

THE INVESTIGATIONS ON IAQ AND SUBJECTIVE EVALUATIONS OF OCCUPANTS
FOR INDOOR ENVIRONMENTS IN JAPANESE OFFICE BUILDINGS

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Abstract

The investigations on IAQ and the subjective evaluations of the occupants for the indoor environments were conducted in 70 Japanese office buildings during the summer in 1986. All of the investigated buildings had air-conditioning systems though some of them were not central systems. All buildings but one in Sapporo operated the systems on the day of investigation. The findings are that 1) some difference exists between IAQ in specially designated buildings in the Law and that in the buildings without designation : 2) the occupants in some office buildings respond similar health complaints to the sick building syndrome as defined by WHO : 3) there are good correspondences between the occupant's evaluations for the indoor environments and the measured data of the environmental factors.

Introduction

In Japan we have the Law for Maintenance of Sanitation in Buildings. In this Law IAQ standards in specially designated buildings, having a total area of not less than 3000 m² and intended for use for offices, entertainment facilities, department stores, libraries, museums and so on, are in acted(1).

We made the investigations on maintenance and management of sanitation in about 150 office buildings of 4 cities located in various parts of Japan.

This study aims to clarify, if any, the difference of IAQ between in specially designated buildings and in the buildings without designations, to find whether the sick building syndrome exists in Japan and to specify the human response of the occupants to indoor environments. In this paper the results of the investigations in Tokyo and Sapporo are presented.

Methods of investigations

Office buildings investigated

70 office buildings in Tokyo and Sapporo were investigated. They had air conditioning systems though some of them were not central ones. All of buildings except one in Sapporo operated the systems on the day of investigation.

We divided these buildings into 3 groups; group A was specially designated buildings in the Law, group B was those having a total area less than 3000 m² and group C was those having a total area not less than 3000 m², where the total area of sections intended for applications other than the applications provided in the Law exceeded 10 % of the total area of sections intended for the applications. The latter 2 groups were without designations in the Law.

The number of buildings in each group was 24, 24 and 22 respectively.

Methods of environmental measurements

Measured factors were temperature, relative humidity(RH), air flow, concentrations of carbon monoxide(CO) and carbon dioxide(CO₂), amounts of suspended particulate matters(SPM) and of settle plate counts of bacteria and fungi, noise level. These factors were examined at the height of 120 cm above the floor and additional measurements at 10 cm were done for temperature.

All factors except bacteria, fungi and noise level were inspected three times, at mid-morning, early afternoon and late afternoon, in a certain work-day during from the first decade of July to the second decade of September in 1986. Others were measured once a day.

Bacteria, fungi and noise level were sampled at one point referring the typical indoor environment in each office building. The other factors were investigated at least 4 measuring points on the different floors in each building. Measuring instruments used in this investigations are shown in Table 1.

Table 1 : Instruments or methods used in environmental measurements

<u>measuring factors</u>	<u>instruments or methods</u>
CO ₂	non-dispersed infrared rays analyzer
CO	electro-chemical oxidation analyzer
SPM	light scattering type density meter : 1 counts per 1 minute(cpm) of its output corresponds to 0.001 mg/m ³ of 0.3 micron stearic acid particles
temperature, and relative humidity	Assman aspiration psychrometer
air flow	Kata-thermometer
noise level	noise level meter and level recorder measuring duration is 10 minutes
bacteria and fungi	settle agar-plate counts method collecting duration is 5 minutes

Questionnaires on subjective evaluation of occupants for indoor environments

The questionnaire was developed with reference to some papers reported the sick building syndrome(2,3,4,5). The questionnaire was comprised three main sections : personal data and characteristics ; subjective symptoms and health complaints ; environmental complaints, thermal sensation, perception for indoor air pollution, recognition of odor, valuation of noise level and so on.

The questionnaire were set out on the same day when the inspections were conducted. Building sanitation inspectors asked each occupant to complete the questionnaire in the morning and collected them in late afternoon. About 50 persons in every building responded and 4359 questionnaires were returned.

Results

Results of environmental measurements

Some results of the environmental measurements are shown in Fig.1. They are frequency histograms of the measuring data divided according to the building specificities. All factors except bacteria, fungi and noise level had 315 samples for group A, 297 for group B and 288 for group C.

The differences were found in all histograms though the mean values were almost the same among 3 groups. With regard to each group, samples of air flow, temperatures, RH and average noise level were concentrated to a certain

range, although concentrations of CO₂ and CO, amounts of SPM and of settle counts of bacteria and fungi were scattered. Throughout 3 groups, about 1 % of the samples of temperature, 5 % of RH, 10 % of CO₂ concentration exceeded the standards ordained in the Law (temp. ; 17-28 °C : RH ; 40-70 % : CO₂ concentration ; 0.1 %). Air flow, CO concentration, amount of SPM were within the range of the standards. The standards does not include those of noise levels and of amounts of bacteria and fungi.

The statistical tests are applied to mean values of some environmental factors which were measured three times a day. The results are summarized in Table 2. On the basis of t-value two-sided test, the mean values of relative humidities between group A and C, of CO concentrations between the groups of A and B, B and C were significantly different at significance level of 0.1 %. At significance level of 1 %, more factors were significantly different.

Table 2 : Results of t-value tests for some environmental factors

factors	between group A and B	B and C	C and A
temperature at the height of 120 cm	**		
temperature at the height of 10 cm	**	**	
temperature difference between two heights		*	
relative humidity	*		***
air flow	**	*	
CO ₂ concentration	**		
CO concentration	***	***	
amount of SPM			

significantly different at significance level of 5 %(*), 1 %(**), 0.1 %(***)

Results of questionnaires

Fig.2 - Fig.3 show some results of questionnaires. They were totalized in every building group, and not in each building.

Personal data except age distributions were similar between 3 groups. Two third of the respondents were males. 70 % in groups A and B, 50 % in group C were aged 20-39. 60 % were simple desk workers and 5 or 10 % were VDT workers. Not less than 10 or 20 % were currently employed during last one year. 35-40 % had the habit of smoking cigarettes. About 10 % of subjects answered having some allergic disease 3 % being prone to illness.

The prevalent health complaints were similar to the sick building syndrome as defined by WHO(5) among 3 groups, namely "mental fatigue", "feeling heavy in the head", "eye and throat irritation" and "nasal obstruction". But the frequency of the complaints except "mental fatigue" were not so high, ranged from 18 % to 32 %, as is shown in Fig.2.

The relations between frequencies of health complaints and building groups are statistically tested by the method of chi-square test. The relations for 4 complaints as "mental fatigue", "diarrhoea", "dizziness" and "sensation of dry skin" were presumed at the significance level of 1 or 5 %.

Totalization in each building revealed that the major subjects of 13 buildings in group A, 14 buildings in group B and 9 buildings in group C complained "mental fatigue" : 2 buildings in group A, 5 buildings in group B complained "eye irritation" : 2 buildings in group A voted "chilly constitution of limb". The number of buildings, where the majority of subjects in each building complained "mental fatigue" and "eye irritation" simultaneously, was only 1 in group A, but in group B it increased to 5. This result suggests the existence of the sick building syndrome in Japan and that IAQ in the buildings without designations are not healthy than that in specially designated buildings in the Law.

The frequency difference of the environmental complaints among 3 groups were obvious, as is shown in Fig.3. But we suspected that the awareness of the occupants for the indoor environment led these results. We tried to analyze the relations between the complaints and real environments. Environmental complaints which the major subjects in each building declared are shown in Table 3. The number of buildings whose indoor environmental factors corresponding to the complaints deviate from typical values are shown in bracket.

Table 3 : Environmental complaints whose response rate is more than 50 %

troublesome aspect	No. of buildings in group		
	A	B	C
thermal discomfort	20(19)	17(17)	10(10)
thermal sensation, feeling not moderate			
temperature difference between two heights			
relative humidity not moderate	3(2)		
disturbance of air movement	6(5)	12(10)	3(3)
discomfort for indoor pollution	18(18)	17(17)	11(10)
smoking, odor, other pollutants			
annoyance of noise	17(16)	20(18)	11(11)

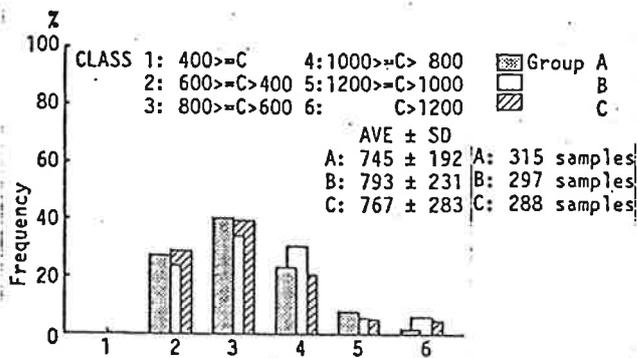
There are good correspondence between the environmental evaluations of occupants and the deviations of the measured data of environmental factors. This fact means that IAQ standards for which occupants have no complaints is severer than the ordained one in the Law.

Concluding remarks

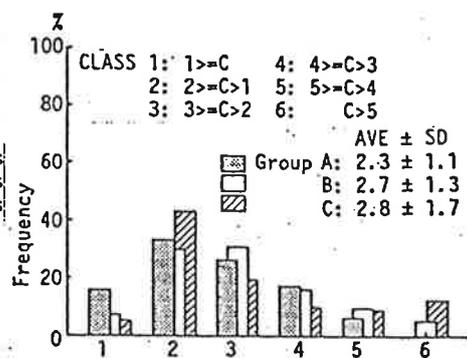
- (1) Some difference exists between IAQ in specially designated buildings in the Law and that in the buildings without designation though IAQ in most office buildings are in the range of the ordained standards in the Law.
- (2) Occupants in some office buildings respond similar health complaints to the sick building syndrome as defined by WHO. This fact suggests the existence of the sick building syndrome in Japan and that IAQ in the buildings without designations are not healthy than that in specially designated buildings in the Law according to the number of complaining buildings.
- (3) There are good correspondence between the occupant's evaluations for the indoor environments and the deviation of the measured data of environmental factors. This fact means that IAQ standards for which occupants have no complaints is severer than the ordained standards in the Law.

References

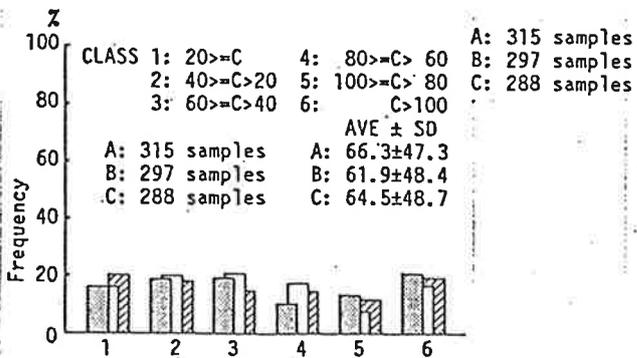
1. Building Management Education Center. Maintenance of Building Sanitation. Tokyo: Building Management Education Center, 1982.
2. McDonald, J.C. Building Illness in a Large Office Complex. D.S.Walkinshaw (Eds.), Indoor Air Quality in Cold Climates: Hazards and Abatement Measures. Pittsburgh: APCA, 1986, pp. 7-22.
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4. Turiel, I. Indoor Air Quality and Human Health. Stanford: Stanford University Press, 1985, pp.108-125.
5. WHO. Indoor Air Pollutants: Exposure and Health Effects. EURO Reports and studies 78. Copenhagen: WHO Regional Office for Europe, 1982.



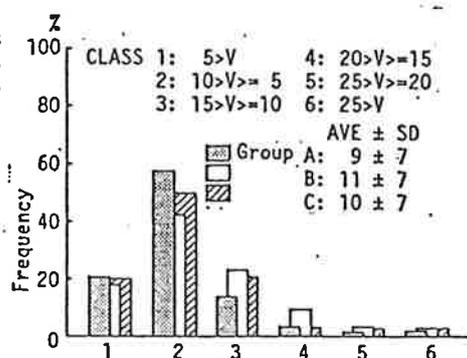
(1) Concentration of CO₂ : C(ppm)



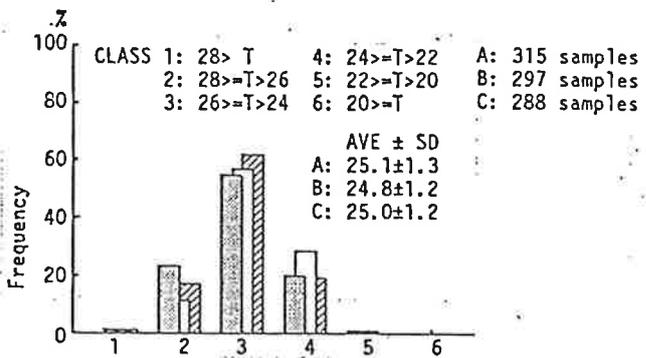
(2) Concentration of CO : C(ppm)



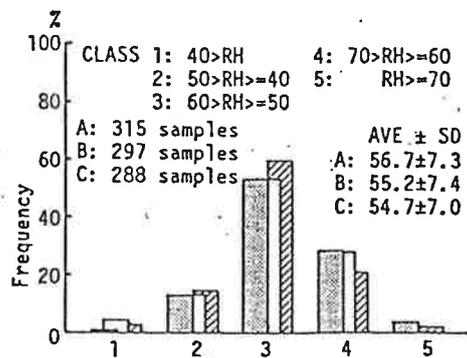
(3) Amount of SPM : C(cpm)



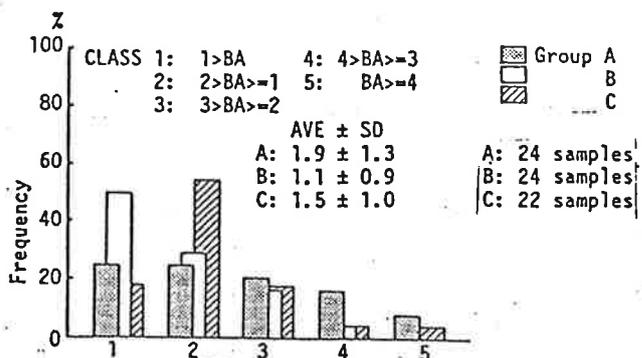
(4) Velocity of Air Flow : V(cm/s)



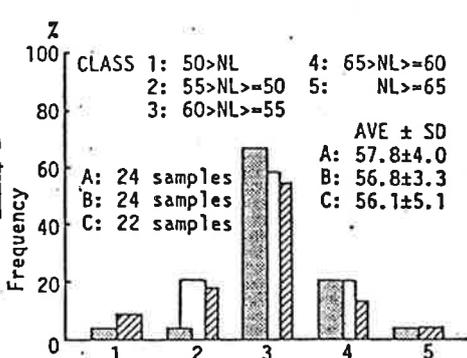
(5) Temperature at the height of 10 cm : T(°C)



(6) Relative Humidity : RH(%)

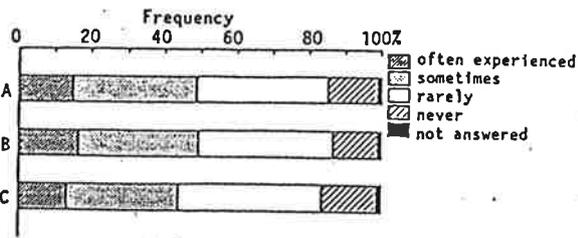


(7) Amounts of Settle Plate Counts of Bacteria : BA(colonies)

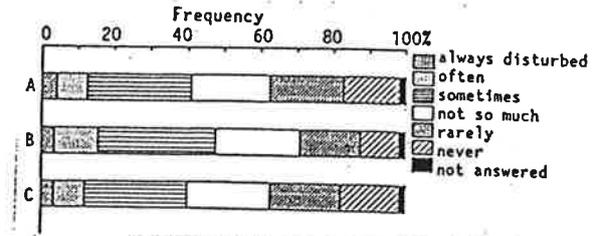


(8) Average Noise Level during 10 minutes : NL(dB(A))

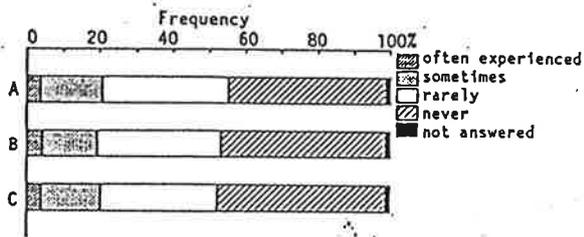
Fig.1 Frequency Histograms of Some Measuring Environmental factors



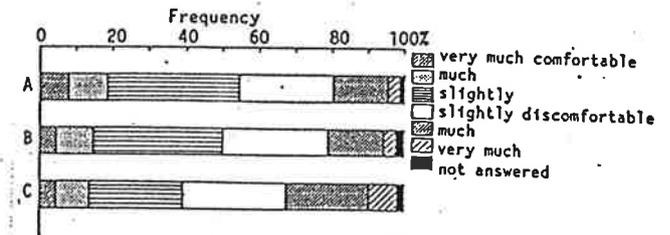
(1) Mental Fatigue



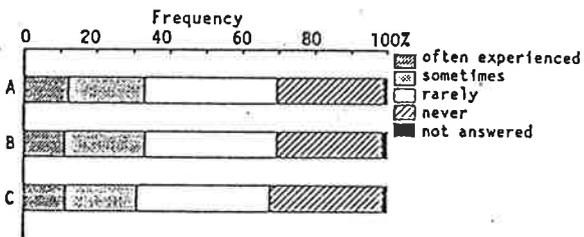
(1) Disturbance by Air Flow



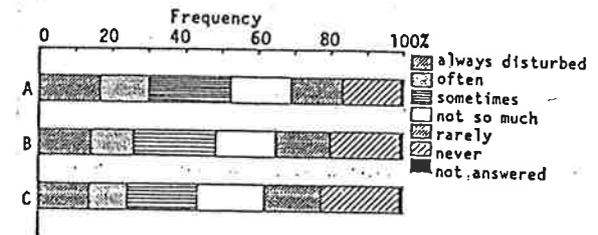
(2) Feeling Heavy in the Head



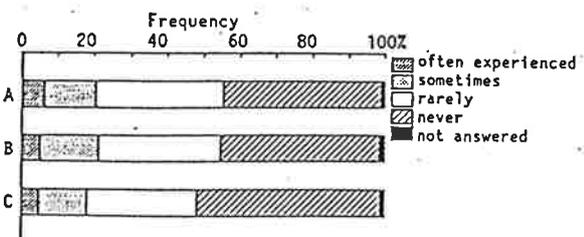
(2) Thermal Sensation



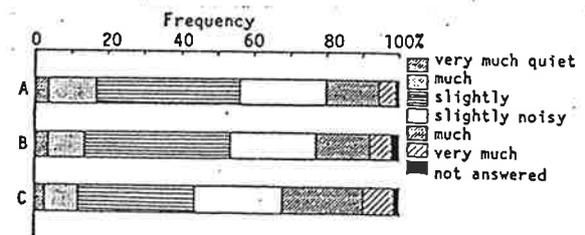
(3) Eye irritation



(3) Disturbance by Passive Smoking



(4) Throat Irritation



(4) Annoyance by Indoor Noise

Fig.2 Results of Questionnaires on Health Complaints

Fig.3 Results of Questionnaires on Environmental Complaints