J. Japan. Soc. Hort. Sci. 79 (2): 200–206. 2010.
Available online at www.jstage.jst.go.jp/browse/jjshs1

Evaluating the Relative Health of Residents in Newly Built Apartment Houses according to the Presence of Indoor Plants

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Mental health and physical condition of residents in newly built apartment houses in Seoul, Korea were evaluated considering indoor plant placement for two terms of observation. Residents demonstrated severe symptoms of sick building syndrome (SBS) for at least two years. Indoor plant placement alleviated the degree of SBS symptoms along with ventilation. Residents showed improvements in mental health during the period of ventilation, which was facilitated by the placement of indoor plants. The placement of indoor plants failed to make significant differences in the vital capacity or blood indices of residents, but led to slight improvements in some factors like forced vital capacity (FVC) and change in total immunoglobulin E levels (T-IgE). From the results above, it could be postulated that the placement of indoor plants alone was not enough to reduce the level of indoor toxic chemical substances. Therefore, the placement of indoor plants could be an environmentally friendly method to reduce the levels of toxic chemical substances with the supplementary application of ventilation.

Key Words: blood index, indoor air quality (IAQ), mental health, sick building syndrome (SBS), vital capacity.

Introduction

The daily lives of city residents are largely lived indoors from home to workplace, so the residents are increasingly interested in indoor air quality (IAQ) in their daily living (Lim et al., 2006).

There have been frequent reports that residents in newly built buildings had some discomfort including mental stress, some physical conditions like flushing, asthma, and fatigue, and other allergic symptoms in the eyes, nose, and throat (Brasche et al., 1999; Carpenter, 1998; EPA, 1991; Godish, 1990). These problems were confirmed as a kind of building-associated disease and so named as sick building syndrome (SBS) (Godish, 1990; Seo et al., 2006). Craighead (1995) and Krause et al. (1991) reported that these symptoms were mainly caused by certain toxic chemical substances in indoor air such as formaldehyde and other volatile organic compounds (VOCs) like benzene, toluene, ethylbenzene, and xylene (BTEX).

Received; January 9, 2009. Accepted; October 2, 2009.
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Considering the previous researches showing that indoor air had larger amounts of these toxic chemical substances than outdoor air (Craighead, 1995; Krause et al., 1991; Sullivan et al., 2001; Wolkoff, 2003), Lim et al. (2006) suggested frequent ventilation and using low pollutant-emitting building materials to reduce the levels of toxic chemical substances in indoor air. However, residents kept their homes airtight to maintain a regular temperature.

With rapid urbanization, city residents have turned to various indoor plants (Bennett and Hill, 1973; Gilbert, 1968, 1971; Rao, 1979; Raza et al., 1991). One of their roles could be air purification by decomposing toxic chemical substances (Coward et al., 1996; Giese et al., 1994; Lohr and Pearson-Mims, 1996; Park and Seong, 2007). Many researchers have observed that indoor plants gave beneficial results in terms of the physical condition, as well as mental health, of residents using environmentally friendly methods (Bell et al., 2001; Hartig et al., 1991; Herzog et al., 1997; Kaplan, 2001; Kondo and Toriyama, 1989; Park et al., 2008; Shibata and Suzuki, 2001, 2002).

Although no studies disputed the positive effects of indoor plants on residents, few demonstrated supporting evidence for this. The present case study tried to evaluate the mental health and physical condition of residents with objective measurements. The degree of residents' SBS symptoms was checked using questionnaires about allergic symptoms in the eyes, nose, and throat. Mental health was analyzed with a symptom checklist-90-revised (SCL-90-R), a standard psychometric examination form. The physical condition of residents was diagnosed by measuring lung function and blood indices. Thus the present case study was conducted with the expectation of clarifying the relationship between indoor plants and human health in detail.

Materials and Methods

Participant organization and indoor plant placement

The 82 households in an apartment complex in Seoul, Korea, took part in the present case study for two terms of observation just after its completion in early October, 2004. The households were classified into two groups according to indoor plant possession. One group of 42 households had plants indoors and the other group of 40 households did not have plants. Every household provided an individual resident spending more than 20 h a day indoors as a participant. The participants gave their personal information such as sex, age, and atopy and provided their living conditions including resident area, the installation of an air cleaner, and the arrangement of newly manufactured furniture within six months (Table 1).

As most households in the present case study managed their indoor conditions in an airtight state during the winter and ventilated during the summer, a term of observation was used with just after indoor plant placement (early October) and were these of airtight state periods (following January) and ventilation (following July). The households with indoor plants installed plants in early October, 2004 to the observation in the first term (from January to July, 2005) and indoor plants placed in early October, 2005, to measure in the second term (from January to July, 2006). After the observation in the first term (July, 2005), all the indoor plants were withdrawn for the observation in the second term with the same initial conditions between the two groups of households. The National Institute of Horticultural & Herbal Science in Korea recommended the indoor plants and their placement methods for the present case study are as below.

In early October, 2004, the households with plants had large pots of areca palm and rubber plants and small pots of bamboo palm and peace lily in their living rooms, a small pot of pothos in the kitchen, and a large pot of elephant bush and small pots of fatsia and rosemary in the bedroom for the first observation. In early October, 2005, the households with plants had a large pot of Satsuma mandarins and small pots of asplenium, gardenia, and peace lily in the living room, a small pot of pothos in the kitchen, and small pots of rosemary and gardenia in the bedroom for the second observation (Table 2).

Symptom evaluation of sick building syndrome

Residents answered a questionnaire to measure the degree of SBS symptoms over three observations: just after indoor plant placement (early October in 2004 and 2005) and the airtight period (following January) and ventilation (following July) in 2005 and 2006. The documentary examination had 12 items regarding physical conditions of flush, asthma, and other allergic symptoms in the eyes, nose, and throat. Participants

Table 1. Conditions of participants and residences.

Item	Classification	Resident without indoor plant (n = 40)	Resident with indoor plant (n = 42)
Sex	Female	38	39
	Male	2	3
Age	20s	4	5
	30s	30	25
	40s	4	7
	50s	2	5
Atopy	Yes	1	4
	No	39	38
Area of residence (m^2)	>70	7	11
	>100	29	27
	>130	4	4
Air cleaner installed	Yes	11	17
	No	29	25
Newly manufactured furniture (within 6 months)	0	7	5
	1–2	7	10
	3–5	12	11
	6–10	14	16

Table 2. Status of indoor plant placement in newly built apartments.

Site	Observation in the 1st term[z]		Observation in the 2nd term	
	Plant	Size	Plant	Size
Living room	Areca palm (*Chrysalidocarpus lutescene*)	Large	Satsuma mandarins (*Citrus unshiu*)	Large
	Rubber plant (*Ficus elastica*)	Large	Asplenium (*Asplenium nidus*)	Small
	Bamboo palm (*Chamaedorea seifrizii Burret*)	Small	Gardenia (*Gardenia jasminoides*)	Small
	Peace lily (*Spathiphyllum* spp.)	Small	Peace lily (*Spathiphyllum* spp.)	Small
Kitchen	Pothos (*Epipremnum aureum*)	Small	Pothos (*Epipremnum aureum*)	Small
Bedroom	Elephant bush (*Portulacaria afra*)	Large	Rosemary (*Rosemarinus officinalis*)	Small
	Fatsia (*Fatsia japonica*)	Small	Gardenia (*Gardenia jasminoides*)	Small
	Rosemary (*Rosemarinus officinalis*)	Small		

[z] 1st term: from indoor plant placement (early October, 2004) to the airtight (early January) and ventilation (early July) periods in 2005; 2nd term: from indoor plant placement (early October, 2005) to the airtight (early January) and ventilation (early July) periods in 2006.

answered each item with one of four degrees of no symptoms (0 point), light symptoms (1 point), moderate symptoms (2 points), and severe symptoms (3 points). All the scores for the 12 items were added as a total score to compare the degree of SBS symptoms. The score range of SBS symptoms was 0 to 36 points. The examination for diagnosing SBS symptoms was conducted with the advice of Yonsei university medical college.

Medical mental health examination

A diagnosis of mental health of residents was conducted with a standard questionnaire form, Symptom Checklist-90-Revised (SCL-90-R) (Derogatis, 1997), twice for each term of observation: airtight period (January) and ventilation period (July) in 2005 and 2006. SCL-90-R had 83 regular items dealing with nine mental health symptoms such as somatization (SOM) (12 items), obsessive-compulsive (O-C) (10 items), interpersonal sensitivity (I-S) (9 items), depression (DEP) (13 items), anxiety (ANX) (10 items), hostility (HOS) (6 items), phobic anxiety (PHOB) (7 items), paranoid ideation (PAR) (6 items), and psychoticism (PSY) (10 items). The additional seven items of the SCL-90-R were excluded from the present case study. Participants answered each item with one of five degrees as no symptom (1 point) to the severest symptom (5 points). All the degree scores for each symptom were summed and calibrated as a percentage for an even comparison between the symptoms. Therefore, the score range for each symptom was 0 to 100%. The symptom score was applied to assess if the participants had potential danger of developing or abnormality of a certain symptom by more than 60 to 70 points.

Clinical examination

We conducted two clinical examinations of residents according to indoor plant possession: a vital capacity check-up and blood indices. The clinical examinations were carried out at Seoul Clinical Laboratory in Seoul, Korea, during the airtight and ventilation periods in the second observation term.

A vital capacity check-up was performed using spirometer. The survey items were forced vital capacity (FVC), forced expiratory volume for 1 s (FEV1), and the rate of FEV1 to FVC. The comparative score was taken as the highest one from eight replications for each item.

Blood indices were compared by measuring the erythrocyte sedimentation rate (ESR), white blood cells (WBC), changes in total eosinophil count (TEC) and total immunoglobulin E (T-IgE). The ESR measurement was conducted with the sediment velocity for 1 h ($mm \cdot h^{-1}$) and the other items were performed by counting the individual cells in a unit volume (1 μL). Then, changes in TEC were calibrated into percentages to the initial value. The normal range for each item was 0 to 20 $mm \cdot h^{-1}$ for ESR, 4,000 to 10,000 cell/μL for WBC, 0 to 7% for changes in TEC, and 0 to 158 cell/μL for changes in T-IgE.

Results

Symptom evaluation of sick building syndrome

An overall view of the total symptom scores indicated that residents demonstrated higher numeric values of SBS symptoms in the second term, with a minimum score of 23 points, than in the first term with a maximum score of 20 points despite poor statistical significance. It was confirmed by Kruskal-Wallis test that the application of only ventilation made no significant difference to the degree of SBS symptoms regardless of the two observation terms, but the combined application of ventilation with indoor plant placement led to a significant decrease in the second observation term (Fig. 1).

The observation in the first term showed a steady degree of SBS symptoms for residents in the households without plants, recording around 20 points during the entire observation term. The placement of indoor plants failed to make any difference in the degree of SBS symptoms, distributing from 18 to 21 points regardless of the application of ventilation. In the second term of observation, the degree of SBS symptoms remained steady at around 24 points for residents in the households without plants up the end of observation. Residents experienced a significant degree of SBS symptoms in the period of ventilation (July), decreasing from 23 to 15 points with indoor plant placement (Fig. 1).

Mental health examination

Considering the general results of the standard mental health examination, residents exhibited no symptoms above 60%, the threshold scale of potential danger to mental health and performed symptom alleviation in the period of ventilation (July) in comparison with the airtight period (January) for two terms of observation. In the period of ventilation, the placement of indoor plants seemed to facilitate the symptom alleviation (Table 3).

In the first term of observation, there were various changes in symptom scales between the airtight and ventilation periods. There were decreases in some symptoms such as O-C, I-S, and ANX but increases in the other symptoms like DEP, HOS, PAR, and PSY. However, no symptoms showed any significant difference. The placement of indoor plants reduced all the symptoms in the period of ventilation. Especially, the symptoms of SOM and HOS recorded noticeable decreases with statistical significance. The observation in the second term found a scale decrease in only one symptom, PSY, in the households without plants in the period of ventilation with poor significance. Other symptoms showed no differences in their scales. However, living with indoor plants reduced certain symptoms with statistical significance including SOM, O-C, I-S, DEP, ANX, and HOS (Table 3).

Clinical examination

While all the residents demonstrated a normal degree of FVC (a range of 3,000 to 6,000 mL), residents recorded higher FVC to a slight degree with indoor plant placement than those without plants in both terms. Considering the normal range of the rate of FEV1 to FVC was above 80%, all the residents showed little difference in the measurement regardless of the observation period (Table 4).

With the normal range of ESR below 20 $mm \cdot h^{-1}$, it was acceptable that participants maintained a normal degree of ESR in the airtight period. It was noticeable that the residents' ESR was significantly increased in the period of ventilation. The increase seemed to be unchanged by the placement of indoor plants. Other blood indices maintained normal ranges between 4,000 to 10,000 cell/μL for WBC, 0 to 7% for TEC, and 0 to 158 cell/μL for change of T-IgE. Residents in the households without indoor plants exhibited higher values for the change in T-IgE, recording 41.16 cell/μL (Table 5).

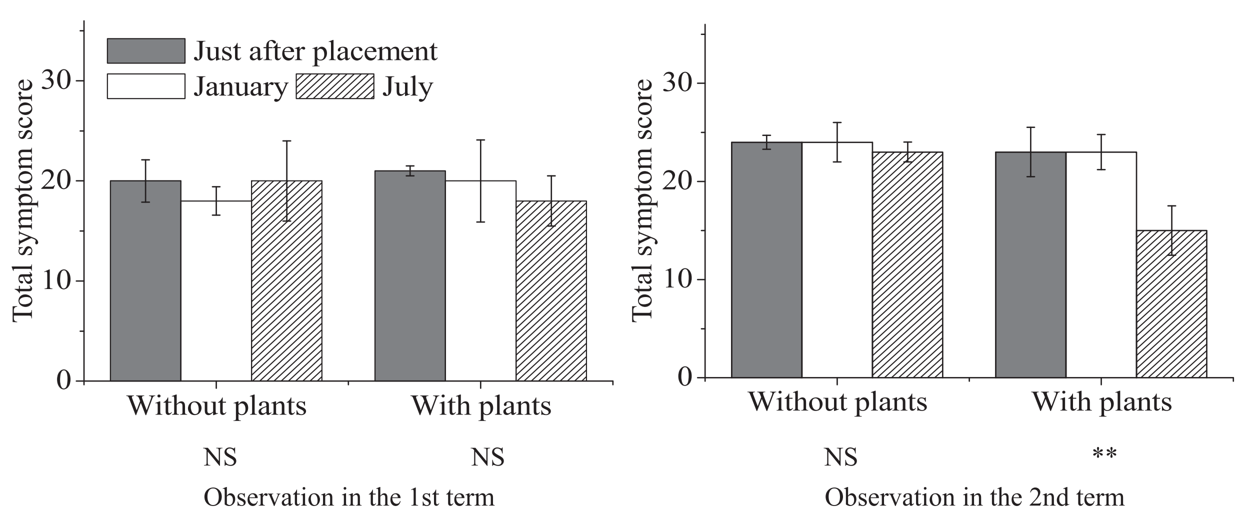

Fig. 1. Symptom evaluation of sick building syndrome as a total score according to indoor plant placement. Vertical bars represent SE of the means (n = 40 for without plants and 42 for with plants).
NS: Non-significance, ** significance at $P = 0.01$ by Kruskal-Willis test.
1st term: from indoor plant placement (early October, 2004) to the airtight (early January) and ventilation (early July) periods in 2005; 2nd term: from indoor plant placement (early October, 2005) to the airtight (early January) and ventilation (early July) periods in 2006.

Table 3. Evaluation of mental health according to indoor plant placement.

Duration	Indoor plant	Measure time	Symptom (Number of items)								
			SOM[z] (12)	O-C (10)	I-S (9)	DEP (13)	ANX (10)	HOS (6)	PHOB (7)	PAR (6)	PSY (10)
1st Term[y]	Without	January	42	39	46	41	42	44	50	45	46
		July	42	37	44	42	41	46	50	46	47
		P value[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
	With	January	44	38	44	40	40	48	49	44	46
		July	40	35	43	38	39	44	47	43	44
		P value	*	NS	NS	NS	NS	*	NS	NS	NS
2nd Term	Without	January	44	41	41	40	40	44	42	40	41
		July	45	41	41	40	40	44	43	41	40
			NS	NS	NS	NS	NS	NS	NS	NS	NS
	With	January	45	42	42	41	42	48	43	42	42
		July	40	37	38	37	38	41	41	40	39
		P value	*	*	*	*	*	**	NS	NS	NS
	LSD 0.05		7.1	4.7	3.8	5.0	4.5	8.5	3.8	4.6	3.8
	0.01		13.1	8.6	7.1	9.2	8.3	15.6	7.1	8.5	7.1

[z] SOM: somatization; O-C: obsessive-compulsive; I-S: interpersonal sensitivity; DEP: depression; ANX: anxiety; HOS: hostility; PHOB: phobic anxiety; PAR: paranoid ideation; PSY: psychoticism.
[y] 1st term: from indoor plant placement (early October, 2004) to the airtight (early January) and ventilation (early July) periods in 2005; 2nd term: from indoor plant placement (early October, 2005) to the airtight (early January) and ventilation (early July) periods in 2006.
[x] NS: non-significance, * significance at $P=0.05$, ** significance at $P=0.01$ by Wilcoxon's rank sum test.

Table 4. Vital capacity check for residents according to indoor plant placement.

Indoor plant	FVC[z] (mL)		FEV1 (mL)		FEV1/FVC (%)	
	January	July	January	July	January	July
Without	3,414±115[y]	3,434±108	2,804± 83	2,786± 81	82.4±0.8	81.4±1.1
With	3,681±154	3,710±145	2,986±105	2,990±100	81.8±1.4	81.1±1.0

[z] FVC: forced vital capacity; FEV1: forced expiratory volume for 1 s.
[y] Mean±SE.

Table 5. Changes in blood indices of residents according to indoor plant placement.

Indoor plant	ESR (mm/h)		WBC (cell/μL)		Change of TEC (%)	Change of T-IgE (cell/μL)
	January	July	January	July		
Without	13.00±2.70[y]	20.78±3.28	6,544±257	6,944±355	6.29±0.56	41.16±5.45
With	12.78±2.16	20.78±3.14	6,689±355	7,156±274	6.89±0.83	33.17±4.52

[z] ESR: erythrocyte sedimentation rate; WBC: white blood cell, TEC: total eosinophil count; T-IgE: Total immunoglobulin E.
[y] Mean±SE.

Discussion

According to the results of Figure 1, residents in newly built apartments seemed to experience a severe degree of SBS symptoms for at least two years without the combined application of ventilation and indoor plant placement. As it was already proved that certain toxic chemical substances responsible for SBS symptoms are emitted from building materials and newly manufactured furniture (Brasche et al., 1999; Carpenter, 1998; Carrer et al., 1999; Craighead, 1995; Krause et al., 1991), Lim et al. (2006) suggested frequent ventilation as an efficient way to reduce the degree of SBS symptoms. However, ventilation showed little difference in the degree of SBS symptoms in both observation terms in the condition without plants. The placement of indoor plants led to a significant decrease in the degree of SBS symptoms in the period of ventilation in the second term. Many researchers pointed out that the placement of plants in indoor space contributed to a decrease in SBS symptoms (Bell et al., 2001; Hartig et al., 1991; Herzog et al., 1997; Kaplan, 2001) (Fig. 1).

The mental health examination of residents indicated that ventilation hardly made a difference to SBS symptoms under the condition without indoor plants in both terms of observation. The placement of indoor plants resulted in noticeable results in reducing the symptoms of mental health such as SOM and HOS in the first term and SOM, O-C, I-S, DEP, ANX, and HOS in the second term. As for these results, many researchers showed evidence that the placement of indoor plants reduced physical fatigue, as well as improved mental health (Kondo and Toriyama, 1989; Shibata and Suzuki, 2001, 2002) (Table 3). Considering the results in Figure 1 and Table 3, it is postulated that the placement of indoor plants could efficiently reduce the degree of SBS symptoms of residents in the condition with ventilation.

The individual application of indoor plant placement or ventilation seemed to make little difference to the physical conditions of residents judging by vital capacity and blood indices. Especially, the dwellers without indoor plants seemed to have more potential sensitivity to some environmental factors because of their larger amount of T-IgE (Tables 4 and 5). In the final analysis of the results above, it was clear that the individual application of ventilation led to little improvement in mental health and physical condition of residents. There are two possible reasons for this. One could be that the indoor plants did not have enough ability to reduce the content of toxic chemical substances indoors. Therefore, residents seemed to attain only visual or olfactory effects from indoor plants. Also, the placement of indoor plants did not reduce the content of toxic chemical substances enough residents obtain improvements in mental health and physical condition because of the low efficiency of indoor plants. The supplementary application of ventilation seemed to improve the efficiency of reducing the content of toxic chemical substances by indoor plants. As a result, the placement of indoor plants could be recommended as an environmentally friendly method to reduce the content of toxic chemical substances indoors.

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