Empirical Study on Ornamental Plants Mitigation Potential for VOCs Emissions from Construction Sealants in Buildings

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Abstract. This study investigates the potential of ornamental plants to mitigate Volatile Organic Compounds (VOCs), a major concern for improving indoor air quality in buildings. The empirical study employed a two-stage approach to quantify plant performance against construction sealant emissions. First, a controlled chamber test was conducted to assess the individual VOCs absorption capacities of nine ornamental plants. Second, those high-performing plants were selected for a subsequent mock-up room test to simulate the real-size effect in practical application. Results from both tests consistently showed that *Spathiphyllum sp.* and *Hedera helix L. cv. Glacier* exhibited high mitigation potential performance for VOCs emissions, where *Chlorophytum bichetii (Karrer) Backer* emerged as the most effective in the mock-up room test. These findings suggested that the significant reduction in VOCs concentrations depend upon species-specific variation in phytoremediation efficiency, necessitating a selective approach to plant specification. It is also recommended that the strategic integration of these biophilic design interventions, as ornamental plant placement, with mechanical ventilation strategies can be allied for a holistic approach to enhancing indoor air quality and supporting occupant health and well-being.

1 Introduction

The quality of indoor air has emerged as a critical public health concern, particularly in developed nations where occupants spend over 80% of their time within enclosed spaces [1]. Modern building practices, which prioritize energy efficiency through enhanced air tightness and reduced ventilation, inadvertently lead to the accumulation of various chemical pollutants, resulting in indoor concentrations significantly higher than outdoor levels [2]. Among the most problematic of these contaminants are Volatile Organic Compounds (VOCs), a diverse group of organic chemicals characterized by their high vapor pressure at room temperature. Common indoor sources of VOCs are household products, cleaning agents, furniture, and crucially, building and finishing materials. Construction sealants, adhesives, paints, and varnishes are recognized as significant, long-term emitters of VOCs [3]. Chronic

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exposure to these compounds has been associated with a spectrum of adverse health outcomes, contributing to Sick Building Syndrome (SBS), and ranging from minor irritations of the eyes, nose, and throat to more severe neurological effects, respiratory dysfunction, and increased risk of cancer [1, 2]

Addressing this challenge requires cost-effective and energy-efficient strategies to complement traditional methods like mechanical ventilation, which entails high operating costs. Biophilic design strategies, or the use of living plants to degrade or absorb has garnered substantial attention as an alternative for enhancing indoor air quality [4]. Studies by NASA in the 1980s first established the potential of common ornamental potted plants to remove key VOCs from sealed environments, paving the way for numerous subsequent studies [5]. The detoxification mechanism is a complex process involving the absorption of gaseous pollutants through the stomata, the direct adsorption onto the leaf cuticle, and the biological degradation of VOCs by the symbiotic microbial communities residing in the root system and on the surface. Species like *Chlorophytum comosum*, *Spathiphyllum wallisii* and *Epipremnum aureum* have shown varying degrees of efficacy in mitigating pollutants like formaldehyde and benzene [4]. However, the application of this technology, particularly in neutralizing emissions from specific, high-flux sources like construction sealants, requires further focused investigation to validate its practical effectiveness under typical indoor conditions.

Despite the VOCs mitigation potential of ornamental plants, a significant research gap remains in quantifying their performance against the emission profiles of specific building materials. Construction sealants, used widely in building envelopes, joints, and perimeter gaps, release a complex mixture of VOCs over prolonged periods. Therefore, a controlled study is necessary to assess the absorption capacity of common indoor plants against these direct and persistent sources of pollution. The objective of this study is to investigate and quantify the VOCs mitigation potential of ornamental plants against the emission flux originating from commonly used construction sealants in a controlled environment to provide empirical data to support the recommendation of specific plants for a biophilic approach to improving indoor air quality in buildings.

2 Method

2.1 Chamber test

To assess the potential of ornamental plants to mitigate VOCs emissions, a series of controlled chamber tests were undertaken. Nine ornamental plant species commonly used in Thai residential and commercial interiors were selected for evaluation. Selection criteria were based on an extensive review of literature focusing on tropical and widely cultivated indoor plants known for their high pollutant-removal capacity, alongside consideration of their commercial availability and popularity in the Thai ornamental plant market. They were selected as *A) Sansevieria trifasciata Prain, B) Chlorophytum comosum Jacques, C) Hedera helix L. cv. Glacier, D) Aglaonema spp., E) Spathiphyllum sp., F) Aglaonema modestum Schott, G) Philodendron xanadu, H) Dracaena braunii Engl.,* and *I) Chlorophytum bichetii (Karrer) Backer*, as shown in Figure 1.

Chamber tests were conducted in a clear acrylic chamber with an internal volume of 0.216 m³ (0.60 × 0.60 × 0.60 m). Each plant was tested individually under controlled temperature (25 ± 2 °C) and relative humidity (50 ± 5%) conditions, with no external air exchange. Silicone-based sealant consisted of a 40-cm strip, as a popular-used construction product for interior construction and finishing, was set as VOCs sources. The two experimental configurations were designed to isolate the influence of plants on VOCs absorption. In the treatment condition, the chamber contained the plant together with its pot, soil, and a VOCs emitting source, as the silicone-based sealant. Meanwhile, in the control condition, VOCs source was placed inside the chamber, allowing comparison of concentration decay attributable specifically to the plant. VOCs concentrations were monitored for 4,320 minutes, with measurements logged at 15-minute intervals, using the Qingping Pro+ Air Quality Monitor, which incorporates Sensirion gas sensors and a 1.2 GHz A7 processor for high-resolution detection. Absorption efficiency for each was calculated from the difference in total VOCs levels between with-plant and without-plant chambers, expressed as absorption capacity using the area under the curve (AUC) to summarize their effect over a period.

A) Sansevieria trifasciata Prain
B) Chlorophytum comosum Jacques
C) Hedera helix L. cv. Glacier
D) Aglaonema spp.
E) Spathiphyllum sp.
F) Aglaonema modestum Schott
G) Philodendron xanadu
H) Dracaena braunii Engl.
I) Chlorophytum bichetii (Karrer) Backer

Fig. 1. Chamber test setups with ornamental plants for absorption capacity to mitigate VOCs emissions

2.2 Mock-up room test

Plants demonstrating the highest VOCs mitigation potential from the chamber test were selected for testing in a mock-up room designed to represent real-world conditions in residential and commercial interior spaces. In the mock-up room experiment, the full-scale environment was conducted in a laboratory room measuring 2.60 x 2.80 x 3.00 m, in an area of 7.28 sq. m, as shown in Figure 2. The four sets of 80-cm strip silicone-based sealants were utilized as VOCs emitting source. VOCs concentrations were monitored for 4,320 minutes, with measurements logged at 15-minute intervals, using the Qingping Pro+ Air Quality Monitor. Air circulation was managed by a typical floor fan place inside the room.

Test 1) Hedera helix L. cv. Glacier
Test 2) Spathiphyllum sp.
Test 3) Sansevieria trifasciata Prain
Test 4) Chlorophytum bichetii (Karrer) Backer

Fig. 2. Mock-up room test setups with ornamental plants to mitigate VOCs emissions in practical applications

In the treatment conditions, twenty ornamental plants were placed in hanging pots mounted on the shelving unit, with the tripod-mounted supplemental lighting positioned in front of the plants. In the control condition, only the plants were removed while all other elements of the setup remained unchanged, allowing VOCs concentration decay to be attributed specifically to the presence of the plants. Absorption efficiency for each test was calculated based on the difference VOCs levels between the with-plant and without-plant conditions as absorption capacity using the AUC to summarize effect over a period.

3 Results and discussions

3.1 Plant absorption capacity in chamber test

Two experimental setups, the treatment and control environments, were implemented to evaluate the effect of plants on VOCs absorption, as shown in Figure 3. For each plant, the approximate area under the concentration versus time curve was calculated for both setups. The difference between these two was taken as the net VOCs absorption capacity by to the plant, as shown in Table 1. *Hedera helix L. cv. Glacier* and *Spathiphyllum sp.* exhibited the largest VOCs removal, each with an absorption amount of 0.88 mg/m³, indicating superior removal capability within the chamber environment. These were followed by *Sansevieria trifasciata Prain* (0.80 mg/m³), *Chlorophytum bichetii (Karrer) Backer* (0.78 mg/m³), and *Aglaonema modestum Schott* (0.77 mg/m³), which also demonstrated strong absorption performance. Moderate efficiencies were observed for *Dracaena braunii Engl., Chlorophytum comosum Jacques,* and *Philodendron xanadu,* with absorption amounts ranging from 0.70 to 0.76 mg/m³. In contrast, *Aglaonema spp.* showed the lowest performance (0.35 mg/m³), suggesting limited capacity to reduce VOCs concentrations under the test conditions. Overall, species with larger leaf area appeared particularly effective for indoor VOCs mitigation applications.

The high performance of *Hedera helix L. cv. Glacier* and *Spathiphyllum sp* has demonstrated in VOCs removal [5] and found to be highly effective in active botanical biofilters and green-wall systems [6, 7]. Plant-mediated VOCs reduction involves multiple pathways and plant surfaces are also critical contributors [4, 5]. While a larger leaf surface area is beneficial for passive uptake, the overall net removal rate is also influenced by substrate characteristics and rhizosphere activity [7].

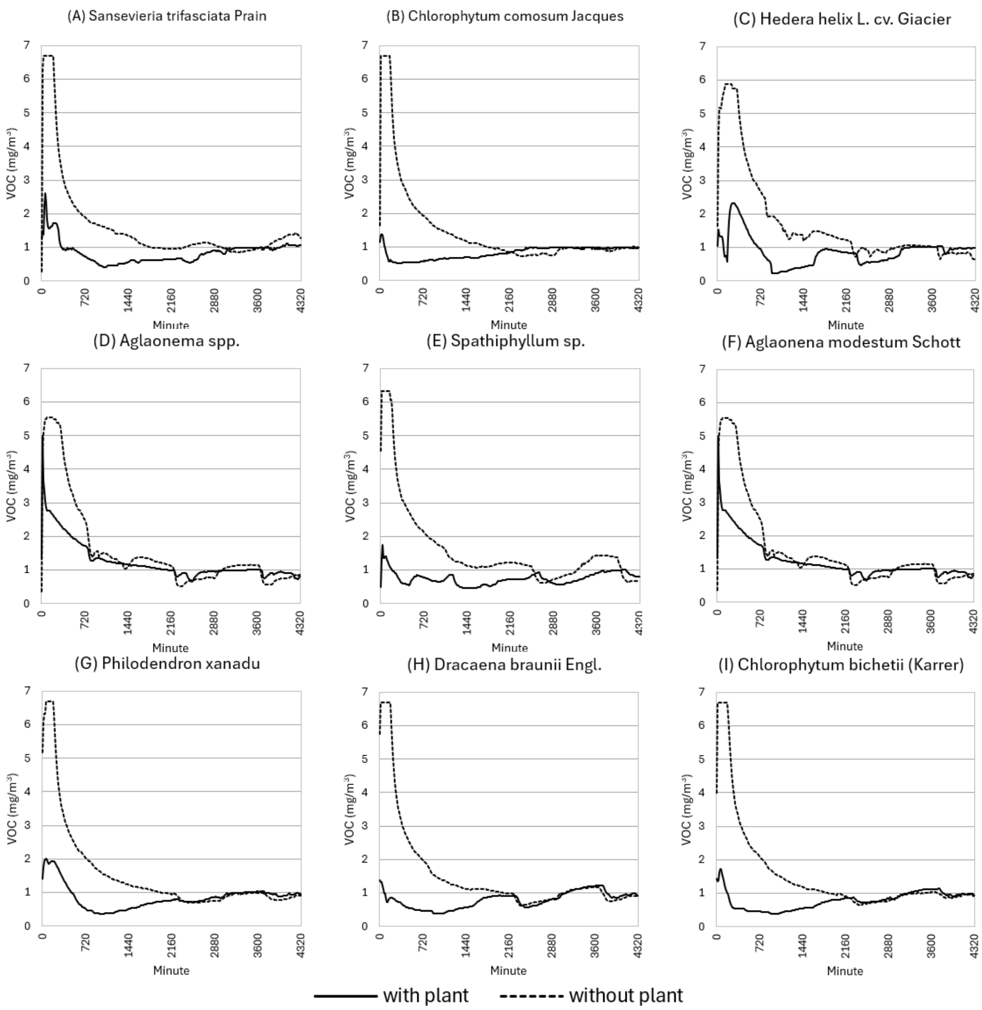

Fig. 3. Chamber test results of total VOCs concentration within 4,320 minutes comparing test with and without plants as A) *Sansevieria trifasciata Prain*, B) *Chlorophytum comosum Jacques*, C) *Hedera helix L. cv. Glacier*, D) *Aglaonema spp.,* E) *Spathiphyllum sp.,* F) *Aglaonema modestum Schott,* G) *Philodendron xanadu,* H) *Dracaena braunii Engl.,* and I) *Chlorophytum bichetii (Karrer) Backer.*

Table 1. Assessment of VOCs absorption by ornamental plants in a chamber test using area under the curve (AUC) analysis

Test	Plants	Area under the curve (mg/m^3)		Absorption amount (mg/m^3)	Absorption capability (mg/min/m^3)
		with plants	without plants		
A	*Sansevieria trifasciata Prain*	3,586	6,973	3,387	0.80
B	*Chlorophytum comosum Jacques*	3,487	6,448	2,961	0.70
C	*Hedera helix L. cv. Giacier*	3,735	7,464	3,729	0.88
D	*Aglaonema spp.*	5,351	6,853	1,502	0.35
E	*Spathiphyllum sp.*	3,200	6,951	3,752	0.88
F	*Aglaonena modestum Schott*	3,717	6,988	3,271	0.77
G	*Philodendron xanadu*	3,637	6,609	2,972	0.70
H	*Dracaena braunii Engl.*	3,374	6,616	3,242	0.76
I	*Chlorophytum bichetii (Karrer) Backer*	3,340	6,676	3,336	0.78

3.2 VOCs mitigation potential by plant in mock-up room test

Based on the results of the chamber experiments, four ornamental plant species demonstrating the greatest VOCs removal potential were identified and selected for further investigation: *Hedera helix L. cv. Glacier, Spathiphyllum sp., Sansevieria trifasciata Prain,* and *Chlorophytum bichetii (Karrer) Backer*. These species were subsequently evaluated in a mock-up experiment, in which 20 pots of each plant were installed. The mock-up room was designed to replicate the dimensions and construction materials of typical residential and commercial indoor environments, allowing VOCs removal performance to be assessed under conditions more representative of occupied buildings. The test results obtained with and without plants in the mock-up room are presented in Figure 4.

Table 2 presents a quantitative comparison of VOCs absorption performance among the four selected ornamental plant species in the mock-up room, based on area under the curve analysis of VOCs concentration versus time profiles with and without plants. The results indicate that the introduction of plants substantially reduced cumulative VOCs exposure compared to the unplanted condition. *Chlorophytum bichetii (Karrer) Backer* exhibited the highest VOCs absorption amount (3,335 mg/m^3) and the greatest absorption capability (0.77 mg/min/m^3), demonstrating superior removal efficiency under the simulated indoor conditions. *Spathiphyllum sp.* also showed strong performance, achieving an absorption amount of 2,692 mg/m^3 with an absorption capability of 0.62 mg/min/m^3, followed by *Hedera helix L. cv. Glacier* (2,281 mg/m^3; 0.53 mg/min/m^3). In contrast, *Sansevieria trifasciata Prain* displayed limited VOCs removal, with a relatively small difference between planted and unplanted conditions, resulting in a low absorption amount of 225 mg/m^3 and an absorption capability of only 0.05 mg/min/m^3.

The considerable variability in VOCs removal effectiveness among species can be attributed to two primary factors: plant size and leaf surface area [5, 8]. In the case of *Sansevieria trifasciata Prain*, the tested plants were of moderate size with relatively limited leaf area, which likely constrained VOCs uptake. Conversely, *Spathiphyllum sp.* and *Chlorophytum bichetii (Karrer) Backer* were fully grown and possessed substantially larger leaf areas, contributing to their higher VOCs absorption performance. Notably, despite having comparatively smaller leaf areas, *Hedera helix L. cv. Glacier* exhibited relatively high VOCs absorption. This suggests that factors beyond leaf area alone, such as leaf morphology or physiological characteristics, may also play an important role in VOCs removal.

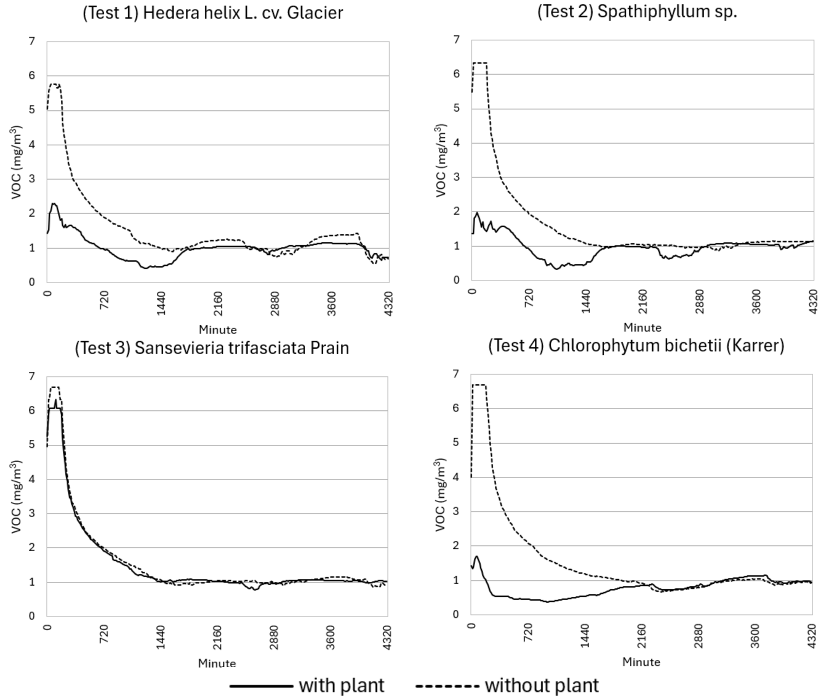

Fig. 4. Mock-up room test results of total VOCs concentration within 4,320 minutes comparing test with and without plants as Test 1) *Hedera helix L. cv. Glacier,* Test 2) *Spathiphyllum sp.,* Test 3) *Sansevieria trifasciata Prain,* and Test 4) *Chlorophytum bichetii (Karrer) Backer.*

Table 2. Assessment of VOCs absorption by ornamental plants in a mock-up room using area under the curve (AUC) analysis

Test	Plants	Area under the curve (mg/m^3)		Absorption amount (mg/m^3)	Absorption capability (mg/min/m^3)
		with plants	without plants		
1	*Hedera helix L. cv. Glacier*	4,343	6,624	2,281	0.53
2	*Spathiphyllum sp.,*	4,122	6,813	2,692	0.62
3	*Sansevieria trifasciata Prain*	6,596	6,821	225	0.05
4	*Chlorophytum bichetii (Karrer) Backer*	3,398	6,732	3,335	0.77

3.3 Application of ornamental plants in buildings

Based on maintenance observations made by researchers during this study, the ornamental plants exhibited clear differences in ease of care and suitability for long-term indoor application, as summarized in Table 3. The maintenance score ranged from 1, representing plants that were easy to maintain, to 3, indicating plants that were more difficult to maintain. Those assigned a maintenance score of 1, including *Dracaena braunii Engl., Sansevieria trifasciata Prain,* and *Chlorophytum bichetii (Karrer) Backer*, were found to be the most resilient under indoor conditions and required low maintenance. Plants classified with a moderate maintenance score of 2, such as *Chlorophytum comosum Jacques, Aglaonema spp.,* and *Philodendron xanadu*, required more regular attention, particularly with respect to watering and lighting, but remained suitable for indoor environments. In contrast, palnts assigned a maintenance score of 3, including *Spathiphyllum sp., Aglaonema modestum Schott,* and *Hedera helix L. cv. Glacier,* were more sensitive to indoor environmental fluctuations and required greater care to maintain. These findings indicate that maintenance requirements vary substantially among ornamental plant species and should be considered alongside VOCs removal performance. For sustainable indoor air quality improvement, plant selection can consider specific light, water, and humidity requirements to ensure the biological filtration remains active [8].

When additional practical factors, particularly maintenance requirements, are taken into account, the optimized evaluation of ornamental plants based on both VOCs absorption capability and ease of maintenance reveals distinct groupings relevant to indoor application. *Sansevieria trifasciata Prain, Chlorophytum bichetii (Karrer) Backer,* and *Dracaena braunii Engl.* demonstrate a favorable balance between VOCs removal performance and low maintenance demand, indicating potential suitability for indoor environments where regular plant care may be limited. *Chlorophytum comosum Jacques* and *Philodendron xanadu* exhibit moderate VOCs absorption with manageable maintenance requirements, suggesting conditional applicability depending on available care and environmental conditions. In contrast, *Spathiphyllum sp.* and *Hedera helix L. cv. Glacier*, despite exhibiting high VOCs absorption capability, require greater maintenance effort, which may constrain their long-term use in typical indoor settings. *Aglaonema spp.* shows comparatively low VOCs absorption. Overall, these findings suggest that *Sansevieria trifasciata Prain, Chlorophytum bichetii (Karrer) Backer,* and *Dracaena braunii Engl.* can be considered for indoor environments aimed at supporting VOCs reduction and indoor air quality improvement, subject to appropriate placement and maintenance conditions.

Table 3. Maintenance score and absorption ability of ornamental plants used in this study

Plants	Maintenance score	VOCs Absorption capability (mg/min/m^3)
Dracaena braunii Engl.	1	0.76
Sansevieria trifasciata Prain	1	0.80
Chlorophytum bichetii (Karrer) Backer	1	0.78
Chlorophytum comosum Jacques	2	0.70
Aglaonema spp.	2	0.35
Philodendron xanadu	2	0.70
Spathiphyllum sp.	3	0.88
Aglaonema modestum Schott	3	0.77
Hedera helix L. cv. Glacier	3	0.88

4 Conclusion

The mitigation of VOCs is a critical challenge in improving indoor air quality. These pollutants are commonly emitted from construction materials and are associated with a range of adverse health effects. Addressing this issue requires cost-effective and energy-efficient strategies that can complement conventional mechanical ventilation systems. This study investigated the potential of ornamental plants as a nature-based and passive strategy for indoor air purification. A two-stage experimental approach was employed to quantify the VOCs removal performance of common indoor plants. In the chamber experiments, nine ornamental plant species were evaluated under controlled conditions. *Hedera helix L. cv. Glacier* and *Spathiphyllum sp.* exhibited the highest VOCs absorption. Based on the results, four high-performing plant species were selected for further evaluation in a mock-up room environment. Under these conditions, *Chlorophytum bichetii (Karrer) Backer* demonstrated the highest VOCs removal efficiency. Overall, the findings confirm that ornamental plants can serve as a viable supplementary strategy for mitigating indoor VOCs concentrations and improving indoor air quality.

Plant size and leaf surface area are widely recognized as critical factors influencing the VOCs removal performance of ornamental plants, as larger or denser foliage can increase the effective area for gas exchange and pollutant uptake. In this study, differences in VOCs absorption performance among plant species may therefore be partly attributable to variations in plant size and leaf area. However, these parameters were not quantitatively measured or controlled, and detailed morphological data were not collected. Observations regarding plant size and leaf area were based solely on visual assessment by the researchers during the experimental period. As a result, the findings should be interpreted as indicative of overall plant performance under the tested conditions rather than as a comparison of intrinsic physiological efficiency among species. Future research should incorporate systematic measurements of leaf area, biomass, or plant maturity and normalize VOCs removal rates accordingly to provide a more precise evaluation of plant-related factors influencing indoor VOCs mitigation.

This research budget was allocated by National Science Research and Innovation Fund (NSRF), and King Mongkut's University of Technology North Bangkok (Project no. KMUTNB-FF-68-B-63).

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