Verification of Indoor Air Quality Before and After Moving in the House with the Countermeasure Against Allergy

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Abstract
Allergy symptoms are intimately related to indoor air quality. It is said that PM2.5 would cause asthma and bronchitis. A whole house air-conditioning system integrated with an electrical dust collector was developed for the countermeasure against allergy. This air-cleaning system could remove fine particles such as PM2.5. The purpose of this study is to make clear the relationship between symptoms of allergy and indoor air quality. The concentrations of fine-particles and airborne fungi, as well as the amounts of mite allergens were measured before and after moving in the house which installed an air-cleaning system. The results showed that the concentrations of fine-particles and airborne fungi were lower than that of the houses before occupying. The amounts of mite allergens were also lower. Most of the residences said that the symptoms of allergy were improved after moving in the houses with the countermeasure against allergy.

Keywords – air-cleaning; field survey; fine-particle; airborne fungi; mite allergen

1. Introduction

Indoor chemical pollution has become a social problem since the 1990s in Japan. Therefore, the Building Standard Law on Sick House Issues was amended in July 2003. Countermeasures for sick house issues such as the ventilation strategy and the inhibition of VOCs emission were steadily taken in the residential sector. However, the allergic disease of the child is increasing recently, which indicated that countermeasures for allergy in houses are not enough. In this study, a whole house air-conditioning system integrated with an electrical dust collector was developed for the countermeasure against allergy. This air-cleaning system could remove fine-

particles as PM2.5. The purpose of this study is to make clear the relationship between symptoms of allergy and indoor air quality before and after moving in the houses which installed countermeasure against allergy. The concentrations of fine-particles and airborne fungi, and the amounts of mite allergens were compared before and after moving in the houses. The performance of the air-cleaning system was also verified through the measurements.

2. Methods

Table 1 shows the outline of the investigated houses. The investigated objects were eleven family units and the total number of measured houses was 31. One or more of the families are affected with allergy disease. Measurements were performed before and after moving in the house with the countermeasure against allergy. In some of the houses, measurements were done twice in about one month and six months after moving in. Most of the houses before occupying were apartments and the age of the buildings were between 4 and 40 years. Air-tightness of the houses after moving in was between 0.52 and 1.6 cm^2/m^2.

Table 1. Investigated houses

Family unit	House	Building type	Completion date of the house	Number of occupants	Air-tightness [cm^2/m^2]	Floor area [m^2]	Measurement date
A	Befor move	Detached house	December, 1980	7	n. d.	n. d.	9/24-9/25, 2009
	After move	Detached house	November, 2009	4	0.59	131.17	2/18-2/19, 2010
B	Befor move	Apartment	January, 1983	3	n. d.	n. d.	4/26, 2010
	After move (1)	Detached house	May, 2010	3	1.36	97.5	8/30, 2010
	After move (2)						12/2, 2010
C	Befor move	Detached house	January, 2002	5	n. d.	n. d.	7/16-7/17, 2009
	After move	Detached house	August, 2009	5	0.55	159.39	6/15, 2010
D	Befor move	Apartment	March, 2003	2	n. d.	41.76	6/28, 2010
	After move (1)	Detached house	July, 2010	3	1.6	164.4	10/18, 2010
	After move (2)						3/11, 2011
E	Befor move	Apartment	(about 40 years old)	4	n. d.	n. d.	8/27, 2010
	After move (1)	Detached house	September, 2010	4	1.17	139.5	10/27, 2010
	After move (2)						4/15, 2011
F	Befor move	Apartment	(about 30 years old)	7	n. d.	171.6	9/3, 2010
	After move (1)	Detached house	August, 2010	7	1.33	147.9	10/21, 2010
	After move (2)						6/20, 2011
G	Befor move	Apartment	(about 4 years old)	2	n. d.	48.36	10/8, 2010
	After move (1)	Detached house	October, 2010	2	1.08	107.66	11/8, 2010
	After move (2)						5/20, 2011
H	Befor move	Apartment	(about 20 years old)	4	n. d.	n. d.	11/22, 2010
	After move (1)	Detached house	October, 2010	4	0.66	150.5	1/24, 2011
	After move (2)						7/21, 2011
I	Befor move	Detached house	(about 31 years old)	5	n. d.	n. d.	6/10, 2011
	After move	Detached house	June, 2011	3	0.52	138.94	11/24, 2011
J	Befor move	Apartment	(about 23 years old)	5	n. d.	50.47	1/20, 2012
	After move (1)	Detached house	January, 2012	5	0.73	113.44	3/19, 2012
	After move (2)						9/10, 2012
K	Befor move	Apartment	(about 42 years old)	4	n. d.	47.99	1/31, 2012
	After move (1)	Detached house	February, 2012	4	0.71	123.3	3/16, 2012
	After move (2)						8/24, 2012

Figure 1 shows the outline of the whole house air-conditioning, ventilation and air-cleaning system for the countermeasure against allergy.

Outside air is supplied from the air inlet and passes through the air-cleaning system which consists of a net pre-filter, a MEPA (Medium Efficiency Particulate Air) filter, an aluminum mesh filter and an electronic cell. Returned air from the stair hall on the second floor is mixed with outside air before passing the aluminum mesh filter. Mixed air is air-conditioned by the heating/cooling coil and supplied to each residential room. Dirty air is exhausted from the air outlet in the toilet, bathroom and kitchen. Large particles are caught by the net pre-filter and the MEPA filter. The air moves through the collector part of the electronic cell where alternate parallel plates are charged positively and negatively, creating a uniform electronic field. The charged small particles are attached to and collect on the plates that have the opposite electrical charge.

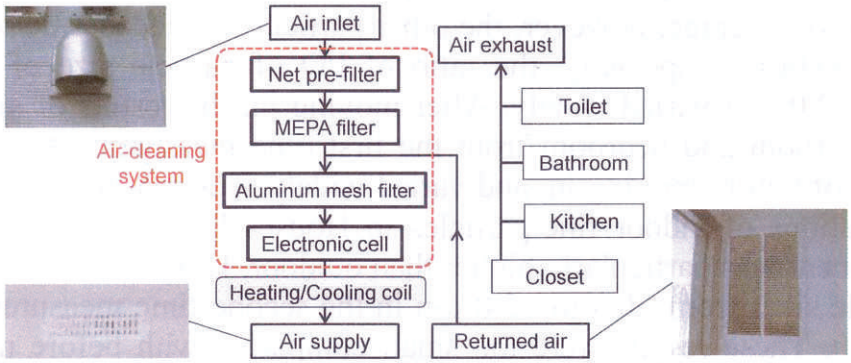

Fig. 1 The whole house air-conditioning, ventilation and air-cleaning system

Measurement items are the concentrations of fine-particles, airborne fungi and the amounts of mite allergens. The concentrations of fine-particles were measured at a height of 1.0 m above the floor level in the living room and bedroom. In the house with the countermeasure against allergy, measurements of fine-particles were also done at the supply opening in each room and the suction opening in the stair hall on the second floor. The light scattering particle counter for aerosol was used. Fine-particles of sizes from >0.3 to >5.0 μm were measured. Sampling air volume was 1.0 L/min. The portable air sampler blew 50 L air to potato dextrose agar medium (PDA). Air borne fungi were cultured in the incubator for more than 5 days at 25 °C, and then the number of fungal colonies was counted. The electric vacuum cleaner vacuumed household dust on the floor in the living room and on the bottom mattress in the bedroom in 1 m^2 area for two minutes. The amount of mite allergen in household dust was analyzed by the ELISA method. All measurements were carried out with the opening in the room closed.

3. Results and Discussion

Figure 2 shows the average concentration of fine-particles in eleven family units. On the whole, the results showed a tendency that the bigger the particle size, the lower the concentrations of fine-particle. According to the

manual of the air-cleaning system, fractional efficiency of large particles (3.0 to 10.0μm) is 99%. On the other hand fractional efficiency of small particles (0.3 to 1.0μm) is 81%. The concentrations of airborne fine-particles in the room after moving in were lower than that of before moving in. Especially, the concentration of the particle size with over 5.0 μm at the supply opening was lower than others. Comparing with the first and second measurements after moving in, the concentrations in the second measurement tended to be lower than the first time in general. One reason might be that a lifestyle at the second measurement was stabilized with time.

Figure 3 shows the average ratio of indoor to outdoor concentrations of fine-particles (I/O) in eleven family units. The results indicated that the bigger the particle size, the larger the ratio of I/O. Before moving in, there were ratios of I/O of particle size obtained from >0.3 to >0.7μm which were below 1.0 on average, however, the other particles exceeded 1.0 sizing from >1.0 to >5.0μm. Especially, the ratio of I/O of particle size of >5.0 μm exceeded 2.0 and varied widely. After moving in, the results of airborne in the living room and bedroom from the first time measurement were larger than that of before moving in, and varied widely. The reason was due to the concentrations of indoor fine-particles in Houses I and J of the first time measurement was particularly higher than outdoor. However, the ratio of I/O of particle sizes from >0.3 to >2.0 μm in the second time measurement was below 1.0. These results were too small comparing with before moving in and first time measurement after moving in. Although the ratio of I/O at the supply opening after move was enormously small at every particle size, the ratio of I/O of particle size of only >5.0 μm in the room exceeded 1.0. It was believed that the airborne particles with big size as >5.0 μm remained in the air not reaching to the suction opening of the ventilation system, and the generation of particles in the room was larger than the amount of removal by the air-cleaning system.

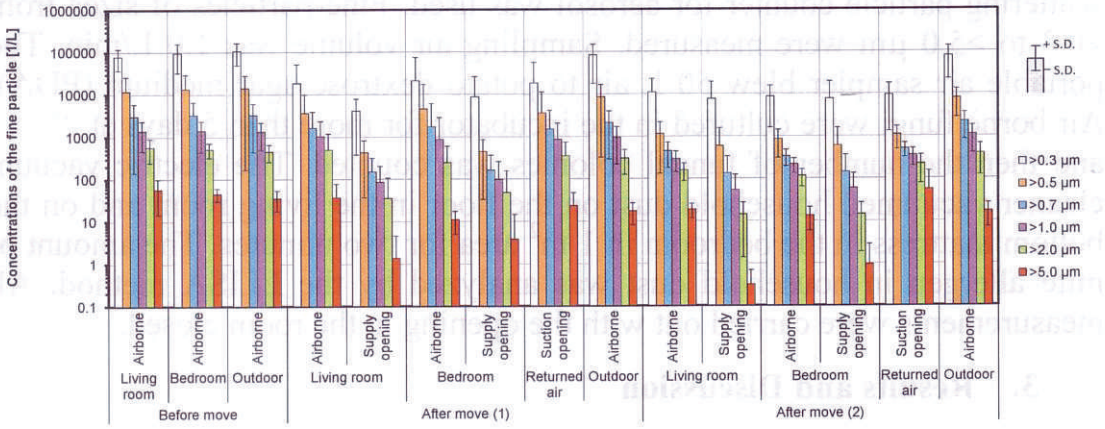

Fig. 2 Concentrations of fine-particles

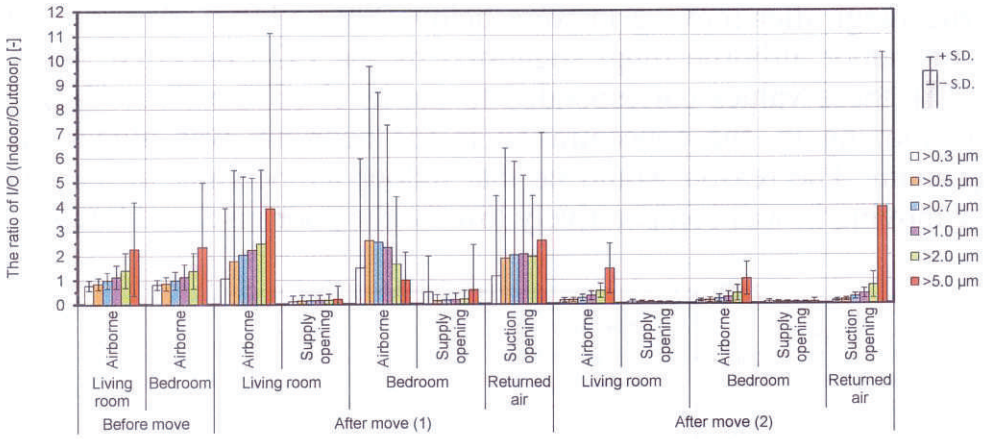

Fig. 3 The ratio of indoor to outdoor concentrations of fine-particles (I/O)

Figure 4 shows the average ratio of after moving to before moving in the house with the countermeasure against allergy (A/B) in eleven family units. The ratio of A/B of particle sizes from >0.7 to >5.0 μm in the living room of the first measurement exceeded 1.0 on average and varied widely. The result of particle sizes from >0.5 to >1.0 μm in the bedroom was similar to that of living room. On the other hand, the ratio of A/B obtained from the second time measurement was below 0.5 of every particle size and the dispersion of data was very small. The reason was due to the concentrations in Houses I and J of the first time measurement was particularly high, and might be that a lifestyle at the second measurement was stabilized with time.

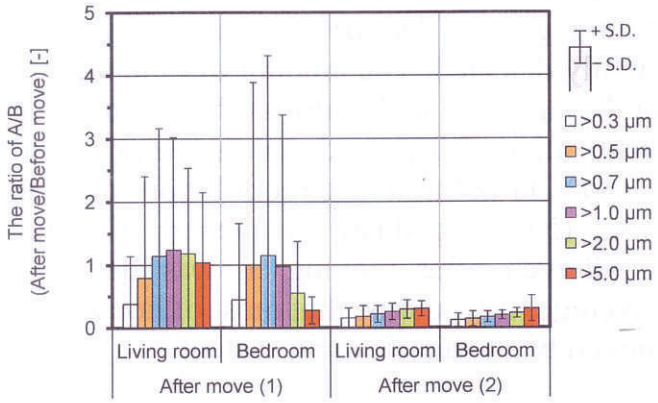

Fig. 4 The ratio of after moving in to before moving in with the countermeasure against allergy (A/B)

Figure 5 shows the average concentration of airborne fungi in eleven family units. In comparison with before moving in and after moving in, the concentrations of airborne fungi in the room after moving in were smaller than that of before moving in despite higher concentration of outdoor air. The average concentrations of airborne fungi before moving in were 356 CFU/m^3 in the living room and 568 CFU/m^3 in the bedroom, and these values varied widely. On the other hand, the average concentrations of

airborne fungi after moving in were below 200 CFU/m^3. According to the level of indoor airborne fungi suggested by the EC Concerted Action 613 (e.g. [2]), these values corresponded to the level of "Low" or "Very low". Before moving in, the concentration in the bedroom was higher than the living room. The reason would be that indoor temperature in the bedroom before moving in was comparatively low for the poor insulated house.

Fig. 5 Concentration of airborne fungi

Figure 6 shows the amount of mite allergen (Der p1), and Figure 7 shows the amount of mite allergen (Der f1) in eleven family units' average. The amounts of mite allergens of both Der p1 and Der f1 after moving in were considerably less than before moving in. In comparison with the living room and the bedroom, the amount of mite allergen in the bedroom tended to be lower than the living room. Der p1 in the second time measurement after moving in was hardly detected. The amount of mite allergen of both Der p1 and Der f1 in the living room and bedroom before moving in exceeded the thresholds of sensitization (2.0 μg/g dust) on average. The sum of allergen Der 1 (Der p1 + Der f 1) in the living room before moving in exceeded the thresholds of onset (5.0 μg/g dust) on average. On the other hand, the amount of mite allergen after moving in was below the thresholds of sensitization on average. It would be that most of house dust mite as airborne allergen was removed by the air-cleaning system.

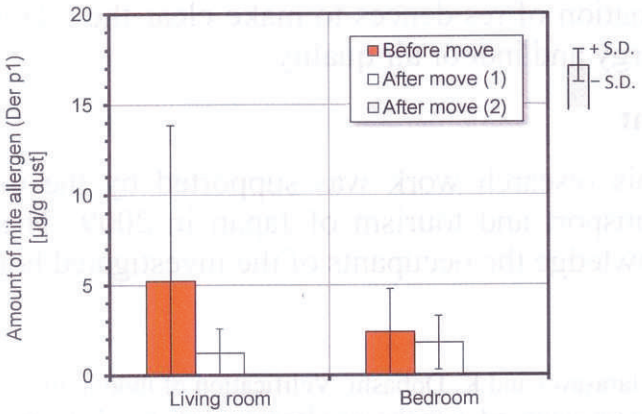

Fig. 6 The amount of mite allergen (Der p1) in household dust

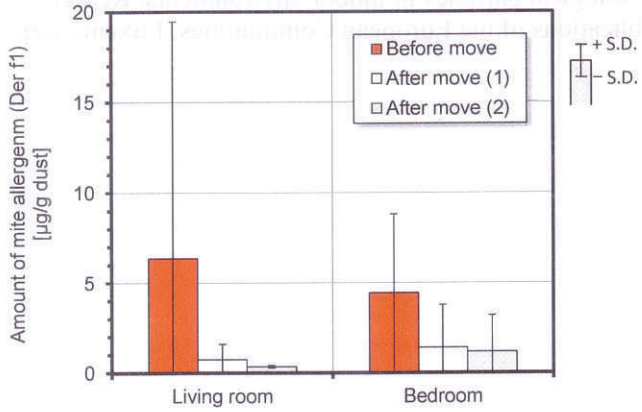

Fig. 7 The amount of mite allergen (Der f1) in household dust

4. Conclusions

The concentrations of fine-particles and airborne fungi, and the amounts of mite allergens were compared in terms of before and after moving in the house with the countermeasure against allergy. The concentrations of airborne fine-particles in the room after moving in were lower than before moving in. However, it would be difficult to remove airborne particle size with >5.0 μm in the room entirely. So it requires inhibition of particles generation in the room other than the air-cleaning system, in order to reduce the size of big airborne particles. The concentrations of airborne fungi in the room after moving in were much smaller than before moving in. Although the amount of mite allergen before moving in exceeded the thresholds of sensitization and onset, the amount of mite allergen after moving in was low. The performance of the air-cleaning system was verified through the measurements in this research work. Most of the residences said that the symptoms of allergy were improved after moving in with the countermeasure against allergy. This is also confirmed by the results from the measurement. In the future, the measurement results would compare with

a medical examination of residences to make clear the relationship between symptoms of allergy and indoor air quality.

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