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Study of the removal difference in indoor particulate matter and volatile organic compounds through the application of plants

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This study was conducted to evaluate the ability of plants to purify indoor air by observing the effective reduction rate among pollutant types of particulate matter (PM) and volatile organic compounds (VOCs). PM and four types of VOCs were measured in a new building that is less than three years old and under three different conditions: before applying the plant, after applying the plant, and a room without a plant. The removal rate of each pollutant type due to the plant was also compared and analyzed. In the case of indoor PM, the removal effect was negligible because of outdoor influence. However, 9% of benzene, 75% of ethylbenzene, 72% of xylene, 75% of styrene, 50% of formaldehyde, 36% of acetaldehyde, 35% of acrolein with acetone, and 85% of toluene were reduced. The purification of indoor air by natural ventilation is meaningless because the ambient PM concentration has recently been high. However, contamination by gaseous materials such as VOCs can effectively be removed through the application of plants.

Keywords: Plant, Indoor air, Particle matter, Volatile organic compounds

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INTRODUCTION

Indoor air-borne loads of volatile organic compounds (VOCs) are usually significantly higher than those outdoors and chronic exposure to these compounds can cause health problems [1,2]. Although indoor air can be protected from pollution by the outdoor environment [3], in a lot of cases indoor air is more contaminated than outdoor air due to sealed rooms, various indoor building materials, and synthetic products such as furniture and carpets.

Another risk comes from the antimicrobial filters that are used in air cleaners, which can contain OIT(2-methyl-3(2H)-isothiazolone). Consequently, using plants to reduce indoor air pollution has recently gained attention for the safe management of air pollution. Since the 1980s, National Aeronautics and Space Administration has proven the efficacy of purifying indoor air quality in a sealed space by adapting the plants, their research is still ongoing [4-6]. However, although it has long been known that plants have an air purification effect, there has not been enough active effort to develop plants for air purification and there is still a lot of disagreement among experts about the results of studies on whether highly efficient air purification plants can be accommodated indoors [7,8].

Indoor air pollutants are classified into gaseous and particle pollutants, and research has shown that the mechanism for removing indoor particulate matter (PM) is mainly due to the adsorption by anions around the plant rather than a purification mechanism in which the pollutants are absorbed through the pores of the plant. In addition, indoor potted-plants can remove air-borne contaminants such as VOCs, over 300 of which have been identified in indoor air [9,10].

Recently, the concentration of ambient PM in Korea has been continuously increasing and the ability to purify indoor air by ventilation has decreased. The concentration of ambient PM

has influenced indoor concentration. Thus, if natural ventilation is not possible, then the indoor environment will be affected by VOCs, which are major pollutants in new buildings.

This study has compared the removal ability of PM and VOCs in indoor air quality purification by plants.

METHODS

In this study, PM and VOCs (i.e., benzene, toluene, ethylbenzene, and xylene) were measured in a new building that is less than three years old. Rubber trees, Rhapis, and Happy trees were selected among the plants in the Ficus genus because these plants were cheap, easy to obtain, and well-known to remove most indoor harmful gases.

PM, VOCs (i.e., benzene, toluene, ethylbenzene, and xylene), and aldehydes (i.e., formaldehyde, acetaldehyde, acrolein mixed with acetone) were measured a week before application of the plant and after application. Sampling of VOCs and aldehydes was conducted at three points: front, middle, and back of the room. PM was measured at the center for 30 minutes. The plant area occupied about 5% of the experimental space, and the plant can occupy up to about 8% of the space.

RESULTS

Table 1 shows the change of PM concentration according to the application of the plant. We used both case and control groups: the case applied plants and the control applied nothing. The case and control groups in two facilities were compared. The result of PM shows a statistical increment in the case group where plants were applied, which is antithetical to the previously known air purification ability of the plant. Therefore, PM is considered to be influenced by the outdoor environment. The plants were placed in the target building and the adaptation period was set for about two months. The reduction rate of fine dust according to the application of the plant was not confirmed. This is probably caused by an inflow of outdoor fine dust in the autumn.

In the case of the VOC substances that are shown in Table 2, the concentration of all substances in the case group applied with the plants and control group was observed to decrease, but there was no statistical significance in the control group. However, there was a statistically significant decrease in all substances except benzene. The result of examining the concentration reduction rate shows that 9% of benzene, 75% of ethylbenzene, 72% of xylene, 75% of styrene, 50% of formaldehyde, 36% of acetaldehyde mixed with acetone, and 85% of toluene were reduced. This suggests that plants in the space are helpful in reducing VOCs.

DISCUSSION

The present study carried out a study of the overall status of indoor air in association with indoor air quality by indoor plant intervention. The occurrence of anions in plants is dependent on the environmental condition in which the plants grow. It has

Table 1. The concentration variance in particulate matter according to plant application

Classify	Concentration (μg/m³)		*p*-value
	Before	After	
Day care center A (>1yr)			
Case	23.39±11.45	44.69±33.99	<0.01
Control	39.32±47.44	18.65±16.62	
Out door	58.39±50.52	41.44±25.41	
Day care center B (>2yr)			
Case	65.75±65.79	67.39±59.89	<0.01
Control	23.85±22.46	43.48±32.25	
Out door	36.57±51.37	121.07±97.75	

Values are presented as mean±standard deviation.

Table 2. Concentration variance in volatile organic compound substances according to plant application

Variable (μg/m³)	Case				Control			
	Before		After		Before		After	
	A	B	A	B	A	B	A	B
Benzene	6.04±1.58	3.63±1.60	4.25±3.26	3.70±2.79	34.50±106.94	4.45±2.67	5.81±9.79	3.96±3.56
Toluene***	446.41±112.25	51.53±16.74	45.53±51.50	20.00±19.65	209.14±253.05	79.29±90.27	37.43±45.38	15.65±19.25
Ethylbenzene***	39.58±11.79	3.10±1.65	6.31±10.16	3.24±4.160	19.70±24.92	3.97±5.40	5.48±8.85	2.13±3.14
Xylene***	32.03±9.29	6.19±3.13	4.92±7.65	5.70±6.64	18.61±23.58	8.92±11.12	4.30±7.18	3.90±5.43
Styrene***	46.87±12.55	6.27±3.57	10.35±13.23	3.84±6.87	24.40±31.00	6.96±10.09	7.70±11.57	1.06±2.07
Formaldehyde***	70.90±24.23	45.68±17.5	38.94±26.61	24.41±18.15	74.21±70.15	40.96±12.46	36.69±25.83	19.97±16.38
Acetaldehyde***	28.78±11.09	11.33±7.78	16.50±10.48	13.20±8.37	26.3±31.76	14.30±8.23	12.25±8.03	10.97±4.73
Acrolein+aceton***	90.78±24.76	27.78±17.03	46.35±29.16	37.55±16.74	70.57±31.76	49.06±24.09	43.00±28.38	32.12±13.93
Total	12	12	36	42	12	12	36	42

Values are presented as mean±standard deviation.
***p<0.001.

been reported that indoor plants are known to confer significant psychological and physical benefits to individuals living and working in environments where they are present, including reduced stress, increased task performance, and decreased symptoms of ill health [11]. It has also been observed that indoor concentrations of pollutants show a decreasing trend [12]. The present study has demonstrated that plants are a good method to purify indoor air when the influence of gaseous pollutants from new furniture is high in the building and natural ventilation is difficult because of a high concentration of PM outdoors. Plants are considered to have good air purification capability where there are no spatial limitations.

In conclusion, the purification of indoor air by natural ventilation is meaningless because the ambient PM concentration has recently been high. However, contamination of gaseous materials such as VOCs can effectively be removed through the application of plants. The results of this study shows that the reduction rate of PM is not observed but a statistically significant decrease of the concentration of VOCs is observed. PM is significantly affected by outdoor concentration, whereas VOCs mainly come from various indoor sources. Furthermore, it can be concluded that the change of pollutant concentration according to the application of plants proves that they can purify indoor pollutants.

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CONFLICT OF INTEREST

The authors have no conflicts of interest associated with the material presented in this paper.

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