Field measurement of formaldehyde in government offices

Osawa Haruki[1*], Miki Yasuhiro[2*], Bogaki Kazuaki[3*] and Sumida Hironori[4*]

[1] Housing Department, National Institute for Land and Infrastructure Management, MLIT (Ministry of Land, Infrastructure and Transport), Japan
[2] National Institute for Land and Infrastructure Management, MLIT, Japan
[3] Building Research Institute, Japan.
[4] Facility Management & Maintenance Planning Office, Government Buildings Department, MLIT, Japan

ABSTRACT
This paper discusses research conducted to determine the status of indoor air chemical pollution caused by formaldehyde in government offices in 2001. This research involved measurements of formaldehyde concentration and questionnaires on the office rooms in approximately 300 buildings. The following conclusions were drawn from this study.

(1) The factors such as the use and the conditions of usage of buildings affect formaldehyde concentration more significantly than the size of buildings and rooms.
(2) The year of construction and the number of stories can be correlated to the concentration to some extent. This is a topic for further study in the future.

INDEX TERMS
Indoor air quality, Field measurement, Formaldehyde, Government offices.

INTRODUCTION
Public awareness is increasing regarding the effect of air quality in houses and non-residential buildings on health and measures against those effects. Accordingly, the regulations on indoor air quality of all buildings were incorporated into the Building Standard Law (revised in July 2002). However, quantitative data on the actual air environment are still insufficient because of complicated procedures of survey and measurements as well as technical and economical bottlenecks of analysis, though such data are indispensable for developing rational measures. In this situation it remains difficult to establish appropriate measures against poor indoor air quality. Therefore field measurements of indoor air environment and summarization of the results are urgently needed.

With this background, the present study was made on the basis of measurements of formaldehyde in 300 government offices all over the country and survey results through questionnaires. The purposes were to establish the guidelines for maintenance and improvement of existing buildings, to determine the factors affecting air environment, and to compile basic data for development of countermeasures. Surveys through questionnaires dealt with the effects of space utilization, interior design, and facility administration on formation of indoor air quality by analyzing the information obtained from staff and facility administrators working in facilities along with data of measured formaldehyde concentration.

OUTLINE OF THE SURVEY
Survey method
The Facility Management & Maintenance Planning Office (hereinafter referred to as “FMMP office”) of the MLIT distributed, via the Regional Bureaus, the passive measuring instrument

(Photo 1) together with the questionnaire, requesting measurement of the formaldehyde concentration and survey through questionnaires. The survey period was set from July to August 2001, taking into account the cooling period. The measuring instrument was a vapor diffusion type (passive without mechanical suction). This was set in the middle of a space for a certain period (basically 24 hours) to adsorb the chemical substances. After measurement, the instrument was immediately sent to the specialized laboratory for precision analysis of adsorbed substances. The FMMP office collected questionnaire sheets, checking their consistency, etc.

Buildings under survey

Considering the regional characteristics, the use of buildings, and their actual age, about 300 buildings were chosen from government offices all over the country. Their major attributes are shown in Table 1. Questionnaires were directed to the staff working in these buildings and building administrators. Note that all of these buildings were designed and constructed according to various standard specifications, effective as of the time construction, of the FMMP office. They comply with a certain standard in terms of thermal insulation and air-tightness of buildings, ventilation and air conditioning (heating/cooling).

The questionnaire consists of two parts; the blanket questionnaire concerning the facility as a whole and the forms "for each accommodation" concerning information of each room(temperature and humidity, usage of ventilation system, type of finish, time of renovation, smoking status etc.) For the formaldehyde concentration (hereinafter called the "concentration"), the number of measurement points was increased according to the size of buildings and rooms. Measurement was also made on the outdoor air temperature for large size buildings.

Photo 1. Passive measuring instrument used for the survey

Table 1. Main attributes and classification of the buildings surveyed

Item	Main attributes and classification
Region (Regional Bureau)	Hokkaido (186), Tohoku (173), Tsukuba (158), Kanto (917), Tokyo (42), Hokuriku (157), Chubu (268), Kinki (409), Chugoku (161), Shikoku (133), Kyushu (406), Okinawa (34)
Year of construction	From 1964 to 2000
Facilities of ministries and agencies	Administration, research and training facilities of twelve ministries and agencies
Size	Small (less than 2000 m^2) Medium (2000 m^2 or more but less than 5000 m^2) Large (5000 m^2 or more)
Use of building	Ordinary office, education, training, testing
Use of room	Ordinary office, executive room, conference, lounge

RESULTS OF SURVEY ON BUILDING SPECIFICATIONS

Frequency distribution of concentration

In order to grasp the concentration relative to the guideline of 0.08 ppm of the Health, Labor and Welfare Ministry, the national frequency distribution of concentration measurements (about 3000 measurements) was compiled for each room (Figure 1).

The mean concentration was 0.03 ppm and the ratio of values exceeding the guideline was 1.5%. Most of data fell within a range from 0.02 to 0.04 ppm, but the frequency of exceeding the guideline was slightly higher in the conference room.

To view the tendency more specifically, the ratio was determined for each use from data that exceeded the guideline (Figure 2). It is known that, among rooms where the guideline was exceeded, the conference room accounts for about one half (about 49%).

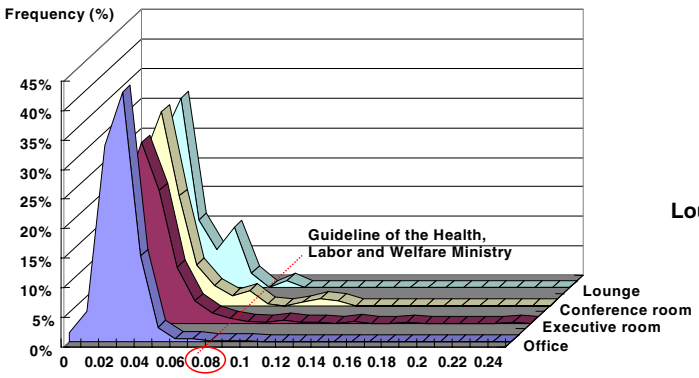

Figure 1. Formaldehyde concentration distribution (by the use of room/nationwide statistics)

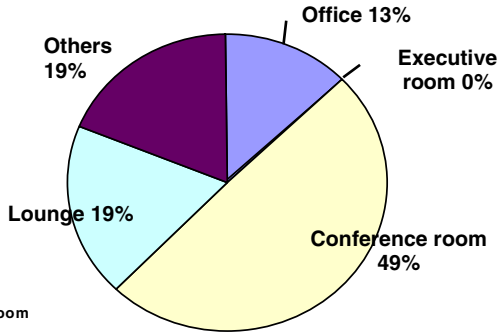

Figure 2. Ratio of rooms where the guideline was exceeded, by the use

Relationship with the region of construction

The mean concentration by region of construction[*1] is shown in Figure 3. The mean value was highest at 0.04 ppm in the Chubu District and lowest at about 0.02 ppm in Tsukuba and the head office in Tokyo. Such variance is considered due to effects of the age of buildings described below.

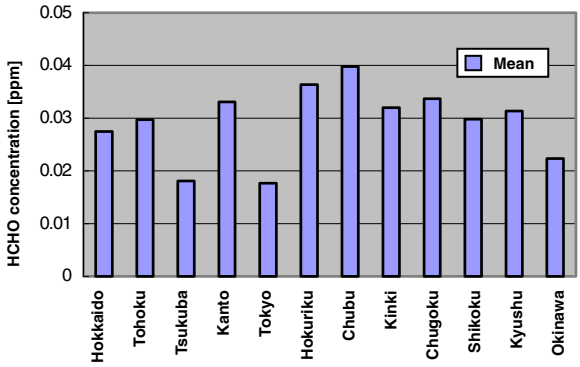

Figure 3. Concentration distribution by the region of construction

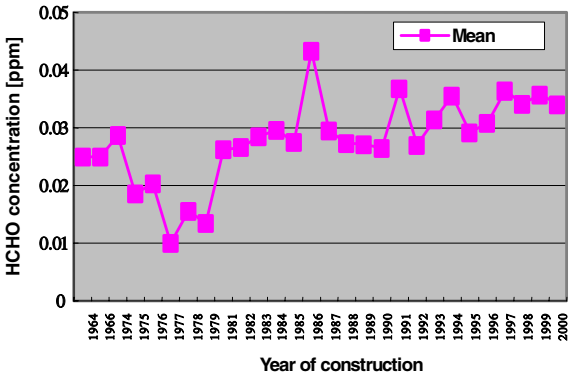

Figure 4. Concentration distribution by the year of construction

Relationship with the year of construction

The mean concentration by the year of construction is shown in Figure 4. The mean value was the lowest in buildings constructed around 1980. As a whole, the concentration rose slightly in newer buildings. Further review is necessary because it is necessary to take into account repairs and renovation.

Relationship with the number of stories in buildings

As a whole, the concentration is lower in higher stories and higher in lower stories. The first floor has lower concentration than the second floor probably because of air inflow.

Relationship with the use of buildings and rooms

The mean concentration by the use of buildings is shown in Figure 5. The buildings for education and training showed the highest value, followed by ordinary buildings. The buildings for testing and research showed the lowest value. For reference, the mean temperature of the buildings from the questionnaire is also shown. The temperature may affect the concentration because the difference among temperature is similar to the difference among the use of buildings. On the other hand, it is considered that buildings for testing and research must maintain a clean air environment as one of the grounds of low concentration. In this case, both temperature and use of buildings are considered to affect the concentration.

The mean concentration by the use of rooms is shown in Figure 6. The conference room

showed the highest value, followed by the executive room, rounge, and office. The mean temperature of the rooms from the questionnaire is also shown like Figure 5. Although emission rate increases by rise in temperature, the concentration is affected by the use of the room. In the case of executive room, the higher value may be attributed to lager emission areas of furniture. The mean values by ministries and agencies, that are data related to the uses, as shown in Figure 7, varies greatly from about 0.025 ppm to 0.04 ppm. This is considered due to differences in the office work pattern and in access of visitors.

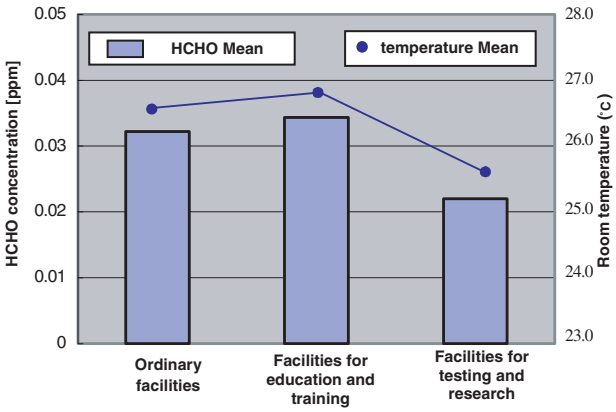

Figure 5. Concentration distribution by the use of buildings and by the room temperature (from the questionnaires)

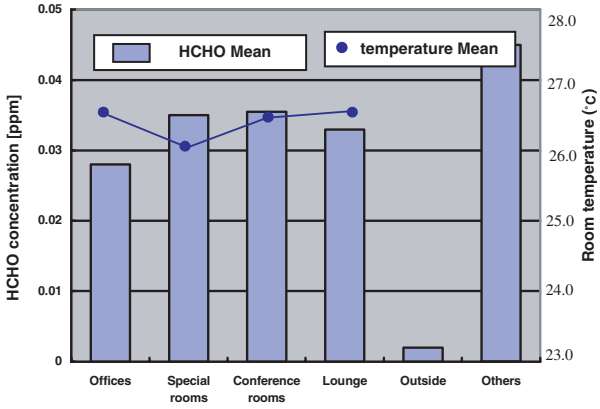

Figure 6. Concentration distribution by the use of rooms and by the room temperature (from the questionnaires)

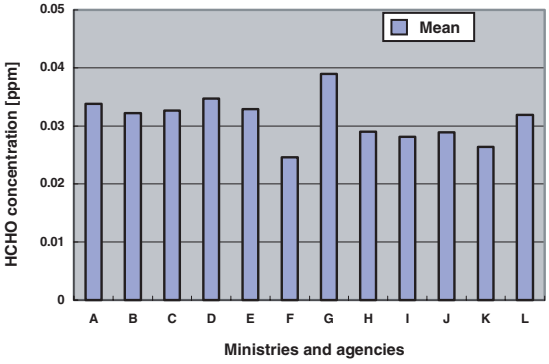

Figure 7. Concentration distribution for ministries and agencies

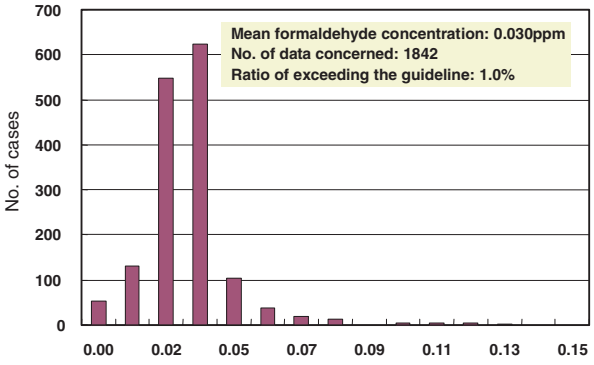

Figure 8. Formaldehyde concentration distribution (from the questionnaires)

SURVEY RESULTS OF INDOOR ENVIRONMENT AND USE CONDITION, AND DISCUSSIONS

Formaldehyde concentration frequency distribution

Figure 8 shows the frequency distribution of concentration measurement data (1857 data sets) used in the analyses discussed below, in addition to the results from questionnaires (a part of measured data referred to in previous sections, which corresponds to the effective responses for the questionnaire). The mean value was 0.0297 ppm, and the ratio of values exceeding the guideline of 0.08 ppm of the Health, Labor and Welfare Ministry was 1%. The distribution characteristic and absolute values were almost the same as Figure 1.

Room temperature and formaldehyde concentration

Figure 9 shows the relationship between formaldehyde concentration and room temperature. Generally, generation of formaldehyde is strongly dependent on the temperature. In houses using much wooden material, the equilibrium concentration is usually expressed by the exponential function of the temperature with a base of 1.09[*2]. However, no significant correlation could be found with the temperature in buildings surveyed in the present study.

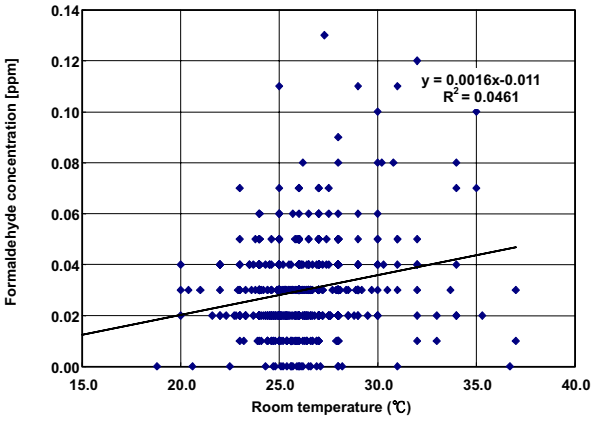

Figure 9. Relationship between concentration and room temperature

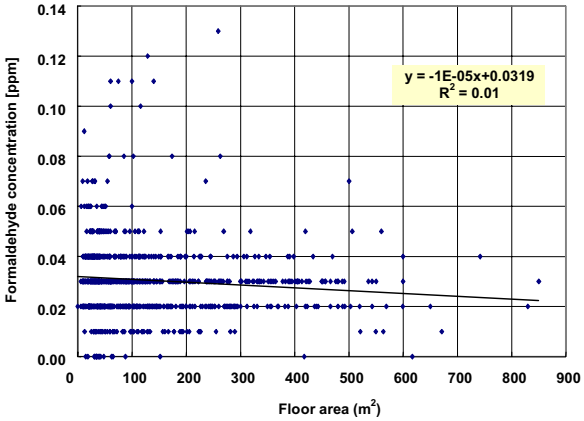

Figure 10. Relationship between concentration and floor area (size) of rooms measured

Humidity and formaldehyde concentration

It is generally assumed that the humidity has a close relationship with emission of formaldehyde. However, this survey did not indicate such a tendency and it may be concluded that such correlation does not exist.

Floor area and formaldehyde concentration

Figure 10 hows the relationship between concentration and floor area of the room under survey. When the room area is relatively small as in the case of dwellings, it is considered to be an important index because it governs the ratio between the indoor air volume and the surface area of materials, which are sources of formaldehyde. In this survey, however, only a minor inverse correlation was observed.

Purchase of furniture and formaldehyde concentration

Surveys were also conducted regarding whether or not furniture had been purchased or built-in. The mean concentration value in 406 rooms where there was purchased furniture was 0.0291 ppm, which was lower than 0.0317 ppm in 422 rooms where there was no purchased furniture. Among these, 77 rooms where the furniture had been purchased within one year had an even lower concentration of 0.0257 ppm. Furniture in government offices is mainly book storerooms, desks, chairs, and drawing-room suites for the office space. The lower concentration may probably be attributed to the fact that wooden materials, which are hazardous sources, were used not as much.

Smoking and formaldehyde concentration

Smoking is also an important source of formaldehyde. However, compared with the mean of 0.0307 ppm for 662 rooms where “smoking was not allowed”, that of 163 rooms where people smoked less than 100 cigarettes and that of 22 rooms where people smoked 100 cigarettes or more remained 0.0302 ppm and 0.02 ppm respectively. Ventilation and other appropriate measures might have been taken, so that no additional measures are necessary concerning formaldehyde.

Interior specifications and formaldehyde concentration

Concerning flooring, the mat (“tatami”) and other floorings showed slightly higher concentration, but PVC materials showed a lower concentration. The concentration of carpets widely used was slightly higher, but the difference was not significant.

As regards the wall, fabric and wooden finishes showed clearly higher concentrations than paint finish.

The ceiling materials of the buildings surveyed were mostly boards, so that no specific findings could be obtained on factors requiring countermeasures.

The type of interior finish is closely connected with the use of the room. Since more frequent provision of wooden furniture in the executive room can be expected to have an

impact, further review must be made to determine the factors (such as the use of rooms) that affect the relationship between concentration and interior finish.
The questionnaire also covered the question on whether or not the room had been renovated. As compared to the mean concentration value of 0.031 ppm of 734 rooms that had not been renovated, that of 32 rooms that had been renovated within one year was 0.0275 ppm while that of 69 rooms that had been renovated more than a year previously was 0.0253 ppm. Renovation, though not specifically intended for improvement of air quality, appeared to be effective in reducing the concentration of formaldehyde.

CONCLUSIONS

In government offices with structures and equipment designed by standard specification , field measurements were made of the formaldehyde concentrations, actual room usage, and behavior of occupants. The following findings were obtained on the broad overview of indoor air environment (formaldehyde concentration) and status of generation of this chemical substance:

(1) The non-structural factors, such as the use and conditions of usage of buildings and rooms have a greater effect on the concentration of formaldehyde than the structural factors such as the size of buildings and rooms.
(2) The year of construction and the number of stories can be correlated to the concentration to some extent, but probable causes are not yet known and should be a subject of the future study.
(3) In the future, a more detailed study must be made by narrowing down types of construction to be surveyed. In addition, it may be necessary to examine more general trends in buildings other than government offices.

[Note]
*1 According to the classification of the Regional Bureaus, MLIT
*2 Referred to as the Inoue's Equation (Reference 5)

ACKNOWLEDGMENTS

This survey was conducted jointly by the National Institute for Land and Infrastructure Management, Building Research Institute, and the Facility Management & Maintenance Planning Office of the Secretariat of the Ministry of Land, Infrastructure and Transport under cooperation from the Central Government Offices Building Maintenance Liaison Conference.

REFERENCES

1.Hori M., et al. Concentrations of Volatile Organic Compounds and Formaldehyde in Office Buildings, *14th Conference for Air Purification and Contamination Control,* pp.165-168, 1996
2.Ushiyama, et al. Field Study on the Perceived Indoor Air Quality in Newly Built Offices, *Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan,* pp.807-808, 1995
3.Fujii, et al. Indoor Air Quality in Office Buildings, *Journal of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan,* Vol. 72-1 (1998-1), pp.47-60
4.Infrastructure Development Council of MILT. The Primary Report on the Architectural Policy for Addressing New Issues in the 21st Century including Measures for the Aged Society, Environmental Measures, and Reconstruction of Cities, 30 January, 2002
5.Inoue, et al. Correlation between Formaldehyde Emissions Measured by Desiccator Method and Formaldehyde Concentrations in Air, *Wood Industry,* Vol.45-7, pp.313-319
6.Osawa, et al. Present Status of the Indoor Air Chemical Pollution in Japanese Houses Based on the Nationwide Field Survey in 2000, *J. Environ. Eng., AIJ,* No.565, pp.65-71., 2003