbenzne of bowling alley was considered to be from wax on the floor.

Table 5 shows guideline values of selected VOCs in Japan. Of all buildings investigated, toluene in book store was the only one case which exceeded the guideline value (80-100 ppb vs. 70 ppb). The manager of the book store may need to have consideration for the ventilation.

As to formaldehyde and acetaldehyde, none of the buildings exceeded the guideline values (formaldehyde: 80 ppb, acetaldehyde: 180 ppb), suggesting that indoor air quality of all the buildings would be in good condition from the viewpoint of pollution by aldehydes.

Table 5. Guideline values of individual VOCs by Japanese Government

Compound	Guideline value
Formaldehyde	100 μg/m^3 (0.08 ppm)
Toluene	260 μg/m^3 (0.07 ppm)
Xylene	870 μg/m^3 (0.20 ppm)
p-Dichlorobenzene	240 μg/m^3 (0.04 ppm)
Ethylbenzene	3800 μg/m^3 (0.88 ppm)
Styrene	220 μg/m^3 (0.05 ppm)
Chlorpyrifos	1 μg/m^3 (0.07 ppb) For children: 0.1 μg/m^3 (0.007 ppb)
Di-n-butyl phthalate	220 μg/m^3 (0.02 ppm)
Tetradecan	330 μg/m^3 (0.04 ppm)
Di-(2-ethylhexyl) phthalate	120 μg/m^3 (7.6 ppb)
Diazinone	0.29 μg/m^3 (0.02 ppb)
Nonanal	41 μg/m^3 (7 ppb), interim value
Acetaldehyde	300 μg/m^3 (180 ppb), WHO
Fenobucarb	33 μg/m^3 (3.8 ppb)
Total VOC	400 μg/m^3 (106 ppb), advisable value

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As to NO_2, we have Environmental Air Quality Standard in Japan (40-60ppb). Almost all of the buildings investigated showed NO_2 which was less than standard. The NO_2 concentration of the Chinese restaurant in department store was relatively high (59 ppb). This was considered to be the influence of cooking.

We have also measured physical parameters such as temperature, relative humidity, noise, wind velocity, illumination and concentration of particulate matter in the buildings and found that those parameters were generally at an appropriate level except for pachinko parlor (data not shown). At pachinko parlor, particulate matter sometimes exceeded standard level, probably due to smoking by customers, and noise level was relatively high, due to the nature of this play.

Overall, air quality in various large-scale buildings and employees' personal exposure level were relatively in good condition. However, it is necessary to note that there were some exceptional cases such as toluene in book store, NO_2 in restaurant and noise in pachinko parlor. Considering the health effects of employees and guests, the necessary technological measures for the decrease of the chemical concentration and

physical parameter will be required.

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REFERENCES

1. Repace, J.L. Environ. Internat. **1982**, *8*, 21-36.
2. Jarke, F.H.; Dravnieks, A., ; Gordon, S.M. ASHRAE Trans. **1981**, *87* (Part 1), 153-166.
3. Arashidani, K.; Hori, H.; Ishidao, T.; Yoshikawa, M.; Ishimatsu, S.; Kawamoto, T.; Kodama, Y. Proceeding of Indoor Air 99 **1999**, *2*, 483-488.
4. Hedge, A.; Erickson, W.A. Proceedings of Indoor Air 99 **1999**, *1*, 155-160.
5. Popa, M.; Ionut, C. Proceedings of Indoor Air 99 **1999**, *4*, 501-506.
6. Yamaguchi, T.; Nakajima, D.; Ezoe, Y.; Fujimaki, H.; Shimada, Y.; Kozawa, K.; Arashidani, K.; Goto, S. J. UOEH **2006**, *28*, 13-27.

KEY WORDS

Volatile organic compounds
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Indoor air pollution
Large-scale buildings
Personal exposure

Investigation of Air Pollution in Hotel and of Employees' Personal Exposure Level

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ABSTRACT

We investigated the condition of air pollution in three hotels and of the personal exposure level of employees in Japan. The survey was performed in August 2005 in Kitakyushu city and Akita city. The measured chemicals were volatile organic compounds (VOCs), aldehydes and NO_2 and the chemicals were collected by a personal passive sampler. The detected VOCs were 10~16 kinds. Toluene, decane and limonene were in relatively high concentration level compared to other VOCs. Concentration of many VOCs was below 5 ppb. The concentration of formaldehyde in indoor air of three hotels were almost less than 20 ppb, below the indoor air quality guideline (80ppb) of the Ministry of Health, Labour and Welfare, Japan. The concentration of acetaldehyde was lower than that of formaldehyde. The NO_2 concentrations were almost low values with below 20ppb.

INTRODUCTION

It has been indicated that the chemicals such as VOCs and formaldehyde, etc in indoor air are strongly associated with both chemical sensitivity and sick building syndrome[1-5].

Indoor air pollution is caused by complex mixtures of pollutants which are directly released into indoor air from various sources[6-9]. The main sources are emission from building materials, household goods, tobacco smoke and combustion gases from cooking apparatus and heater.

Organic gases and vapors draw particular interest because these chemicals are found

in nearly all buildings with comparatively low concentrations and because these chemicals are thought to be related to health problems caused by indoor air pollution[10-12]. For example, formaldehyde emitted from adhesives used for the plywood, paneling and wallpaper, and furniture could cause sick house syndrome.

At present, it is well known that some of VOCs for some people could cause the eye and respiratory tract irritation[13], headache and dizziness, and that formaldehyde could cause the eye, nose and throat irritation[14,15].

Many researches regarding indoor pollution have been carried out to measure VOCs and aldehydes in dwelling atmosphere[16-18]. However, an environmental investigation in the building that many public people use is a few. This is important because a lot of people including employees may spend most of time of a day in the building[19,20].

The purpose of the present study was to evaluate the condition in indoor air of three hotels in Japan and of personal exposure of the employees.

METHOD

Studied hotel

The investigated three hotels (A, B and C) are of popular type. Those were constructed 4, 15 and 8 years ago, respectively. The sampling locations were front, guest room, restaurant, office, and lobby.

The number of employees to investigate the personal exposure were 3～10 persons per each hotel. The investigation of personal exposure was done in hotels A and B in Kitakyushu city, Japan, but it was not done in hotel C in Akita city.

Collection and analysis of chemicals

The VOCs, aldehydes and NO_2 were collected by using passive sampler and then determined by using chemical analysis.

The chemicals in indoor and outdoor air were collected during 24 hours. The determination of personal exposure was carried out during working-period. The personal sampler was hooked on to an employee's breast.

After sampling, the VOCs and NO_2 samples were stored in a freezer and aldehyde samplers were stored in a refrigerator until analysis.

The analysis of VOCs collected on activated charcoal cartridge (Sigma-Aldrich) was as follows. The cartridge was moved to a test tube, 1 ml of carbon disulphide was added and then VOCs were extracted. The VOCs in extracted solution were analyzed by using a capillary gas chromatograph-mass spectrometer –apparatus (Hewlett Packard,

USA) with auto sampler.

The aldehydes were collected by a silica gel tube containing 2,4-dinitrophenylhydrazine, extracted by 3 ml acetonitril and were determined by using HPLC (Shimadzu LC-10 AD, Japan).

The NO_2 was collected in a cellulose filter badge sampler (Tokyo Roshi Kaisha, Ltd, Japan) that impregnated a triethanolamione. The NO_2 absorbed on filter was extracted with a mixture solution of sulfanilic acid, phosphoric acid and 0.1 wt% N-(1-naphthy) ethylenediamine dihydrochloride. The NO_2 in the extracted solution was determined by using UV-VIS spectrophotometer (Shimadzu UV-2200A, Japan).

RESULTS

VOCs concentration

The VOCs detected from three hotels were from 10 to 16.

The concentrations except for decane and limonene in hotel A were below 5 ppb. The concentrations of decane and limonene in maintenance room showed the level of 20 -25 ppb (Figure 1). The exposure level of the employee of hotel A was obtained at the same level as the concentration of working place.

The VOCs concentrations except for decane in hotel B were of below 5 ppb. The decane concentration was of 5 ppb or more in a lot of places. Lobby and office showed the level of 10 ppb.

The decane concentrations of hotel C were also in the level as high as hotels A and B. The characteristic fact of hotel C was that toluene concentration was relatively high (>30 ppb).

Aldehydes concentration

The formaldehyde (HCHO) and acetaldehyde (CH_3CHO) from all rooms of three hotels were detected. The HCHO concentrations in three hotels were obtained in higher values compared with CH_3CHO concentration. The HCHO concentrations except for guest room and maintenance room of hotel A were at the level less than 20 ppb, but HCHO concentrations in guest room and maintenance room were of a comparatively high level from 40 ppb to 80 ppb (Figure 2). The HCHO and CH_3CHO concentrations of hotels B and C were less than 20 ppb and 10 ppb ,respectively.

The exposure level of the employees of hotels A and B was dependent upon concentration of the workplace.

NO_2 concentration

As shown in Table 1, NO_2 concentration of all places except for Chinese restaurant of hotel B were below 15 ppb. The NO_2 concentration of Chinese restaurant was obtained in comparatively high level of 40 ppb.

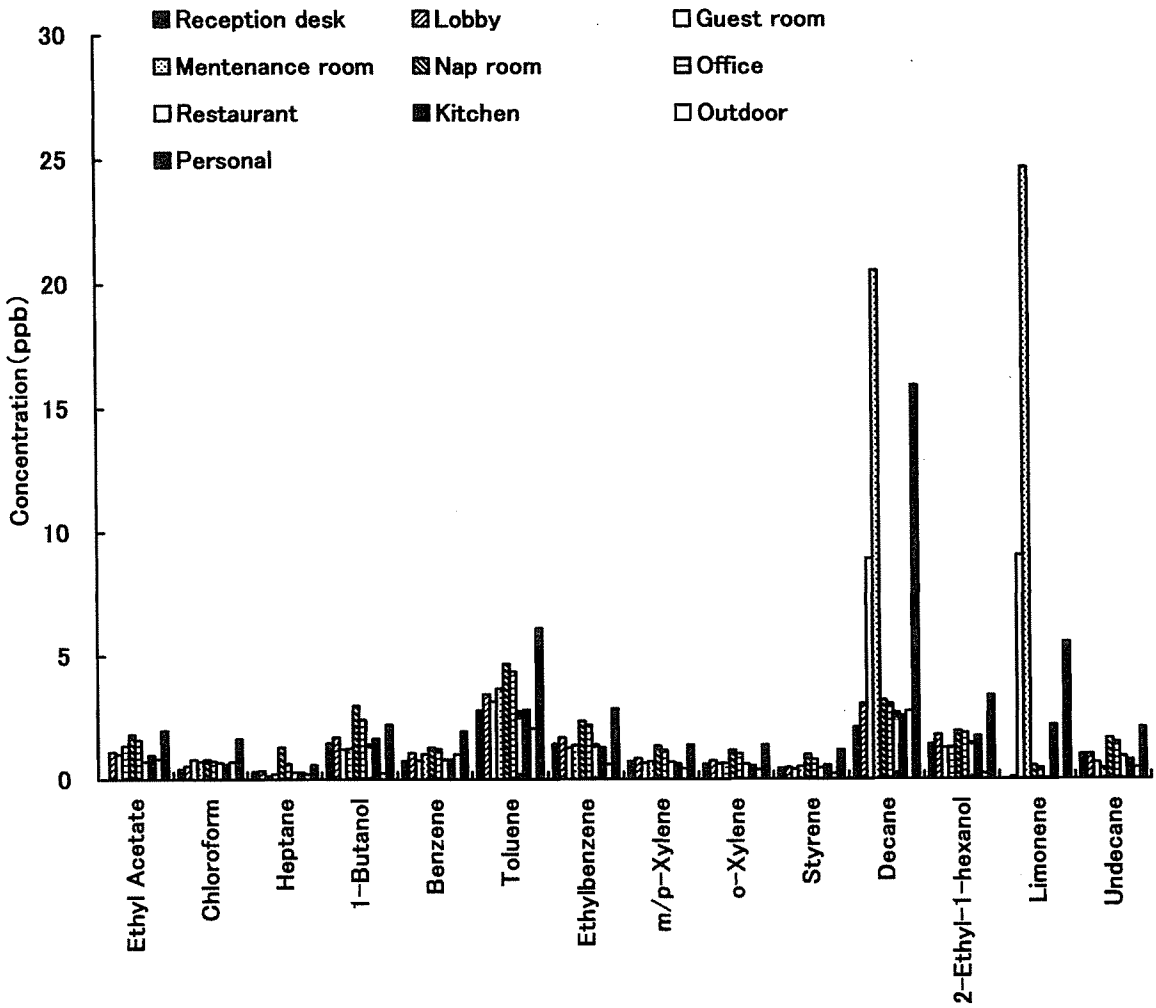

Figure 1 VOCs concentration in indoor air of hotel A

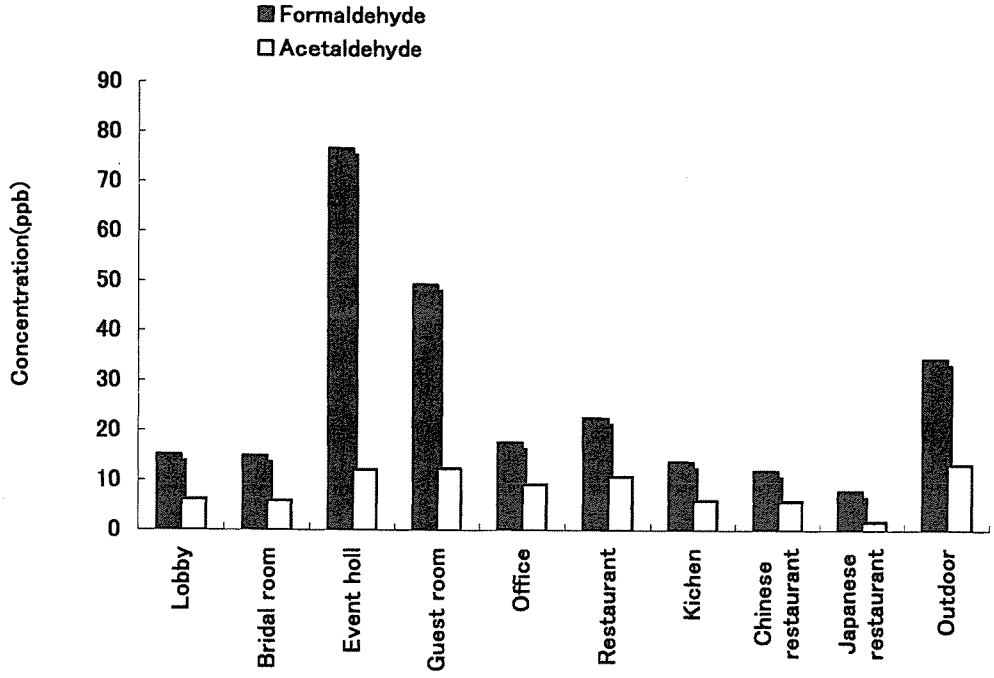

Figure 2 Acetaldehydes concentration of hotel A

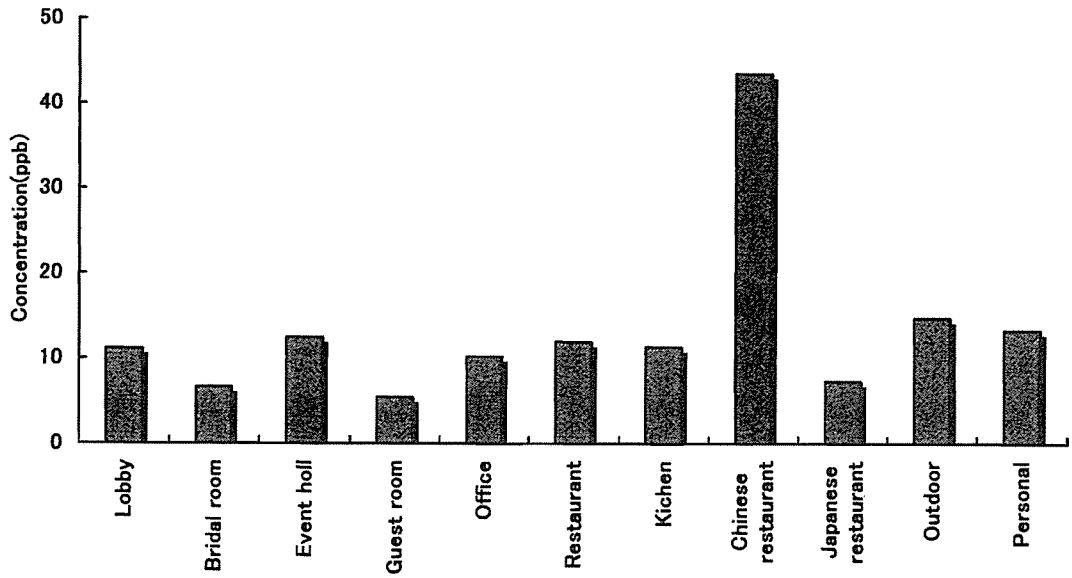

Figure 3 NO_2concentration of hotel B

DISCUSSION

Sick building syndrome related to indoor pollution has instituted a major social problem. The present study has investigated the environmental condition of typical hotel where many persons go in and out, and employees are working.

From ten to sixteen kinds of VOCs were detected from three hotels. 1-Butanol, ethyl benzene, 2-ethyl-1-hexanol, limonene and toluene were thought to be generated by the building materials in indoor. Decane, limonene and toluene were recognized as being clearly high value. It is thought that toluene, trimethylbenzene, limonene and decane are generated by the glue, aromatic, cleaner and wax.

The concentrations of toluene, xylene, ethyl benzene and styrene of indoor in hotels were level less than Guideline Ministry of Health, Labor and Welfare of Japan of pollutant in indoor air.

Though 3-5 kinds of aldehydes were obtained, we determined formaldehyde and acetaldehyde because these two aldehydes were of special interest from the viewpoint of health effect.

Formaldehyde concentration was all in higher value than acetaldehyde concentration and than that of outdoor air. The formaldehyde concentrations in the indoor of three hotels were at the level less than the value of WHO guideline or of guideline of the Ministry of Health, Labour and Welfare, Japan (80 ppb). It is thought that the source of formaldehyde will be the glue of building materials.

The NO_2 concentrations in the indoor air of three hotels were at the level less than Environmental Air Quality Standard in Japan (40～60 ppb).

The personal exposure level of employees was low and was equal to the level of the concentration in indoor air of office.

Overall, VOCs, aldehydes and NO_2 in three hotels investigated were in generally low level and less than various environmental standards.

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REFERENCES

1. Hedge, A.; Erickson, W.A. Proceedings of Indoor Air 99 **1999**, *1*, 155-160.

2. Niven, R.M.; Fletcher, A.M.; Pickering, C.A.; Faraghen, E.B.; Potter I.N.; Booth W.B.; Jones T.J.; Potter P.D. Occup Environ Met **2002**, *57*, 627-634.
3. Molhave, L.; Bach, B.; Pedersen, O.F. Environment International **1986**, *12*,165-167.
4. Apter, A.; Bracker, A.; Hodgson, M.; Sidman, J.; Leung, W.Y. Allergy and Clinical Immunology **1994**, *94*, 277-288.
5. Hodgson, M. Occupational Medicine, State of Art Reviews **1995**, *10*, 167-175.
6. Wolkoff, B. Indoor Air (Supl. 3) **1995**, 1-73.
7. Joint Research Center Institute for the Environment; Formaldehyde emissions from wood based materials; guideline for the establishment of steady state concentration in test chamber, Report No.2 of Enviroment and Quality of Life, EUR12196 EN **1996**.
8. Brown, S.K. Indoor Air **1999**, *9*, 209-215.
9. Brown, S.K. PhD thesis, RMIT University, Melbourne, Australia **2000**.
10. Wieslander, G.; Norback, D.; Bjornsson, E.,; Janson, C.; Borman, G. Intl Arch Occup Environ Health **1997**, *69*, 115-124.
11. Anderson, E.L.; Albert, R.E. Risk assessment and indoor air quality, Lewuis Publish 1999, 22-24.
12. Molhave, L. Proceedings of Healthy Buildings **2000**, *1*, 3-14.
13. Popa, M.; Ionut, C. Proceeding of Indoor Air 99 **1999**, *4*, 501-506.
14. Krzyzanewski, M.; Quackenboss, J.J.; Lebowitz, M.D. Environ Res **1990**, *52*, 117-125.
15. Bernstein, R.S.; Stayner, L.T.; Elliott, L.T.; Kimbrough, R.; Falk, H.; Blade, L. Am Ind Hyg Assoc J. **1984**, *45*, 778-785.
16. Arashidani, K.; Hori, H.; Ishidao, T.; Yoshikawa, M.; Ishimatsu, S.; Kawamoto, T.; Kodama, Y. Proceeding of Indoor Air 99 **1999**, *2*, 483-488.
17. Otson, R.; Fellin, P.; Tran, Q. Atmos Envir **1994**, *28*, 3563-3569.
18. Having, H.; Dahl, R.; Korsgard, J.; Linde, S.A. Indoor Air **1992**, *2*, 121-126.
19. Repace, T.L. Environ Internat **1982**, *8*, 21-36.
20. National Reserch Council . Indoor pollution, National Academy Press, Washington, D.C. **1981**

KEY WORDS

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