Relationship between indoor allergen and occupants' allergic symptoms before and after moving in the house with the countermeasure against allergy

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ABSTRACT

Allergic symptoms are closely related to indoor allergens, such as airborne particulate matter, fungi, and house dust mite. This paper introduces a central air-conditioning system integrated with an electrical dust collector developed as a countermeasure against allergy. Here, it was demonstrated that this air-cleaning system can remove fine particles of PM2.5. Objectively, this study aims to elucidate the relationship between indoor allergens and occupants' allergic symptoms. Thereby, the concentrations of fine particles, airborne fungi, and the amount of mite allergen in the dust were measured before and after the subject occupants moved into the house installed with an air-cleaning system. In addition, the ratio of active CD4+ T cells in the occupants' blood was measured as an indicator of their allergic symptoms. The results showed that the concentrations of fine particles, airborne fungi, and the amount of mite allergens in the houses with a countermeasure against allergy, as well as the ratio of active CD4+ T cells, were significantly reduced after the occupants have moved in, demonstrating an improvement in the state of the occupants' allergic symptoms with the installation of the air-cleaning system in their houses.

KEYWORDS

Air-cleaning system, Indoor allergen, Filed survey, CD4+ T cells, Allergic symptom

1 INTRODUCTION

The promotion of highly insulated and airtight houses in Japan since the 1980s has been a parallel move with the reduction of CO_2 emissions in the region. Consequently, indoor chemical pollution has become a social problem since the 1990s. To address the issue, the Building Standard Law of Japan on sick house syndrome concerns was revised in July 2003, and various countermeasures, such as the mandatory installation of ventilation system, were carried out. Nonetheless, it was pointed out that allergic diseases, i.e., asthma and atopic dermatitis, are related to the indoor environment. Despite the increasing number of allergic patients, countermeasures against allergens in houses were not enough. One of the reasons points to the inadequate elucidation of the relationship between indoor environment and allergic symptoms in the patients' houses. In this study, a central air-conditioning system integrated with an electrical dust collector was developed as a countermeasure against allergy. This air-cleaning system is capable of removing fine particles of PM2.5. Practically, this study aims to clarify the relationship between indoor allergens and occupants' allergic symptoms. To date, the efficient performance of the system has been verified based on the measurement results in 31 houses investigated (Mitamura, T. et al., 2013). Specifically, this paper presents a comparative study

of indoor allergens and the ratio of active CD4+ T cells, as an indicator of allergic symptoms prior to and after moving into the houses, with a countermeasure against allergy.

2 METHODS

2.1 Air-cleaning system

Figure 1 shows an outline of the central air-conditioning, ventilation, and air-cleaning system installed in the house as a countermeasure against allergy. Outside air (OA) is supplied from the air inlet and passes through the air-cleaning unit that consists of a net pre-filter, a medium efficiency particulate air (MEPA) filter. A large size of particles is caught by this unit. Returned air (RA) from the stair hall on the second floor is mixed with OA after passing through the air-cleaning unit. Subsequently, RA passes through the electric precipitator, which consists of an aluminium mesh filter and an electronic cell. It then 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. The fractional efficiency of the electric precipitator for a small size of particle E1 (from 0.3 to 1.0 μm) based on the ASHRAE Standard 52.2-1999 is 73%. Next, the fresh air passing through the electric precipitator is air-conditioned by the heating/cooling coil and is supplied (SA) to each residential room. Dirty air is exhausted (EA) from the air outlet in the toilet, bathroom, and kitchen.

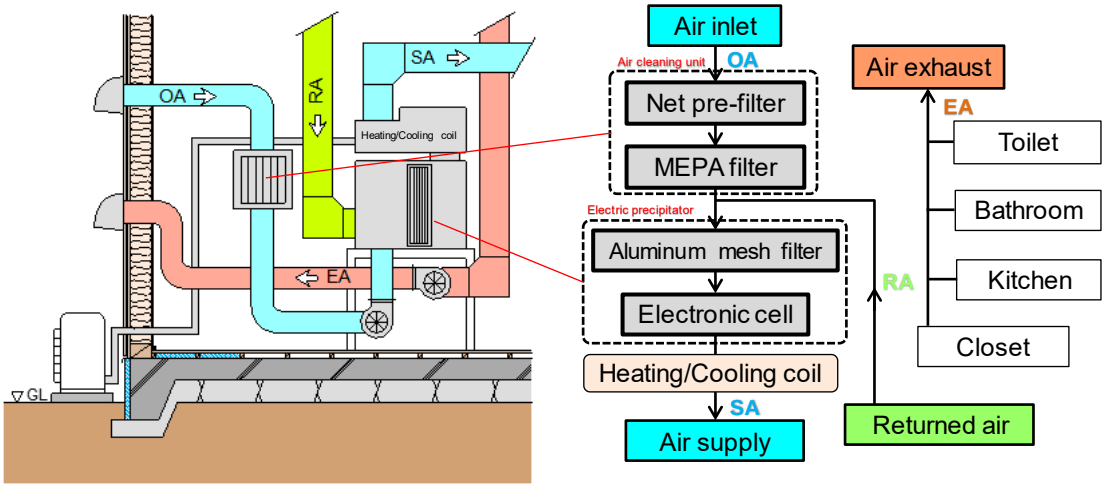

Figure 1: The whole house air-conditioning, ventilation and air-cleaning system

2.2 Investigated houses

A total of 40 family units and 107 houses were subjected to the investigation and measurements. In these targets, at least one family member has an allergic disease. Measurements were performed prior to and after the subjects moved into the house installed with a countermeasure against allergy. In some of the houses, measurements were repeated twice in roughly 1 month and 6 months after moving in. Before being occupied, most of the houses were apartment buildings used for over 10 years. Houses with a countermeasure against allergy were highly insulated and airtight.

2.3 Measurements

Indoor allergens were measured according to the concentrations of fine particles, airborne fungi, and the amount of mite allergen. Fine particle concentrations were measured 1.0-m above floor

level for both the living room and bedroom. The light-scattering particle counter for aerosol was used. Fine particles at six size levels, from >0.3 to >5.0 μm, were measured. Sampling air volume was set at 1.0 L/min; a portable air sampler blew 50 L of air to potato dextrose agar medium. The airborne fungi were cultured in the incubator for more than 5 days at 25 °C, and then the number of fungal colonies was counted. An electric vacuum cleaner was used to collect household dust on the living room floor and on the bottom mattress in the bedroom in a 1-m^2 area for 2 min. The amount of mite allergen in the household dust was analysed by enzyme-linked immunosorbent assay (ELISA). All measurements were carried out with an opening in the closed room. Additionally, CO_2 concentration was measured in an area of the houses to determine the indoor ventilation characteristics. Mann–Whitney U test was used to compare the differences in these values before and after occupying a house with a countermeasure against allergy.

Accordingly, the occupants were examined medically in Gunma University Hospital. The ratio of active CD4+ T cells was measured through a blood test as an indicator of the occupants' allergic symptoms. Here, a lower value of the ratio of active CD4+ T cells indicates less allergic symptoms. These examinations, along with the measurements of indoor allergens, were performed before and after the occupants moved into the house with a countermeasure against allergy. Comparison of the differences before and after occupying the house was carried out via the Wilcoxon signed-rank test.

3 RESULTS AND DISCUSSION

Figure 2 shows the box-and-whisker plots of the average CO_2 concentration in the living room and bedroom before and after the occupants moved into the house with a countermeasure against allergy. After occupancy, there were significantly lower concentrations in both rooms ($p < 0.01$). Specifically, the average CO_2 concentration after the occupants moved in was 645 ppm in the living room and 720 ppm in the bedroom. Prior to the occupancy, the mechanical ventilation equipment was not often installed, and ventilation airflow seemed insufficient. In addition, some of the houses had heating appliances, such as an oil stove used in winter.

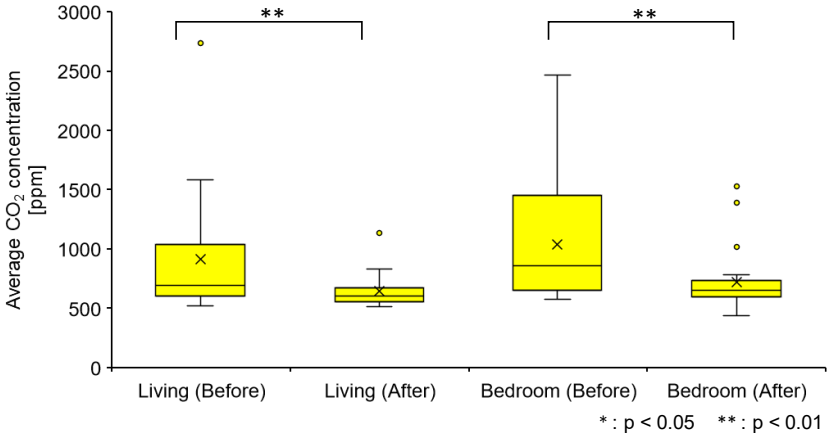

Figure 2: Average CO_2 concentration

Figure 3 shows the box-and-whisker plots of the concentration of fine particles in the living room and bedroom before and twice after the occupants moved into the house with a countermeasure against allergy. Notably, significantly lower concentrations of six levels of particle sizes were recorded after the occupants moved in ($p < 0.01$). In particular, the smaller the particle size, the lower the concentration. Fine particles causing asthma, within the size range of 1.0 to 5.0 μm, were suggested to have been effectively removed with the air-cleaning

system. Based on the first and second measurements made after the occupants moved in, the concentration was kept low except for particle sizes greater than 5.0 μm. Moreover, such fine particles were settled in the floor, which indicates that they may not have been sufficiently removed through the air-cleaning system.

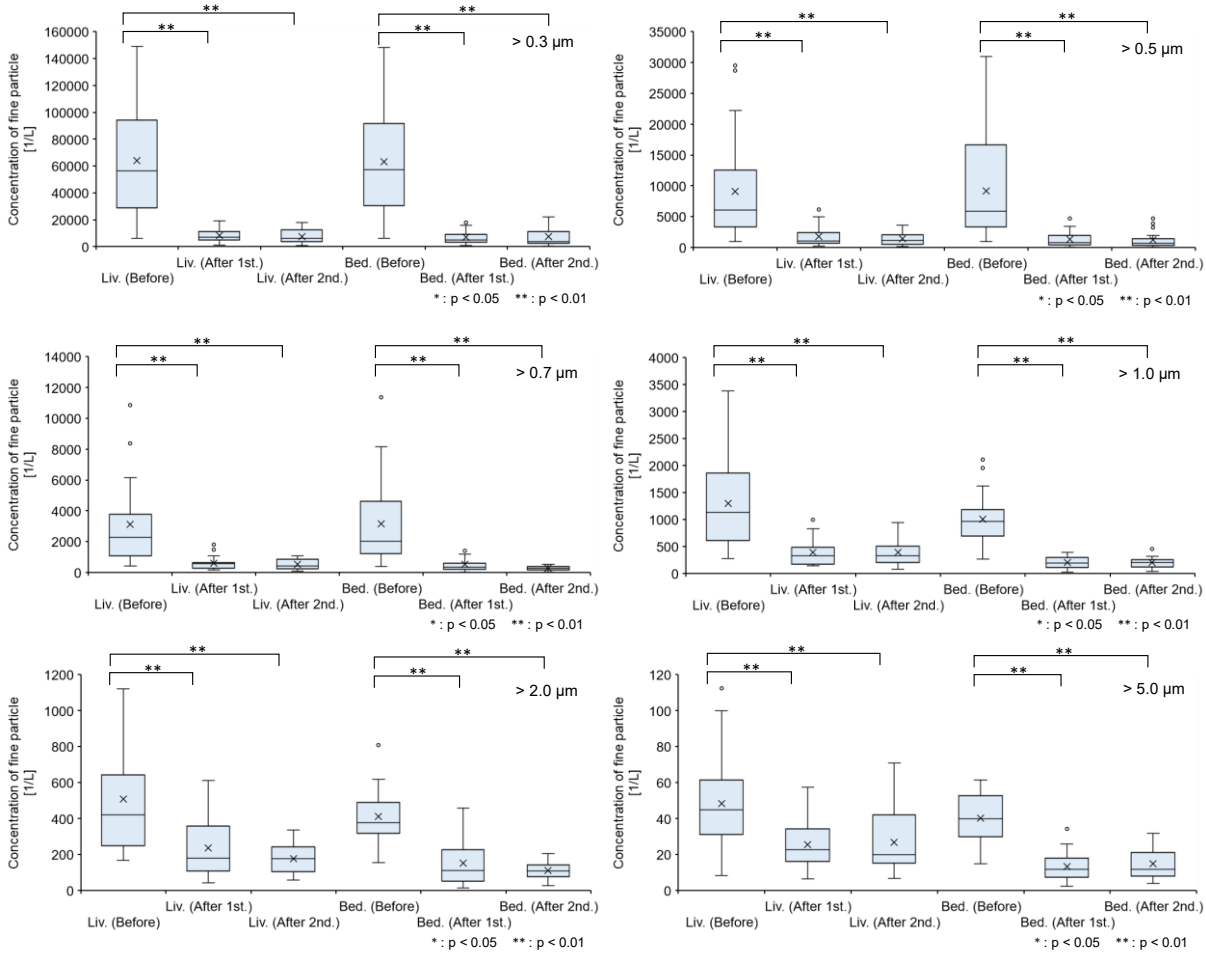

Figure 3: Concentrations of fine particles

Similarly, Figure 4 shows the box-and-whisker plots of the concentration of airborne fungi in the living room and bedroom before and twice after the occupants moved into the house with a countermeasure against allergy. After the occupants moved in, significantly lower concentrations of airborne fungi ($p < 0.01$) were recorded. The average concentrations of airborne fungi prior to occupancy were 365 CFU/m^3 in the living room and 296 CFU/m^3 in the bedroom, and these values varied widely. In contrast, the average concentrations of airborne fungi after the occupants moved in were below 100 CFU/m^3, much lower than 1,000 CFU/m^3 specified as the standard by the Architectural Institute of Japan.

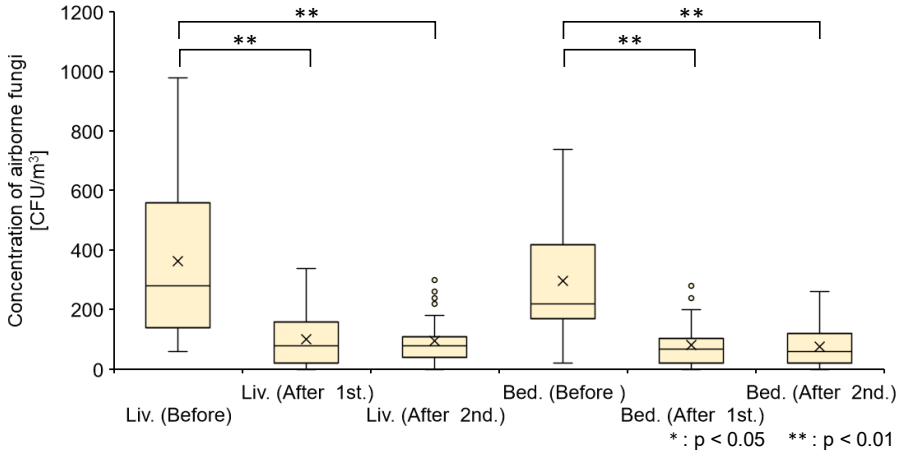

Figure 4: Concentration of airborne fungi

Figure 5 shows the box-and-whisker plots of the amount of mite allergen (Der 1) in the living room and bedroom before and twice after the occupants moved into the house with a countermeasure against allergy. After the occupants moved in, the amount of mite allergen became significantly lower ($p < 0.01$). Additionally, the amount of mite allergen in the bedroom tended to be lower than in the living room. Specifically, the average amounts of mite allergen before occupancy were 2.6 µg/g dust in the living room and 6.8 µg/g dust in the bedroom, which exceeded the average sensitization threshold of 2.0 µg/g dust.

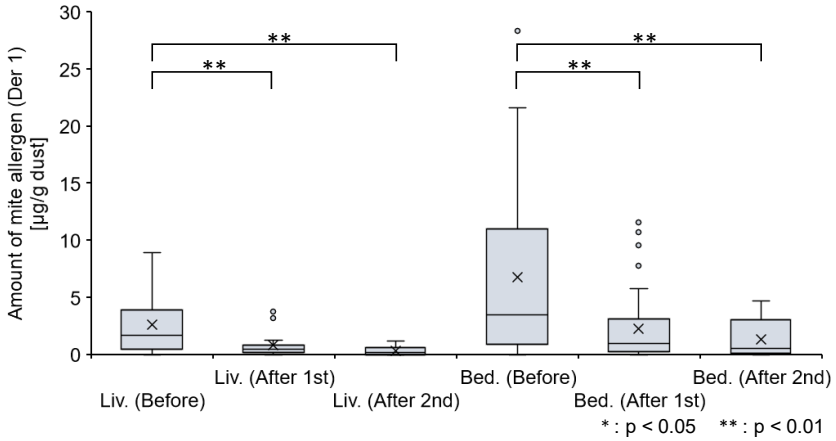

Figure 5: The amount of mite allergen (Der 1) in household dust

Figure 6 shows the box-and-whisker plots of the ratio of active CD4+ T cells for healthy subjects before and after they moved into the house with a countermeasure against allergy. The ratio of active CD4+ T cells after under 3 and 4–6 months of occupancy was not significantly lower compared with that prior to the occupancy. On the contrary, the ratio of active CD4+ T cells after over 7 months of occupancy was significantly higher ($p < 0.05$). However, the difference between both average values was not significant.

Figure 7 shows the box-and-whisker plots of the ratio of active CD4+ T cells for allergic patients before and after they moved into the house with a countermeasure against allergy. After under 3 months of occupancy, the ratio of active CD4+ T cells was not significantly lower compared with that prior to the occupancy. In contrast, after 4–6 months and over 7 months, the ratios became significantly lower ($p < 0.01$ and $p < 0.05$, respectively). Thus, the allergic symptoms of allergic patients improved with a countermeasure against allergy after moving into the house.

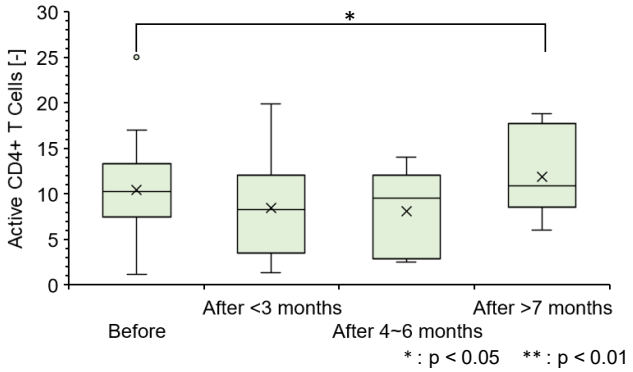

Figure 6: The ratio of active CD4+ T Cells for healthy subjects

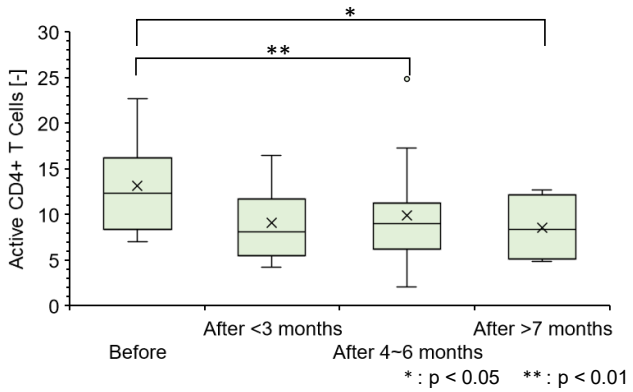

Figure 7: The ratio of active CD4+ T Cells for allergic patients

4 CONCLUSIONS

This paper presented a comparison of the concentrations of fine particles, airborne fungi, and the amount of mite allergen, prior to and after the subjects' occupancy in the house with a countermeasure against allergy. Based on the results, the amount of indoor allergen was significantly reduced after the occupants moved in. In addition, the measured ratio of active CD4+ T cells from the blood of the occupants indicated no significant reduction for the healthy subjects but was considerably reduced for the allergic patients, given a time frame of after 4–6 months and over 7 months of occupancy. Such results indicate that improvement of indoor environment led to the reduction of allergic symptoms.

5 ACKNOWLEDGEMENTS

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6 REFERENCE

Mitamura, T. *et al.* (2013). *Verification of Indoor Air Quality Before and After Moving in the House with the Countermeasure Against Allergy*. 11th REHVA World Congress and the 8th International Conference on IAQVEC Clima2013 Congress.