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Research Article

Indoor TVOC Emissions from Residential Construction Materials and the Role of Ornament Plants in Mitigation

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Abstract

Volatile organic compound (VOC) emissions from building materials are a primary source of indoor air pollution. This study investigated total volatile organic compound (TVOC) emission profiles from five materials commonly used in Thai residential buildings, including paint color, engineered wood, and sealants, and evaluated the mitigation potential of nine ornament plants using controlled chamber tests. TVOC concentration monitoring results revealed that silicone-based sealants produced high initial emissions with rapid decay patterns. To assess phytoremediation efficiency, ornament plants were then introduced into chamber tests. The results demonstrated significant variation in plant TVOC uptake. *Dracaena braunii* Engl. emerged as the effective species, achieving an absorption rate per leaf surface area of 20.42 $mg/m^3.m^2$. These findings underscore that while construction material emissions posed degrees of respiratory risks, strategic plant selection offered a viable solution for improving indoor air quality. Ornament plants can significantly accelerate TVOC mitigation, providing a practical framework for enhancing well-being in post-construction residential environments.

Keywords: Indoor air quality, Ornament plants, Residential construction materials, Total volatile organic compounds

1 Introduction

Indoor air quality (IAQ) is a critical element for achieving occupant health, comfort, and productivity within built environments [1]. Energy efficiency requirements in buildings, which often result in greater airtightness, can unintentionally increase indoor pollutant concentrations, thereby intensifying concerns about IAQ. Among the various pollutants, Volatile organic compound (VOC) is recognized as major contributors to indoor air contamination, emitted from a wide range of building and finishing materials, including paints, adhesives, sealants, silicone-based products, engineered wood, laminated surfaces, flooring materials, and furniture [2], [3]. VOCs are carbon-based materials with high vapor pressure at room temperature, facilitating their release into indoor environments long after application [4]. The emissions are influenced by their chemical composition. In paints, for example, pigments and additives play a critical role, with darker or more saturated colors often relying on petroleum-based or heavy-metal-containing compounds that produce higher emissions than certified low-VOC or zero-VOC formulations [5], [6].

Initial off gassing tends to decline within the first days or weeks after construction or renovation, but emissions may persist for months or years depending on material properties and ventilation conditions. Exposure to VOC is associated with both acute and chronic health effects [7]. Short-term exposure can trigger symptoms of Sick Building Syndrome (SBS), including headaches, mucous membrane irritation, and dizziness [8], [9], while prolonged exposure is linked to hepatic and renal damage, central nervous system disorders, and elevated risks of certain cancers [10], [11]. Furthermore, common indoor VOCs like formaldehyde and benzene are classified as known human carcinogens [12].

The World Health Organization (WHO) indicates that total volatile organic compound (TVOC) concentrations exceeding 500 μg/m³ can cause discomfort and sensory irritation, and levels above 1,000 μg/m³ may lead to chronic respiratory and long-term health issues [13]. Given that urban populations spend approximately 90% of their time indoors, managing indoor VOC levels is essential for occupant well-being, cognitive performance, and productivity [14].

The residential environment utilizes materials that contain or release VOC, creating a high surface-to-volume ratio that significantly contributes to indoor air pollution. Primary sources include structural components and finishing products such as engineered wood, paints, sealants, adhesives, and coatings. These products were required by the Leadership in Energy and Environmental Design (LEED), which promoted healthier indoor environments, to undergo rigorous testing and to establish strict VOC content limits [15]. These requirements defined acceptable indoor VOC concentration thresholds of 0.5 mg/m³, reinforcing the role of green building practices in minimizing occupant exposure and supporting sustainable building design [16].

To mitigate VOC, a comprehensive approach combining source control with ventilation and filtration is essential [17]. It is crucial for selecting low-emission or certified green-label products since their vast surface coverage can lead to significant cumulative emissions. When materials are applied, mechanical systems must prioritize an initial decay period, providing intensive ventilation during the critical beginning hours to exhaust peak concentrations. For long-term air quality management, mechanical systems should maintain high air exchange rates to dilute persistent low-level releases and utilize targeted exhaust in high-emission zones [9]. Additionally, these strategies and filtration as phytoremediation through ornament plants can act as a bio-filter [18], offering sustained absorption of remaining pollutants

As traditional physiochemical air filtration methods often entail high maintenance and energy costs, the use of ornament plants, as phytoremediation, has emerged as a sustainable alternative for improving indoor air quality [18]. The concept of internal biological air cleaning originated with the National Aeronautics and Space Administration (NASA) Clean Air Study in the late 1980s, which demonstrated the ability of potted plants to remove common indoor pollutants [20]. Early scaling metrics, derived from this seminal work, suggested that air-purifying plants in mid-sized containers could potentially clean the air of an average house [21]. Laboratory investigations have clarified that VOC removal was achieved through a combination of direct and indirect mechanisms. Direct absorption occurred through the plant foliage, where leaf cuticles can physically adsorb VOC. *Nematanthus*, *Chlorophytum orchidastrum, Nephrolepis cordifolia,* and *Schefflera arboricola* showed significant performance, with VOCs removal [22]. The VOC removal efficiency could be evaluated based on the rate of transpiration and the concentration of chlorophyll [23].

Controlled chamber studies have consistently shown that removal efficacy varies depending on plant selections and environmental conditions [21], [24], [25]. Targeted testing against chemical substances has identified resilient and highly effective families from *Araliaceae, Asparagaceae*, and *Araceae*, demonstrating a high absorption ability for common pollutants [12], [26]-[28]. These studies underscored that the performance of phytoremediation is influenced by factors, such as plant selection, light intensity, and pollutant concentration. Despite clear efficacy in laboratory settings, the median clean air delivery rate of passive potted plants has been found to be low [21]. This limited removal capacity means that achieving meaningful mitigation in residential spaces would require an impractically high plant density [11]. This challenge has driven the development of active botanical biofilters, or green wall systems [29]. The advanced horticultural technologies overcame the limitations of passive diffusion by mechanically forcing contaminated indoor air through the root matrix and substrate, thereby maximizing contact with the highly active rhizosphere microbial community [30].

In the tropics, such as Thailand, indoor TVOC necessitated climate-specific protocols [31]. The Thai Rating of Energy and Environmental Sustainability (TREES) standard marked a TVOC concentration of 0.5 mg/m³ before occupancy [32]. The synergy of temperature and relative humidity played a primary role, accelerating off-gassing rates and diffusion dynamics of materials [33], [34]. It was often compounded by mechanical cooling practices that prioritize energy conservation by minimizing air exchange rates. Studies have identified solvent-based paints and adhesives as major contributors to poor indoor air quality, with monitoring data revealing carcinogenic compounds, such as benzene, exceeding recommended thresholds. Consequently, chamber testing has become an indispensable methodology for simulating localized conditions and screening materials based on their actual performance in tropical environments [35]. Establishing these assessment protocols was essential for developing localized building standards and mitigation strategies [36]. In terms of phytoremediation efficiency, the family of *Asparagaceae* exhibited high efficiency in VOCs removal through stomatal uptake and cuticular wax [37].

Growing awareness of these health risks has contributed to the green building certifications, which include requirements under the low-emitting materials and indoor air quality credits [15], [32]. Despite international guidelines, practices are rarely adopted in Thailand due to a lack of verified VOC emission data for local materials. Many common building materials remain untested or lack standardized certification. This gap restricts the ability of designers, contractors, and regulators to make informed decisions on material selection and indoor air quality management. There is limited empirical data on the TVOC emission characteristics of construction materials commonly used in Thai residential buildings, making it difficult to evaluate the effectiveness of ornament plants in mitigating these pollutants. Bridging this research gap will provide the empirical evidence needed to inform material selection and support the implementation of phytoremediation strategies. By addressing these objectives, this study aims to investigate TVOC emissions from construction materials and to evaluate the mitigation potential of ornament plants for improving indoor air quality.

2 Materials and Methods

2.1 *Material settings*

This study investigated the emissions of TVOC from construction materials commonly used in high-end residential condominiums in Bangkok, Thailand. The case study focused on a super-luxury residential condominium project, with unit prices ranging from 6,000-6,500 USD/m^2. The selection of construction materials and specifications for this research was sourced from the building specification sheets of the projects. Architectural elements such as paint color, engineered wood flooring, and sealants were recognized as major contributors to indoor TVOC levels, and this study therefore emphasized interior application and finishing materials that represented typical construction practices in Thai condominiums. Five representative construction material products were selected for TVOC emission testing as: acrylic water-based paints, engineered wood flooring, and sealants, as shown in Table 1.

2.2 *Emission testing*

To evaluate TVOC emissions from residential construction materials, chamber experiments were conducted.

The setups were tailored to the characteristics of the tested samples, replicating the chamber test method established by ISO 16000-9 (2006) [38]. A clear acrylic chamber with a fixed internal volume of 0.216 m^3 (0.60 × 0.60 × 0.60 m) was employed. The sampling selected materials under controlled environmental settings is illustrated in Figure 1. The paint color and sealants were typically applied onto cement-based panels and allowed to dry briefly before being placed in the chamber.

Table 1. Selected construction material products used in typical residential units in this study.

Materials	Description	Applied to	Area (mm^2)
Wall paint	Acrylic water-based paint for interior use	Interior wall	500x500
Engineered wood flooring	Laminated engineered wood with high density fiberboard (HDF) core uses a decorative film and a durable wear layer.	Wooden flooring	400x450
Acid-based silicone sealant	An acid type silicone used for sealing joints, highly flexible and suitable for sealing, leaking prevention and common sealing.	Gaps in the aluminum frame and glass	400x1
Non-acid silicone sealant	A nonacid type of neutral silicone used for sealing joints. It is low odor, highly flexible, and suitable for common sealant and gluing job.	Gaps in the aluminum frame and glass	400x1
Acrylic sealant	Acrylic Sealant, water-based, fast skinning, high elastic acrylic sealant which cures in contact with air and humidity, with high adhesion performance on different materials.	Gaps in woodworking	400x1

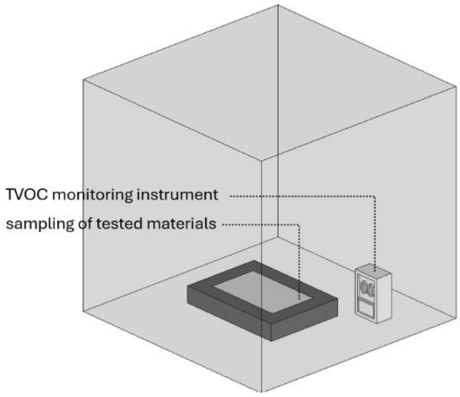

Figure 1. Chamber test setups in controlled environments for construction materials emissions testing.

The experimental setup was set to an enclosed chamber without an air change rate (ACH) for a static test from incoming diluted air (Table 2). Temperature and humidity were monitored and controlled (temperature (29.1 ± 0.7 °C) and relative humidity (76 ± 7%)). Their surface loading factors were calculated as the ratio of exposed area (m^2) to chamber volume (m^3), resulting in values ranging from 0.02 to 1.16 m^2/m^3.

TVOC concentrations were monitored using the Qingping Pro+ Air Quality Monitor. Its performance was validated by the third-party evaluations from the South Coast Air Quality Management District, with reference-grade instruments. The processing integrated the Sensirion SGP30 gas sensor, which ensured a TVOC accuracy of ±20% through high-resolution detection, powered by a 1.2 GHz A7 processor to maintain real-time data processing. The device recorded at 15-minute intervals over a duration of 4,320 minutes, producing time-dependent emission profiles for each material. To account for background interference, blank chamber tests were conducted prior to sample measurement under the controlled environments, while the background levels were subtracted from the recorded values.

Table 2. Controlled environments in the chamber setups for construction materials emission testing.

Materials	Temperature (°C)	Relative humidity (%)	Loading factor (m^2/m^3)
Wall paint	29.0	76.2	1.16
Engineered wood flooring	30.3	75.7	0.83
Acid-based silicone sealant	28.8	65.3	0.02
Non-acid silicone sealant	29.1	67.8	0.02
Acrylic sealant	30.7	69.2	0.02

2.3 Ornament plant mitigation testing

To evaluate the potential of ornament plants in mitigating TVOC emissions in indoor environments, a series of controlled chamber experiments was conducted. Nine ornament plants in a 4-inch pot size commonly cultivated in Thai residential and commercial interiors were selected for this study, namely *Sansevieria trifasciata* Prain, *Chlorophytum comosum* Jacques, *Hedera helix* L. cv. Glacier, *Aglaonema* spp., *Spathiphyllum* sp., *Aglaonema modestum* Schott, *Philodendron xanadu, Dracaena braunii* Engl., and *Chlorophytum bichetii* (Karrer) Backer, as illustrated in Figure 2. The plant specimens had a cultivation maturity ranging from 1-12 months, corresponding to the commercial pot sizes typically found in the Thai market. To isolate the TVOC absorption capacity of each plant, two experimental setups were performed to isolate the effect of with-plant conditions, replicating the chamber test method of the emission testing mentioned in subsection 2.2, as illustrated in Figure 3. In the first experiment or a control condition, the TVOC source was placed inside the chamber, without the plants, as illustrated in Figure 3a. In the second experiment or treatment conditions, the chamber contained the plants and the TVOC source, as illustrated in Figure 3b. This enabled a direct comparison of TVOC concentration decay rates attributable to the plant, excluding the background influence of soil and container. The TVOC source consisted of a 40-cm strip of non-acid silicone sealant.

As detailed in Table 3, each plant setup was placed in the chamber individually under controlled conditions of temperature (23.3 ± 1.1 °C)and relative humidity (81 ± 13%), with TVOC concentrations monitoring at 15-minute intervals over a duration of 4,320 minutes. Illuminance levels within the testing area, located near a glass window to utilize natural daylight for plants, were monitored at 15-minute intervals.

Figure 2. Ornament plants used for mitigation testing.

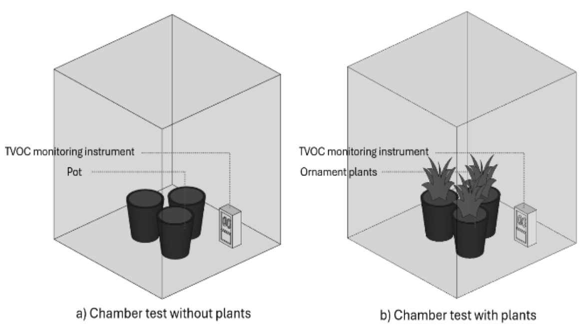

Figure 3. Chamber test setups in controlled environments without plants (a) and with plants (b)

It was recorded using a UNI-T UT381A illuminance meter, yielding a mean daytime illuminance of 2,015 lux. The TVOC emission profile was analyzed using descriptive statistics to characterize decay patterns and to estimate the time required for concentrations to decline to the LEED v4 threshold of 0.5 mg/m³. This combined experimental and analytical approach enabled differentiation of materials based on both their initial emission intensities and long-term off-gassing behaviors. Absorption efficiency was determined by comparing total TVOC decay rates between the with-plant and without-plant setups, expressed as both percentage reduction and net decay acceleration. For each setup, absorption efficiency was also quantified as absorption capacity using the area under the curve (AUC) analysis to summarize effects over time.

For comparisons of TVOC absorption capacities, the total leaf area of each plant was determined using an image-based measurement method with scale calibration. Individual leaves were placed on a white background alongside a ruler as a reference object to ensure accurate scaling. Images were captured with the camera positioned perpendicular to the leaf surface. They were then imported into AutoCAD software to trace leaf boundaries using the polyline and the enclosed area tools. The measured values were summed to obtain the total leaf area per plant for further analysis of absorption performance, as detailed in Table 3.

Table 3. Controlled environments in the chamber setups for ornament plant mitigation testing.

Ornament plants	Temperature (°C)	Relative humidity (%)	Leaf surface area (m^2)
Sansevieria trifasciata Prain	23.5	87	0.04
Chlorophytum comosum Jacques	23.7	73	0.03
Hedera helix L. cv. Glacier	22.4	71	0.02
Aglaonema spp.	22.2	82	0.08
Spathiphyllum sp.	23.6	92	0.15
Aglaonema modestum Schott	22.4	88	0.11
Philodendron xanadu	24.1	93	0.11
Dracaena braunii Engl.	23.7	68	0.01
Chlorophytum bichetii (Karrer) Backer	23.8	75	0.10

3 Results and Discussion

3.1 Emission profiles of construction materials

Based on the chamber test results in Figure 4, the TVOC concentration was plotted over time. The non-acid silicone sealant and acid-based silicone sealant exhibited the highest initial TVOC concentrations, which is characteristic of highly volatile, solvent-rich materials. Their peaks occurred very early, within 180 minutes. The water-based paints had lower initial peaks and took a much longer time to reach their maximum measured emission, suggesting a slower release of TVOC compared to the solvent-based products. Source controls and solvent classifications can be carefully considered for concentrations in specific individual compounds over an extended period [39], [40].

Sealants showed the fastest initial decay after their peak, particularly the acid-based silicone sealant. This suggests that the primary TVOC

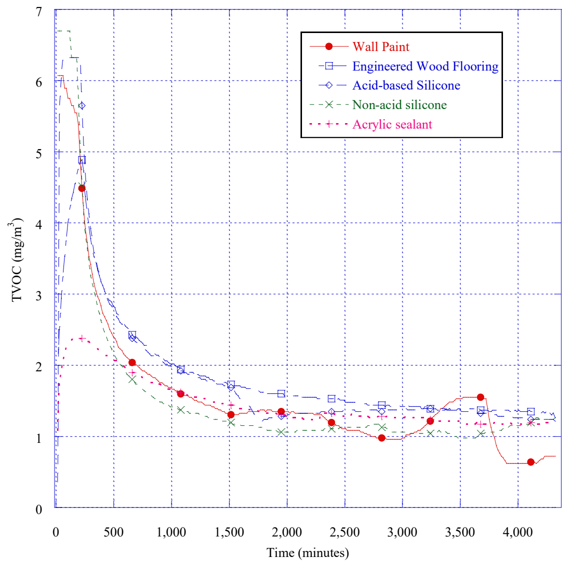

Figure 4. TVOC emission concentration from construction materials in the chamber tests prior to loading factor normalization

released from sealants is highly volatile and dissipates quickly as the material cures [41], [42]. The non-acid silicone sealant displayed the high air purifying performance, starting at a moderate peak and decaying to the lowest final concentration by the end of the test. The water-based paints had a slower and less significant final decay, indicating a more prolonged, low-level release of TVOC. The observed emission profiles highlighted the critical role of material selection in minimizing TVOC exposure within buildings. Effective TVOC reduction depends not only on initial content claims but also on the long-term emission characteristics of materials, reinforcing the importance of informed material selection in building design. However, based on the test results, variations in material settings and applications across the tested samples necessitated a normalization process to evaluate emission characteristics, considering factors such as concentration levels, initial peak emissions, and prolonged decay patterns. Additionally, further research is needed using chamber tests under tropical conditions, such as in Thailand, where environmental factors significantly influence pollutant dynamics.

High humidity and temperatures can exacerbate indoor health risks by increasing TVOC emission rates from materials [12], [17], [33]. Future studies should therefore investigate how these tropical conditions affect long-term performance and emission reduction efficiency in real-world settings.

A linear regression analysis was performed to develop a prediction model for characterizing emission profiles and their respective decay rates, as shown in Figure 5. The results indicate that silicone-based sealants and wall paint exhibit an acute initial surge in TVOC concentrations followed by rapid decay patterns. To reach the target concentration threshold of 0.5 mg/m³, the non-acid and acid-based silicone sealants achieved recovery earliest, at approximately 8,180 and 9,220 minutes, respectively, followed by wall paint at approximately 9,770 minutes. In contrast, the acrylic sealant demonstrated a lower initial peak with a notably prolonged emission decay, maintaining a higher plateau and a slower release rate during the later experimental stages. In practical terms, prioritizing materials with rapid decay rates is recommended for indoor applications, while addressing materials with prolonged emission profiles remains essential for improving long-term air quality. To scale chamber results to real-size rooms, the area-specific emission rate can be adjusted for loading factor and air change rate, accounting for the dilution volume and ventilation conditions of actual indoor settings.

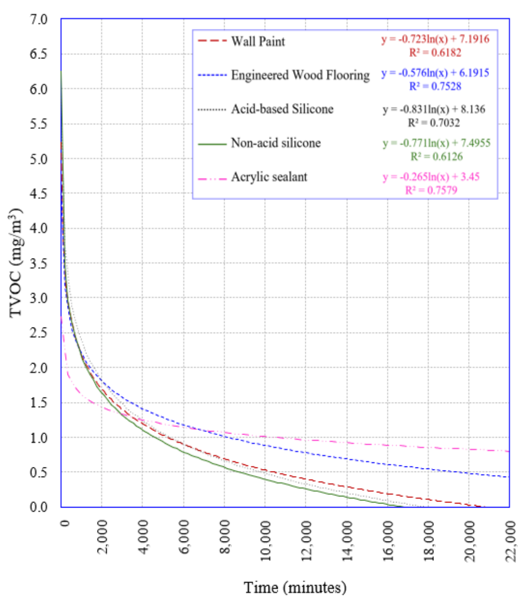

Figure 5. Prediction model using linear regression analysis for emission profiles of the building materials

3.2 Plant absorption performance

Two experimental setups were conducted to evaluate the influence of ornament plants on TVOC absorption. In the first setup, serving as the without-plant conditions, it included only the pots, soil, and the TVOC source to establish a baseline concentration for comparison. The second setup, referred to as the with-plant condition, the test chamber contained potted ornament plants and a TVOC source, a non-acid silicone sealant, which was selected for its high TVOC emission rates [42] and its consistent decay pattern with rapid decay patterns observed during the emission testing in subsection 3.1.

The results of the control condition, without-plant setups condition, are presented in Figure 6, while those of the treatment conditions, with-plant setups, are shown in Figure 7. It can be observed that the ornament plants significantly accelerate TVOC mitigation. While the without-plant condition exhibited a prolonged decay period with high initial peaks, the with-plant condition demonstrated rapid concentration reduction. This accelerated removal is likely attributable to the plant's phytoremediation performance. The presence of ornament plants not only decreased the peak exposure risk but also ensured an efficient transition to low-concentration indoor environments.

To quantify the TVOC absorption capability of each, the approximate area under the concentration–time curve was calculated for both setups, and the difference between these two areas represented the net TVOC removal attributable to the plants, as summarized in Table 4, presenting the TVOC absorption amount (mg/m³), obtained by dividing the TVOC absorption capability (mg·min/m³) by the total experiments. The phytoremediation potential of the ornament plants revealed a consistent pattern, where *Spathiphyllum* sp. and *Hedera helix* L. cv. Glacier exhibited high efficacy, achieving absorption amounts of 0.88 mg/m³. Conversely, *Aglaonema* spp. demonstrated the low potential, with a significantly reduced absorption amount of 0.35 mg/m³. Most other plants maintained a relatively uniform performance range (0.70–0.80 mg/m³). Analysis of the TVOC absorption rate under the leaf surface area highlighted *Dracaena braunii* Engl. as an effective plant.

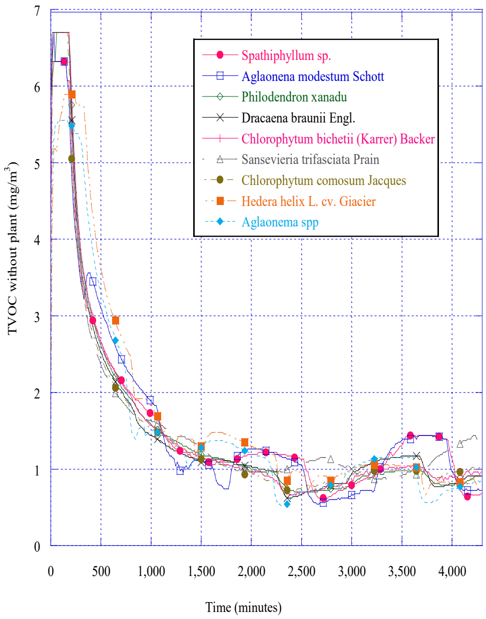

Figure 6. Variation of total TVOC concentration over time under the without-plant setups.

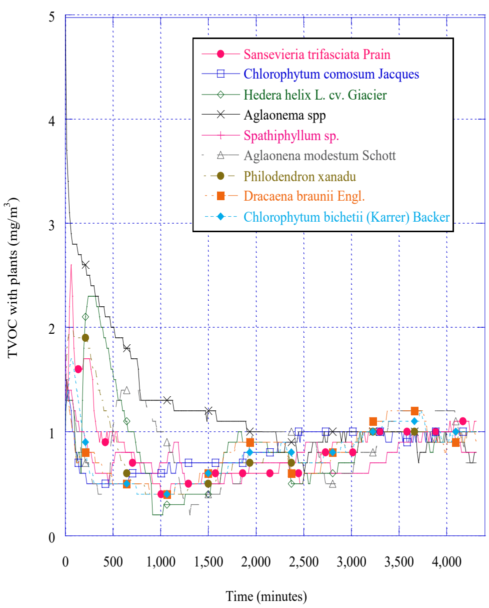

Figure 7. Variation of total TVOC concentration over time under the with-plant setups.

Table 4. Rate of TVOC absorption capacity and absorption amount between chambers tests with-plant and without-plant setups.

Plants	Absorption capability (mg·min/m^3)	Absorption amount (mg/m^3)	Absorption amount per leaf surface area (mg/m^3.m^2)
Sansevieria trifasciata Prain	3,387	0.80	6.37
Chlorophytum comosum Jacques	2,961	0.70	6.87
Hedera helix L. cv. Glacier	3,729	0.88	17.62
Aglaonema spp.	1,502	0.35	1.47
Spathiphyllum sp.	3,752	0.88	1.92
Aglaonena modestum Schott	3,271	0.77	2.31
Philodendron xanadu	2,972	0.70	2.09
Dracaena braunii Engl.	3,242	0.76	20.42
Chlorophytum bichetii (Karrer) Backer	3,336	0.78	2.55

Despite containing a small leaf surface area in this study, it achieved the highest absorption rate at 20.42 mg/m^3.m^2. *Hedera helix* L. cv. Giacier followed closely with a high performance of 17.62 mg/m^3.m^2.

These rates significantly outperform other tested plants, such as *Aglaonema* spp., which can be observed at 1.47 mg/m^3.m^2. This efficiency suggests that TVOC removal is driven by plant specification traits rather than total leaf size or controlled environments. The role of root-zone microorganisms in long-term TVOC removal can be emphasized, indicating the high per-unit performance of plant parameters absorption in *Dracaena* species [43].

Selection of species represented the critical determinant, as interspecific variations in stomatal density, leaf morphology, cuticular wax composition, and metabolic detoxification pathways [27], [44].

Plants in the *Asparagaceae* family, such as *Dracaena braunii* Engl., utilized a multifaceted microcosm to mitigate TVOC, involving stomatal uptake and subsequent translocation to the root zone, where phytoremediation occurred via metabolic breakdown by both the plant and associated rhizosphere microorganisms. It exhibited high per-unit absorption rates due to its high metabolic activity and leaf surface characteristics [26], [28], [30].

Studies underscored the efficacy in mitigating indoor air pollutants across varying scales. In chamber experiments, *Dracaena* species have demonstrated high removal capacities, effectively reducing concentrations of hazardous gases such as benzene and formaldehyde [37], [43], [45]. Meanwhile, in real-size room environments, the removal performance was suggested as a strategic density of plants for improving indoor air quality, particularly in areas with limited ventilation [46], [47]. It was recognized as a critical role in optimizing TVOC removal with functions of phytoremediation as an energy-efficient alternative to traditional systems [48]. The experimental data indicated that the absorption rates per unit area observed in the *Asparagaceae* family revealed physiological attributes and stomatal characteristics as the primary determinants of localized phytoremediation efficiency.

To reduce TVOC concentration, plant selection should be prioritized. For indoor settings with enclosed space, *Dracaena braunii* Engl. is practically effective in achieving a high TVOC absorption rate. Further optimization of indoor air quality necessitates the maintenance of a rhizosphere microcosm during long-term implementation. A strategic combination of high-capacity species and those with efficient per-unit absorption rates offers a sustainable framework of TVOC mitigation for the enduring performance of these botanical filtration systems.

4 Conclusion

This study evaluated TVOC emissions from commonly used interior construction materials in Thai residential buildings and assessed the removal performance of selected ornament plants under controlled chamber conditions. Among the tested materials, silicone-based sealants exhibited the highest initial TVOC emissions, followed by engineered wood flooring and acrylic water-based paints. Although sealant emissions decayed relatively quickly, low-level VOCs persisted, emphasizing the importance of material selection and adequate ventilation during the first 24–72 hours after installation.

Based on the test results, *Dracaena braunii* Engl. demonstrated high TVOC absorption performance, achieving an absorption amount of 20.42 $mg/m^3.m^2$. These results are consistent with prior literature highlighting the removal capacity of the *Asparagaceae* family, influenced by species-specific physiological characteristics, including leaf surface area, foliage density, and interactions between plant roots, substrate, and rhizosphere microorganisms. Plant-mediated TVOC reduction occurs through multiple pathways, with plant surfaces playing a critical role in pollutant uptake [21], [49]. While a larger leaf surface area enhances passive absorption, the TVOC removal efficiency is also influenced by substrate properties and rhizosphere activity [25], [50]. While pot sizes in this study were standardized to reflect typical indoor applications, future research should explore plant performance through additional physiological parameters, such as leaf architecture, root system, biomass, and maturity, to facilitate comparisons of TVOC removal. Additionally, incorporating analytical models to assess removal capacities for specific chemical substances or materials would allow evidence-based study regarding material emissions, and would strengthen the creation guidelines for optimizing plant selection in various indoor settings for enhancing indoor air quality. The findings emphasize that effective indoor TVOC mitigation should adopt a comprehensive strategy that combines source control and pollutant removal. Selecting low-emission or certified building materials, particularly for high-emitting products such as sealants and interior finishes, is essential for minimizing initial TVOC release. This approach should be complemented by appropriate ventilation strategies to dilute and disperse residual emissions. In parallel, the strategic integration of high-performing ornament plants offers a practical, nature-based solution to further enhance indoor air quality. Together, these measures provide a holistic framework for improving indoor environmental quality and supporting occupant health and wellbeing within green and healthy residential building design.

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Author Contributions

K.C.: investigation, data analysis, and preparation of the original draft; W.T.: conceptualization, investigation, data analysis, project administration, and final manuscript proofreading. All authors have read and approved the final version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors utilized the ChatGPT 5.4 tool to enhance the language and readability of the manuscript.

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