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Design Strategies of Dwelling Health Problems Related to Dampness in Cold Climatic Regions of Japan

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ABSTRACT:

To make up the indoor environment healthfully and comfortably for inhabitants is the foundation of the interior design in dwelling. Especially, in Japan, the design of indoor moisture environment has been one of the most important problems for a long time. Interdisciplinary reviews and epidemiological investigation on moisture problems and related health effects have reported that dampness increase the risk of health problems such as asthma and allergic symptoms, etc. From the viewpoint of the improvement in the quality of life related to indoor air quality, it is necessary to assess the detail of such damages through field measurements.

In order to recognize these problems, twenty-four residential buildings were measured during the rainy season of 2003. This paper describes the measurement results of mold and dust mites related to moisture problems of residential buildings, from the viewpoint of the relationship between occupant health problems and moisture environment.

Keywords: Residential buildings, Dampness, Health problems

1. INTRODUCTION

Indoor thermal environment, air quality and occupant health in residential buildings in the cold climatic regions of Japan have been investigated by authors through field measurements and questionnaires since the 1980's. In the winter of 2002, the indoor environment, energy consumption and occupant health of approximately 800 residential buildings in twelve main cities in the cold climatic regions of Japan were investigated by means of a questionnaire (Ishikawa et al. 2003). As a result, the actual conditions of the residential performance, indoor thermal environment and the indoor air quality have been clarified, and several problems related to the indoor environment have been grasped. In particular, approximately 60% of residential buildings still have vapor condensation on the surfaces of walls and windows during the winter. In half of the houses with vapor condensation, it appears to be the cause of mold growth and the presence of dust mites. In addition, some of the occupants of these houses suffer from health problems. In Japan, moisture problems in buildings have been an issue for a long time. However, the investigated results show that these problems remain, despite the development of building construction technologies. Interdisciplinary reviews and epidemiological investigation on moisture problems and related health effects have reported that dampness increase the risk of health problems such as asthma and allergic symptoms, etc (C.-G. Bornehag et al. 2001 and 2002). From the viewpoint of the improvement in the quality of life related to indoor air quality, it is necessary to assess the detail of such damages through field measurements.

In order to recognize these problems reported by occupants, twenty-four residential buildings were measured during the rainy season of 2003. The buildings investigated were selected from the respondents of a previous questionnaire and these occupants' had mentioned about some problems related to vapor condensation. This paper describes the measurement results of mold and dust mites related to moisture problems of residential buildings, from the viewpoint of the relationship between occupant health problems and these factors.

2. OUTLINE OF INVESTIGATION

2.1. INVESTIGATED HOUSES

The investigation was conducted during the rainy season. Houses were selected from among houses that had been studied by a previously questionnaire survey in 2002. Table 1 describes the investigated houses. The indoor thermal environment and indoor air quality of twenty-four houses were investigated. Most of the houses are of wood-frame construction, and some are apartment houses made of reinforced concrete. Houses constructed post-1990 have insulated walls, ceilings and floors. Houses 7 and 8 were originally traditional farm houses, which have a large floor area and no insulation on the building envelope, and were partially repaired in the 1970's and 1950's, respectively. The floor of House 6 was renovated in 1996 due to vapor condensation on the floor surface in the underfloor space. Almost all of the examined houses contain a kerosene space heater with a flue for exhausting fumes, an electric heater with heat storage, or an unvented portable kerosene heater. Many of the houses have a mechanical ventilation system for the entire house. However, Houses 1, 12 and 25 are relatively airtight in order to improve indoor thermal comfort and have no mechanical ventilation system. House 4 has a mechanical ventilation system that is not used by the occupants. All houses exhibit vapor condensation on the surface of the walls, window glass or window frames, from the winter until the rainy season. Furthermore, some occupants indicated that vapor condensation has brought about the growth of mold. A number of the occupants suffer from health problems such as allergies and atopic dermatitis.

Table 1: Description of investigated houses

No.	Construction (Detached, Appartment)	Completion	Floor area, m^2	Main heating equipment	Ventilation system	Opinions to the health and building damages related to moisture problems
1	wooden(D)	1995	134.0	vented kerosene heater	not equiped	vapor condesation on the window surface, growth of mold on the wall surface, children suffering from atopic
2	RC(A)	2000	90.2	unvented kerosene heater	exhaust ventilation system	not observed
3	wooden(D)	1997	125.4	vented gas heater	mechanical ventilation sysytem by each room	vapor condensation on the window surface, dry feeling during winter, living with a cat
4	wooden(D)	1995	unknown	vented kerosene heater	exhaust ventilation system	growth of mold on the ceiling surface
5	wooden(D)	1996	198.0	electric heater	exhaust ventilation system	child suffering form allergy
6	wooden(D)	1996	unknown	vented gas heater	not equiped	growth of mold on the floor in the closet, child suffering form allergy
7	wooden(D)	1977	247.5	firewood stove with a chimney	not equiped	vapor condensation on the window surfece
8	wooden(D)	1953	231.0	firewood stove with a chimney	not equiped	not observed
9	wooden(D)	1980	231.0	vented kerosene heater	not equiped	vapor condensation on the window surfece
10	wooden(D)	unknown	unknown	electric heater	exhaust ventilation system	vapor condensation on the window surfece
11	wooden(D)	1994	95.7	unvented kerosene heater	not equiped	vapor condesation on the window surface, child suffering from atopic dermatitis
12	wooden(D)	1999	unknown	water heating system with panel radiators	exhaust ventilation system	vapor condensation on the window surface, wife suffering from allegry
13	wooden(D)	1999	145.7	electric heater	exhaust ventilation system	vapor condensation on the window surfece
14	wooden(D)	2000	unknown	vented kerosene heater	not equiped	vapor condesation on the wiondw surface, growth of mold on the window wooden frame
15	wooden(D)	2002	131.7	electric heater	exhaust ventilation system	not observed
16	wooden(D)	2001	174.7	electric heater	exhaust-supply ventilation system	wife suffering form allergy
17	wooden(D)	2000	247.7	electric heater	exhaust ventilation system	children suffering form allergy, growth of mold on the woonden bathtub
18	wooden(D)	2002	140.0	electric heater	exhaust-supply ventilation system	not observed
19	wooden(D)	2002	176.0	electric heater	exhaust ventilation system	vapor condensation on the window surfece
20	RC(A)	1997	unknown	unvented kerosene heater	exhaust ventilation system	vapor condensation on the window surface, wife suffering from allegry
21	wooden(D)	1996	131.7	vented kerosene heater	exhaust ventilation system	wife suffering from bronchial asthma, son atopic rhinitis, grandmother allergy
22	wooden(D)	1999	162.4	electric heater	exhaust ventilation system	husband suffering from atopic rhinitis
23	RC(D)	1998	215.3	air conditioning	not equiped	vapor condensation on the window surface, growth of mold on the window wooden frame
24	wooden(D)	1996	161.6	electric heater	mechanical ventilation system by each room	vapor condensation on the window surfece

2.2. METHOD OF INVESTIGATION

The investigation was conducted during the month of July in 2003. Indoor thermal environment, fungal colonies and dust mites were investigated. The temperature and relative humidity in the living room and bedroom were measured continuously by small data loggers. Indoor air fungal spores in five rooms, including the living room, bedroom and bathroom, were collected by a centrifugal sampler using a Potato Dextrose Agar (PDA) medium. These samples were incubated at 25^{o}C for three days, and the number of colony-forming units was counted. The number of mites in the living room and bedroom was measured after collection using a vacuum cleaner. The sampling filter was attached to the head of the vacuum. Each sample was collected by vacuuming 1 m^2 of floor surface for 30 seconds. Samples were frozen at approximately -15^{o}C for a few days and the number of mites was counted. The actual conditions of moisture damages reported by the occupants in a questionnaire were recognized through the interview to them in this investigation.

3. RESULTS

3.1. VAPOR CONDENSATION AND GROWTH OF MOLD

In most investigated houses, the vapor condensation and growth of mold had been observed. Main findings are referred to in this paper. In House 1 the growth of mold has been observed on the surface of walls and vapor condensation has been observed on the glass surfaces of windows. Since this house, which had originally been insulated, had a moisture problem related to the growth of mold, the wall insulation was repaired five years ago, both to prevent mold growth and improve the thermal performance of the building envelope. Although this repair of the building envelope should have led to increased airtightness, no ventilation system was installed, and as such, the high airborne moisture content was maintained, encouraging the growth of mold. In House 4, mold growth was observed on the surface of the ceiling, apparently due to water leakage in the roof and the high moisture content of the ceiling material. In House 6, the growth of mold was observed only on the floor surface of a Japanese-style closet (*Oshi-ire*). This house originally had vapor condensation in the underfloor space, and so the floor was renovated in 1996. This mold growth may have been caused by the high moisture content of the plywood used in the renovation. Incidentally the relative humidity of closet space had been maintained around 60% and there were not vapor condensation on the wall surface. The closet space is usually enclosed, so the moisture inside cannot escape. The growth of mold on the wooden window frame in House 14 was caused by vapor condensation on the glass surface during winter. In House 17, the growth of mold was observed on the surface of the bathtub. The apparent reason for this growth is that the occupants did not operate the mechanical ventilation system in the bathroom.

3.2. INDOOR TEMPERATURE AND HUMIDITY

Figure 1 shows the temperature and relative humidity of the measured houses averaged for visiting time. The indoor relative humidity of most houses ranged from 50% to 70%.

3.3. NUMBER OF MITES

Figure 2 shows the results for the number of mites in the living room and bedroom. Houses 3, 6, 8, 21 and 24 contained large numbers of mites. The occupants of House 21 preferred sweeping to vacuuming, and the occupants of House 24 had not cleaned the living room or bedroom for several days. These results appear to indicate a correlation between the number of mites and the behavior of occupants with respect to house cleaning habits.

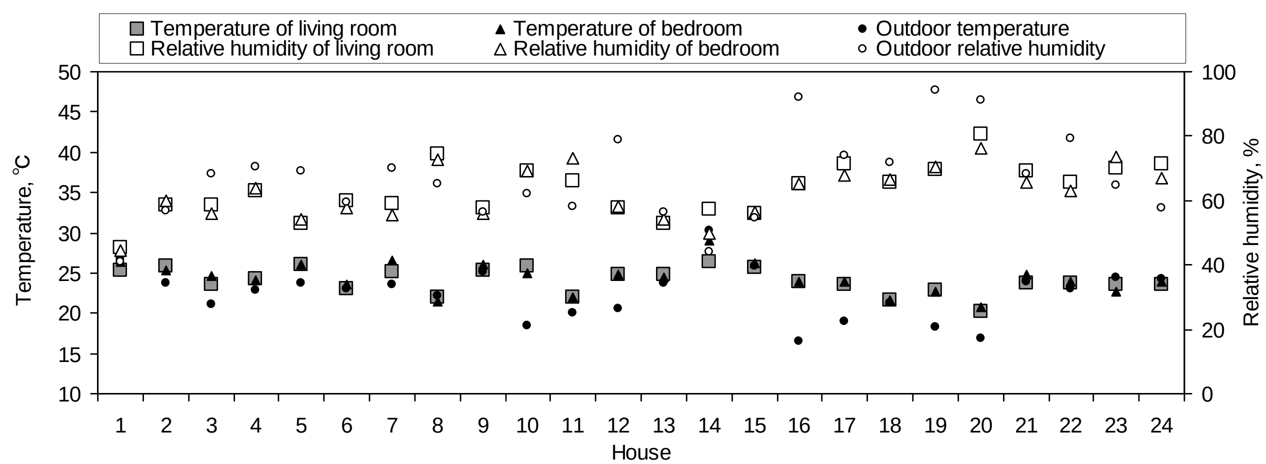

Figure 1: Indoor temperature and relative humidity averaged for visiting time

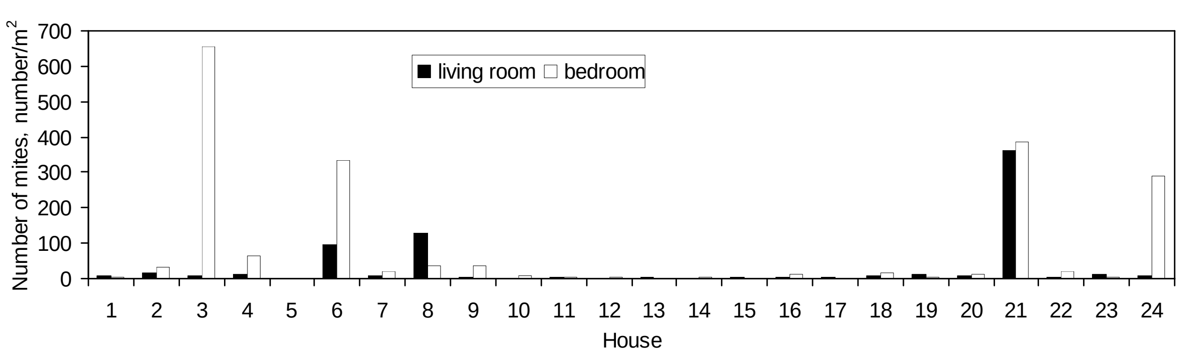

Figure 2: Number of mites in each room

3.4. FUNGAL SPORES

Figure 3 shows the concentration of airborne fungi. The standard value measured by the method in this investigation should be generally 200 CFU/m^3. The concentration of airborne fungi in all of the investigated houses was higher than that value. The guideline indicated in this figure has been discussed in committee among European microbiology researchers, and is used as a temporary standard. In most of the houses, the concentration of airborne fungi ranged from 500 to 2000 CFU/m^3, which indicates the presence of numerous fungal spores in the indoor air.

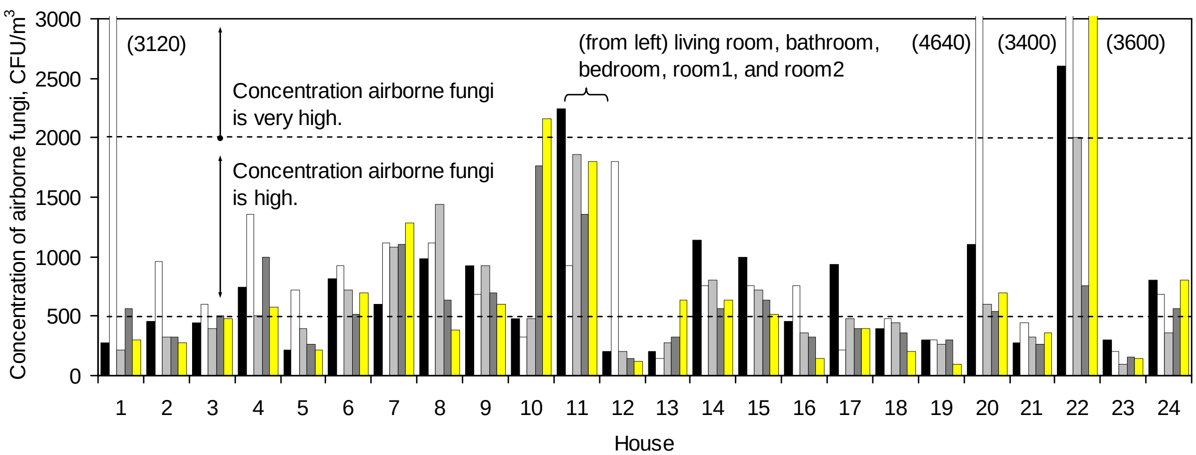

Figure 3: Concentration of airborne fungi in each room

4. DISCUSSION

In 11 of the investigated houses, occupants reported health problems. The present measured results are compared with occupant health problems from the viewpoint of the relationship between health problems and some factors related to dampness in buildings.

House 1 had been repaired several years ago in order to improve the thermal environment, but no mechanical ventilation system was equipped. Therefore, airborne moisture could not be exhausted effectively. Occupants of this house complained of vapor condensation on glass surfaces during the winter and the growth of mold on wall surfaces. Mold growth was observed in a bedroom and in Room 1 both. In addition, one of the occupants of this house, a child was suffering from atopic dermatitis. During the rainy season investigation, the concentration of airborne fungi in Room 1, a child's room, was high but the number of mites was relatively low, suggesting the possibility of a correlation between occupant health problems and the concentration of airborne fungi. As shown in Figure 3, the concentration of airborne fungi in each room of House 11 was high, and occupants reported that one child was suffering from allergies. Occupants of Houses 20 and 23, which were of reinforced concrete construction, reported the growth of mold on the floor (*tatami* mat) surface during the rainy season of the first year after moving into the house. Moisture contained in the concrete may have diffused into the houses, thus increasing the indoor humidity. In House 20, although mold growth was not observed during the investigation, the concentration of airborne fungi was high. In House 23, vapor condensation on the glass surfaces of windows caused mold growth on the wooden window frame and wall surface. The occupants of Houses 20 and 23 reported that a number of the occupant were suffering from health problems related to allergies, indicating that occupant health problems may be affected by the concentration of airborne fungi related to dampness in buildings.

Houses 5, 12, 16 and 22 are equipped with a mechanical ventilation system, and, with the exception of House 22, the concentration of airborne mold in these houses was relatively low, but remained higher than the standard value of 200 CFU/m^3. Although the concentration of airborne mold in House 22 was very high, no mold growth was observed.

The number of mites present in Houses 6 and 21 were larger than in other houses, as shown in Figure 2. The occupants of House 6 reported that one child was suffering from an allergy to a particular plant. In addition, the concentration of airborne fungi in House 6 was high. The child's health problem may have been caused by indoor air pollution due to the growth of mold and the presence of mites. The occupants of House 21 reported that they preferred sweeping to vacuuming and rarely cleaned using a vacuum cleaner. The large number of mites may be related to occupant behavior with respect to cleaning habits. The occupants of House 21 reported that the wife was suffering from bronchial asthma, one child was suffering from atopic rhinitis, and an elder occupant was suffering from allergies, suggesting a correlation between occupant health and indoor air pollution.

The concentration of airborne fungi was high in all of the measured houses, indicating that in houses having occupants that are suffering from certain health problems, the concentration of airborne fungi and the number of mites is large.

5. CONCLUSION

From the viewpoint of the relationship between occupant health problems and indoor air pollution related to dampness in buildings, factors such as the indoor thermal environment and indoor air quality were measured during the rainy season of 2003. The buildings investigated were selected from among respondents to a previous questionnaire survey, which revealed problems related to vapor condensation. The results indicated that in houses having occupants that are suffering from certain health problems, the concentration of airborne fungi and the number of mites present tended to be large. However, no clear correlation between occupant health problems and indoor air pollution related to dampness in buildings was found, and further investigation is required.

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REFERENCES:

Ishikawa Y, Hasegawa K, et al. (2003) Design Strategies of Dwelling Thermal Performance in Rather Cold Climate Regions of Japan –Investigation of Indoor Temperature and Energy Consumption in Houses of Tohoku City Area-, 6th Asia Design Conference, Tsukuba, Japan, October 14 -16.

C.-G. Bornehag, G. Blomquist, F. et al. (2001) Dampness in Buildings and Health - Nordic Interdsciplinary Review of the Scientific Evidence on Associations between Exposure to "Dampness" in Buildings and Health Effects (NORDDAMP), Indoor Air, 11, pp 72 - 86.

C.-G. Bornehag, J. Sundell, S. et al. (2002) Dampness in Buildings as a Risk Factor for Health Effects, EUROEXPO: a Multidisciplinary Review of the Literature (1998-2000) on Dampness and Mite Exposure in Buildings, Indoor Air, 14, pp 243 - 257.