

Measurements of Biological Contaminants and Particulate Matter Inside a Dwelling in Japan

SATOSHI NAKAI^{1*}, HIROSHI NITTA², MASAJI ONO², KEIKO ABE³ AND MASAHIRO SAKAGUCHI⁴

Abstract To investigate the biological contaminant levels inside dwellings in Japan, the authors measured fungal indices, airborne mite allergens (Der 1 and Der 2), and suspended particulate matter (SPM). Measurements were continuously conducted at one dwelling located in Yokosuka-city, Kanagawa. The biosensors for fungal index were set at 12 points inside and 2 points outside the dwelling. An SPM sampler was placed in the living room, and samplers for collecting allergens were placed in the living room and in the washroom. The peak level of the fungal index was recorded during July, which is the rainy season in Japan. The highest value in the dwelling was 6.9 in the toilet, and the second highest was 6.6 near a window in the living room that faces southeast, and behind the sofa. The highest monthly SPM level was 21.5 $\mu\text{g}/\text{m}^3$ during October, and the highest monthly allergen level (Der 1) in the living room was 25.7 pg/m^3 during November. A positive relationship between the fungal index and mite allergens was not observed, and the levels of contaminants were not as those found in other studies. However, further study to investigate the distribution of biological contaminants is needed because indoor temperature and relative humidity are comparatively high.

Key words Indoor environments; Dampness; Fungal index; Mite allergens; SPM; Japanese dwelling.

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Introduction

Recently, many epidemiological studies have been conducted to investigate the relationship between indoor biological contaminants, such as molds and mildew, and human health in Western countries (Andrae et al., 1988; Platt et al., 1989; Strachan et al., 1990; Dales et al., 1991; Brunekreef, 1992; Jaakkola et al., 1993; Spengler et al., 1994; Verhoeff et al., 1995). Most of these studies

show a positive relationship between home dampness/mold and respiratory health. Mold is considered to play an important role in home condition and residents' health. In the Republic of China, where higher temperature and higher humidity is recorded than in Western countries, a similar epidemiologic study was conducted with a similar result (Li, 1996). Indoor moisture problems such as mold/mildew and dew condensation are becoming important in Japan as well, because the dwellings in Japan are becoming tighter than several decades ago and indoor humidity is at a high level. However, few epidemiological studies on the health effects of home dampness/mold and measurements of biological contaminants inside dwellings have been conducted in Japan (Nakai, 1996).

In this study, to investigate the indoor biological contaminant levels in Japan and the relationship among contaminants, temperature and relative humidity, the authors have measured fungal indices, airborne mite allergens (Der 1 and Der 2), and suspended particulate matter (SPM) inside one dwelling through approximately one year. A fungal index qualifies the environmental conditions in relation to the ability of fungal growth, and it indicates the growth response of the sensor cells under a given environment for seven days. The response is measured against the corresponding response of sensor growth in a standard climate (Abe, 1993).

Methods

Subject dwelling

Measurements were conducted in a Japanese dwelling located in Yokosuka-city, Kanagawa, approximately 70 km south of Tokyo. The dwelling is a condominium

¹Institute of Environmental Science and Technology, Yokohama National University and CREST, JST, 79-7 Tokiwadai, Hodogaya, Yokohama 240-8501, Japan, Tel: +81-45-339-4364, Fax: +81-45-339-4373, e-mail: nakai@kan.ynu.ac.jp, ²The National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-0053, Japan, ³Institute of Environmental Biology, JDC Corporation, 4036-1 Nakatsu Aikawa, Aiko, Kanagawa 243-0303, Japan, ⁴Department of Immunology, National Institute of Infectious Diseases, Toyama 1-23-1, Shinjuku, Tokyo 162-8640, Japan, *Author to whom correspondence should be addressed

located on the ninth floor of a twenty-one-story residential building, with a reinforced concrete structure. The number of the above-type dwellings is increasing in Japan. The floor space is approximately 60 m² with a height of 2.2 m (see Figure 1). The living room has a wooden floor without a carpet, and the floors of room-1 and room-2 are covered with carpet. All doors between rooms are usually open. An air-conditioner is located in the room-1, and is used every night in the summer. An unvented kerosene heater and a vented heater are often used in the winter. Three occupants, two adults and one toddler, are living in the dwelling.

Measurements

All monitoring points are displayed in Figure 1. Measurements were conducted from June 1, 1995 to the end of May 1996. One measurement period was the first four weeks in every month.

A fungal index was measured by a biosensor using a xerophilic fungus, *Eurotium herbariorum* J-183. A sensor piece was prepared as follows. Strain J-183 was inoculated onto an agar plate of YS-35 medium (1 g of yeast extract, 35 g of sucrose, and 2 g of agar in 100 ml of medium) and cultured at 20°C for 2 weeks. After the cultivation, conidia that formed on the plate were suspended in a spore-suspending medium (0.5 g gelatin and 0.5 g glucose in 100 ml distilled water), collected by centrifugation at 700×g for 5 min, and rinsed three times with sterilized water. The collected conidia were suspended to a concentration of 10⁶ spores per ml in the medium. A drop of conidia suspension was placed on a gas-permeable transparent film and air dried for 1 hour at room temperature. The film on which the spores were adhered was covered by another film and

fixed in a slide mount to prevent scattering of spores into the environment during growth and sporulation of the biosensor condiospores dispersed in nutrients (Abe, 1993; Abe et al., 1996).

Biosensors were set at 12 points inside and 2 points outside the dwelling. Each biosensor was set through four weeks. After every measurement, each biosensor was immediately dried over silica gel and preserved at 4°C over the gel, and the hyphal length of the sensor was measured.

Airborne mite allergens and SPM were collected using NIES portable samplers (Ono et al., 1989). Two NIES samplers were placed close to a television set in the living room, one for collecting mite allergens and the other for SPM measurement, and one sampler for mite allergens was placed in the washroom, where people wash their faces and hands, and undress and dress for taking a bath. In this study, total SPM less than or equal to 10 µm diameter were collected without division of coarse (≥ 2.5 µm) and fine (≤ 2.5 µm) particles. Each filter for mite allergens (AP40, Millipore) and for SPM (AF07P, 37 φ, Fluoropore) was replaced every week.

Mite allergens collected in each filter were quantified by a sandwich ELISA after weighing the filter. Although Der p and Der f allergens were measured separately for group 1 and group 2, only the sum of both allergens as Der 1 and Der 2 are presented. Detailed descriptions of the method for analyzing the fungal index and mite allergens have been reported elsewhere (Abe, 1993; Sakaguchi et al., 1992).

Temperature and relative humidity inside a room (room-1) through each measurement period were also measured by an Isuzu Quartz Precision Thermo-Hygrograph with bimetal and hair method (No. 3-3122).

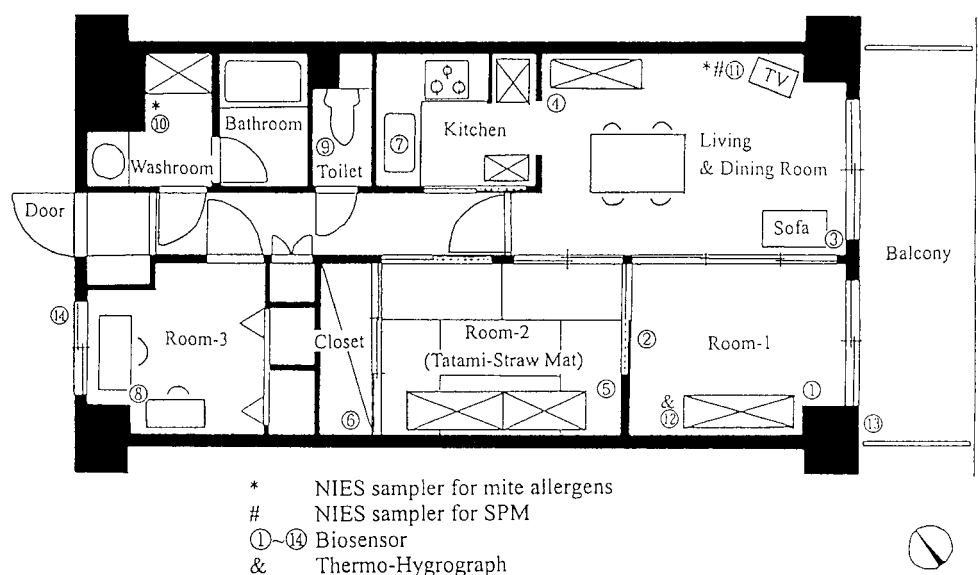


Fig. 1 Monitoring points

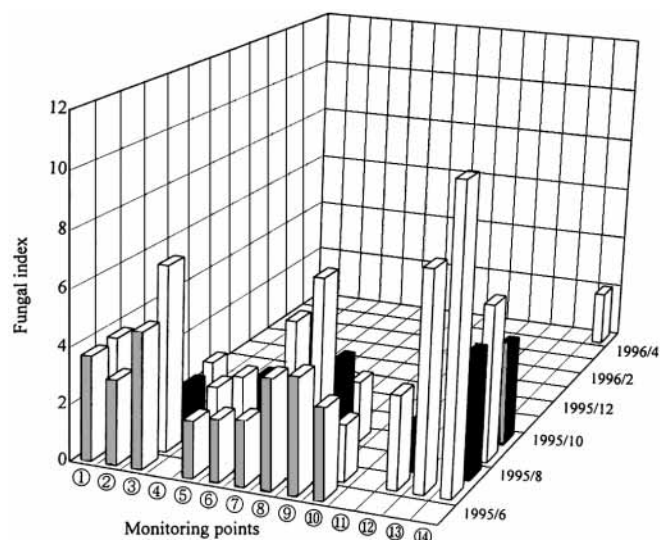


Fig. 2 Fungal indices by monitoring points and measurement periods

Statistical analysis

The monthly mean level for each contaminant was calculated, and weekly mean levels were also calculated for allergens and SPM. Monthly and weekly variations of each contaminant level were described and the relationship among contaminants, temperature and humidity was discussed.

Results

Fungal index levels

The results of the fungal index measurement are displayed in Figure 2. Fungal indices appeared at several

measurement points during June 1995 and September 1995, and most values were less than 4. Peak levels appeared during July, which is the rainy season in Japan. The highest value was 10.7 outside the door facing to the northwest (measuring point (14)). The highest value inside the dwelling was 6.9 in the toilet (9), and the second highest was 6.6 by the living room window, which faces to the southeast, and behind the sofa (3). All index levels by the living room walls (4) and at the point close to SPM sampler in the living room (11), and most index levels at all points from November to May were under the detection limit (<1.7).

Monthly SPM, mite allergens, temperature, and humidity levels

Table 1 shows the results of monthly SPM, mite allergen (Der 1), temperature, and humidity levels. The highest monthly SPM level was $21.5 \mu\text{g}/\text{m}^3$ during October, and the lowest was $14.1 \mu\text{g}/\text{m}^3$ during December. The highest Der 1 level in the living room was $25.7 \text{ pg}/\text{m}^3$ during November and the lowest was $1.4 \text{ pg}/\text{m}^3$ during August. The highest Der 1 level in the washroom was $10.9 \text{ pg}/\text{m}^3$ during November and the lowest was $1.1 \text{ pg}/\text{m}^3$ during August. Nearly all of the Der 2 allergen levels were under the detection limit.

The highest and the lowest values were described for temperature and relative humidity. Temperature became lower from August to December, but even during December dropped only as far as 16°C . Although the highest relative humidity was lower in the winter than summer, the value during every month became more than or nearly 70%. The highest value was 89.9%

Table 1 SPM and mite allergen levels (four-week mean), and temperature and relative humidity inside the dwelling

	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
SPM ($\mu\text{g}/\text{m}^3$)												
Living room	18.5	19.4	14.3	14.5	21.5	16.2	14.1	9.1	11.9	21.5	27.6	26.7
Allergen (Der 1, pg/m^3)												
Living room	6.0	3.3	1.4	4.4	5.6	25.7	11.2	7.2	5.2	11.0	7.0	7.2
Washroom	3.8	1.2	1.1	2.4	3.8	10.9	6.9	9.9	6.2	7.0	5.7	7.2
Temperature ($^\circ\text{C}$)												
Max.	25.5*	29.8	31.8	29.3	27.4	25.7	23.5	23.6	23.6	21.9	22.0	24.5
Min.	21.5*	22.9	22.5	21.8	20.3	16.4	16.0	11.1	14.7	14.7	14.0	17.8
Relative humidity (%)												
Max.	84*	90	88	88	78	68	72	72	66	77	74	81
Min.	67*	48	53	41	34	31	22	30	23	25	27	32
Outdoor Temp. ($^\circ\text{C}$) ^a												
Max.	28.6	34.5	35.6	34.6	27.8	22.2	16.9	19.7	20.7	23.2	25.2	28.8
Min.	14.6	19.4	23.7	15.1	11.6	5.4	-1.1	-0.3	-2.8	0.7	2.7	10.6
Outdoor RH (%) ^a												
Mean	83	81	75	72	69	53	46	53	52	58	60	70
Min.	41	48	40	28	16	17	14	15	15	19	15	18

* Measurement was conducted only during fourth week in June

^a Data of Yokohama Observatory from the Annual (1995) and the Monthly (January to May, 1996) Report of the Japan Meteorological Agency

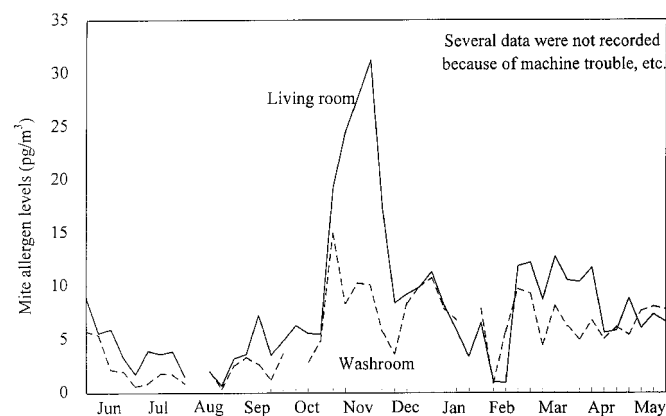


Fig. 3 Weekly indoor mite allergen levels (Der 1)

during July. The outdoor temperature and relative humidity at Yokohama, which is close to Yokosuka, from the Annual Report (1995) and the Monthly Report (January to May 1996) of the Japan Meteorological Agency are also shown in Table 1.

Weekly variation of mite allergen levels

Figure 3 shows the weekly mean levels of airborne mite allergen (Der 1) in the living room and the washroom. Several data were not recorded because of machine trouble or other reasons. Der 1 levels in the living room were generally higher than those in the washroom, but the allergen level pattern in both rooms was similar throughout the measurement periods. Der 1 levels were low in the summer and tended to become higher toward the winter, although the values during November were much higher than in other months. The highest Der 1 allergen level in the living room (31.3

pg/m³) and that in the washroom (10.3 pg/m³) were recorded during November.

Relationship among contaminants

Positive relationships between allergen levels and fungal indices did not appear, since peak of fungal index appeared in summer and peak of allergen appeared in autumn. Correlation coefficients among weekly levels of allergen, temperature and humidity are shown in Table 2. Weekly mean levels were used for allergen levels and SPM levels for correlation analysis, and the highest and the lowest levels during every week were used for temperature and humidity. Temperature and humidity were highly correlated (0.67–0.90). Correlation coefficient between Der 1 levels in the living room and in the washroom was 0.71, but no relationships between Der 1 and SPM levels were observed (–0.10). Der 1 levels were not positively correlated with temperature and humidity, and instead had a negative relationship with temperature and humidity (–0.64 to –0.32).

Discussion

Peak levels of fungal index appeared during July, the rainy season in Japan. Monthly mean humidity in Yokohama in July, 1995 was 81%. Many molds/mildew seem to grow rapidly in this season due to high humidity inside and outside dwellings, and high temperature. The high fungal index levels inside a dwelling are usually observed in bathrooms and toilets in which people use large quantities of water, as well as outside (Abe et al., 1996). Our results show a similar

Table 2 Correlation coefficients among allergen levels (Der 1), SPM, temperature and relative humidity

	Der 1 in the washroom	SPM in the living room	Max temperature	Min temperature	Max humidity	Min humidity
Der 1 in the living room	0.71 (<0.001)	0.02 (0.895)	–0.36 (0.017)	–0.32 (0.034)	–0.51 (<0.001)	–0.42 (0.004)
Der 1 in the washroom		–0.10 (0.493)	–0.55 (<0.001)	–0.58 (<0.001)	–0.64 (<0.001)	–0.54 (<0.001)
SPM in the living room			–0.19 (0.200)	–0.03 (0.827)	0.10 (0.531)	0.16 (0.303)
Max temperature				0.90 (<0.001)	0.67 (<0.001)	0.61 (<0.001)
Min temperature					0.73 (<0.001)	0.75 (<0.001)
Max humidity						0.76 (<0.001)

Correlation coefficient (P-value)

Coefficients were calculated based on weekly mean for Der 1 and SPM, and the highest and the lowest value during each week for temperature and relative humidity

pattern, but the reason why the high index levels were observed outside the dwelling is that raindrops might have fallen onto the sensor. Abe (1993) showed that indoor fungal index became nearly 30 in a Japanese house during October. Our results indicate a lower index, even though the measurement period was during the rainy season. In another study, each sensor was replaced every week, although we set a sensor through four weeks and the fungal index level was an average. If indoor climate is stable, fungal index levels during one week and four weeks are almost the same. On the other hand, if climate or life pattern changes, fungal index level varies during a short time, and high fungal index level weeks and low level weeks may appear during a month. In the latter case, the monthly level is lower than the weekly level with a high fungal index. This may be the reason why the results were different. However, it is difficult to conclude whether the moisture problem in this dwelling is not serious, or whether our result underestimates true fungal growth. It may be necessary to continue the monitoring, because temperature and relative humidity inside the dwelling do reach high levels.

SPM levels inside dwellings may be contributed to by smoking, outdoor traffic, and human activity. In another Japanese study, indoor SPM levels in the dwellings according to the distance from the roadside were measured in Tokyo (Ono et al., 1989), and the mean level in the dwellings located far from the road with heavy traffic was $58.9 \mu\text{g}/\text{m}^3$. The value was much higher than our results. The reason may be that no residents smoke, that the dwelling does not face to the road, and that the dwelling is not on the ground level.

Airborne mite allergen (Der 1) levels were much higher during November than other months. As a result, mite allergen levels were negatively correlated with indoor temperature and relative humidity. Irie et al. (1993) showed that airborne mite allergen in Japan increased remarkably in autumn and the levels in autumn were higher than in other seasons. Our result is similar. In Japan, the futon (Japanese bedding: mattresses, bedclothes, blankets and quilts) for winter use are usually kept in closets throughout the other seasons. When the residents begin to use them in the late autumn, many mites attached to the blankets might be scattered into the indoor air. Miyamoto and Ouchi (1976) showed that the peak number of live mites in house dust appeared during summer and the peak of dead bodies appeared during autumn. We might have collected dead mites and a few live mites. If it is true, live mites are not poured into indoor air, and the health effects by inhaling mite allergen would be due to dead

mite allergen. As we mentioned, airborne mite allergen may be poured into air by human daily activity, therefore we can prevent the health effects of airborne mite allergen. In this study, we measured only airborne mite allergens. If we had measured dust mite allergen, which peaked during summer, the allergen levels might have been correlated with the fungal index.

Allergen levels in the living room and the washroom were correlated, although the levels in the living room were higher. In the dwelling, doors between rooms are usually open. Even though the source of mite allergen may exist near the sampling place in the living room, air in each room may be cross-contaminated and the pattern of mite allergen levels in both rooms may be similar.

In this study, only one dwelling was the subject of measurement, and the dwelling is not a traditional type of Japanese house. The types of Japanese homes now vary. It may be necessary to investigate the distribution of indoor biological contaminant levels in many Japanese dwellings. We did not investigate residents' daily activity, time for opening windows, etc., which may affect the contaminant levels and/or distribution. When investigating contaminant levels, house characteristics as the determinants/contributors for indoor biological contaminants should also be discussed.

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