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Effects of Pothos and Sansevieria Plants on Removing Indoor Air Pollutants

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ABSTRACT

Reducing the concentration of volatile organic compounds (VOCs) in both indoor and outdoor environments is a key objective for safeguarding human health and protecting the environment. This study investigated and compared the phytoremediation capacities of *Sansevieria trifasciata* 'Hahnii' and *Epipremnum aureum* in mitigating major components of indoor air pollution. Benzene, acetone, methanol, and ethanol were introduced into airtight glass chambers, and air samples were collected using a gas-tight syringe at 15 minutes, 6 hours, and 24 hours after exposure. The residual concentrations of these pollutants were analyzed using gas chromatography to assess the plants' absorption capacities and their potential for VOC removal. The results revealed that pollutant absorption was influenced by several factors, including the type and concentration of the pollutant, plant species, and the extent of green surface area. Both plant species exhibited effective phytoremediation capabilities. As a C3 plant, Pothos (*Epipremnum aureum*) reduced indoor air pollution by 52%, while Sansevieria (*Sansevieria trifasciata* 'Hahnii'), a CAM plant, achieved a 35% reduction. Within the first 6 hours following pollutant introduction, 19.7% of the pollutants were removed, with an additional 30.3% reduction observed over the subsequent 18 hours. Across all treatments, the highest rate of pollutant absorption occurred within the initial 6-hour period and declined thereafter—except in the case of benzene, which exhibited a delayed absorption pattern, increasing after the first 6 hours. These findings underscore the potential of ornamental plants as an effective and sustainable strategy for reducing VOC concentrations in indoor environments.

Introduction

A significant portion of civilizational advancement has come at the cost of the natural environment, which has now reached critical degradation levels that pose threats to both human health and ecological systems (Gawrońsk, 2023). Urban populations spend approximately 85–90% of their time indoors (Soreanu et al., 2013), often unaware of their continuous exposure to air pollutants (Gawronska and Bakera, 2015). Notably, indoor air has been reported to be 5–7 times more polluted than outdoor air. Since the severity of pollutant effects is closely tied to exposure duration, indoor environments often present greater health risks compared to open-air settings (Beattie and Seibel, 2007).

Volatile organic compounds (VOCs) are organic chemicals that readily vaporize under normal environmental conditions, contributing significantly to environmental pollution. Due to their high volatility, mobility, and resistance to degradation, VOCs can travel long distances in the environment. Based on volatility, organic pollutants are categorized into three groups: very volatile organic compounds (VVOCs), VOCs, and semi-volatile organic compounds (SVOCs). Compounds such as benzene, acetone, and alcohols fall within the VOC category, which is particularly relevant to indoor air quality (David and Carolina, 2021).

Primary sources of indoor VOC pollution include a wide range of household products, such as paints, paint strippers, solvents, wood preservatives, aerosol sprays, cleansers, disinfectants, moth repellents, and air fresheners. Additional sources include stored fuels, automotive products, dry-cleaned clothing, pesticides, and various building materials and office equipment, including copiers and printers. Other contributors encompass correction fluids, carbonless copy paper, glues, adhesives, permanent markers, and photographic solutions used in crafts and graphic work (EPA, 2023).

The presence of VOCs in indoor air poses significant risks to human health, highlighting the need for effective management strategies. Plants have been identified as a green and sustainable means to regulate VOC concentrations in indoor environments, thereby improving air quality and promoting human well-being (Cruz et al., 2014). Phytoremediation—derived from the Greek *phyto* (plant) and Latin *remedium* (remedy)—refers to the use of plants to reduce or eliminate pollutants from soil, water, and air (Soroori et al., 2021). Given the wide variety of both plant species and pollutant types, phytoremediation strategies must be tailored to specific conditions. Consequently, the application of phytoremediation varies across environmental contexts, depending on desired outcomes and plant performance (Gawrońsk, 2023).

Phytoremediation has been proposed as an environmentally friendly method for removing indoor air contaminants. Plants absorb harmful organic compounds through their leaf surfaces and stomata (Danaee and Abdossi, 2019). Substantial evidence indicates that plants can effectively remove airborne particles, mineral gases, and VOCs, positioning them as a promising natural solution for mitigating indoor air pollution (Gong et al., 2019).

Epipremnum aureum, commonly known as Pothos, belongs to the arum family (Araceae). It has been widely reported to absorb significant amounts of formaldehyde and other airborne pollutants, rendering it highly effective for indoor air purification. This resilient species thrives in low-light conditions, is inexpensive, widely available, and easily propagated. A distinctive feature of Pothos is its trailing growth habit, which allows it to cover otherwise underutilized indoor surfaces such as walls and window sills, thereby increasing its pollutant absorption potential within indoor environments (Torpy and Zavattaro, 2018). It is also capable of withstanding environmental stress and surviving across a range of conditions, making it particularly efficient at removing air pollutants such as benzene, trichloroethylene, xylene, and formaldehyde. Moreover, its evergreen vines and small, green, heart-shaped leaves contribute to indoor air quality by producing oxygen (Kulkarni et al., 2018).

Sansevieria trifasciata, commonly known as “Mother-in-Law’s Tongue,” has been cultivated for over two centuries, although it was formally named only in 1903. Among its many cultivars is the compact ‘Hahnii’ variety, distinguished by its shorter, broader leaves compared to the typical long, narrow-leaf forms (Walker, 2022). *Sansevieria* is another highly effective plant for purifying polluted indoor air. Functioning as a natural filter, it absorbs toxic pollutants including formaldehyde, benzene, toluene, alcohol, and trichloroethylene (Mansfield et al., 2020). It is also well known for its aesthetic appeal and medicinal value. Uniquely, *Sansevieria* is capable of converting substantial amounts of CO_2 into O_2 during the night through Crassulacean Acid Metabolism (CAM) photosynthesis, making it especially suitable for bedrooms or other enclosed spaces where multiple plants can further enhance air quality (Tan et al., 2022).

Numerous studies have demonstrated the ability of various plant species to remove VOCs such as benzene, toluene, and trichloroethane (TCE). Kim et al. (2011) reported changes in the phytoremediation efficiency of 62 indoor plants—including *Pittosporum tobira* and *Salvia elegans*—following repeated exposure to toluene. The efficiency of toluene and xylene removal was further enhanced by cultivating foliage species such as *Fatsia japonica* and *Dracaena fragrans* ‘Massangeana’ (Kim et al., 2014). Additional research demonstrated the phytoremediation potential of plants including *Smunda japonica*, *Selaginella tamariscina*, *Davallia mariesii*, *Polypodium formosanum*, *Psidium guajava*, *Lavandula* spp., *Pteris dispar*, *Pteris multifida*, and

Pelargonium spp. through exposure to gaseous formaldehyde (Kim et al., 2010).

Given the strong correlation between air pollution and increased mortality from cardiovascular and respiratory diseases, it is essential to improve our understanding of pollutant dispersion and mechanisms of action. Developing and implementing effective strategies to eliminate or reduce airborne pollutants is crucial to mitigating these health risks. In many major cities in Iran, ambient air pollution levels regularly exceed permissible limits, making the reduction of indoor air pollution particularly urgent, especially considering the amount of time people spend indoors.

While substantial research has focused on common VOCs such as formaldehyde, toluene, and xylene, less attention has been paid to compounds frequently found in specific environments—such as hospitals, factories, beauty salons, and laboratories—where acetone and alcohols often accumulate. To address this gap in knowledge, and in light of the established phytoremediation potential of *Sansevieria trifasciata* and *Epipremnum aureum*, this study was designed to assess the ability of these two plant species to purify indoor air by removing a range of VOCs.

Material and methods

Plant materials

The experiments were conducted at the Laboratory Building of Islamic Azad University, Science and Research Branch, Tehran, Iran. The selected plants were purchased from a greenhouse in Shahsavar, Mazandaran, Iran, and were acclimated for two months in the laboratory under controlled indoor conditions. The environment was maintained at 23–25 °C with 40–50% relative humidity (RH), supplemented with light for 8 h daily (Kim et al., 2011). The plants were watered once a week, and all plants received water a day before the gas treatments.

Treatment system

For this study, custom-built glass chambers (50 × 50 × 50 cm; interior volume of 125 L) were used. The chambers were fully sealed with special adhesives to ensure they were airtight. Each chamber was equipped with insulated valves for gas injection and air sampling. The experiment was arranged in a factorial design with a completely randomized block format and three replications.

To evaluate the phytoremediation capacity of *Sansevieria trifasciata* and *Epipremnum aureum*, the plants were exposed to key indoor pollutants—acetone, benzene, ethanol, and methanol—in closed chambers. Each treatment included three glass test chambers: one containing a single pot of Pothos (1.650 cm^3) or two pots of Sansevieria (1.386 cm^3 each). Once the plants were placed in the chambers, the doors were sealed completely to prevent air exchange.

Gas measurement

Residual pollutant levels in the chambers were measured by injecting specific amounts of the pollutants in liquid form into the chambers via airtight valves using specialized syringes (Table 1). Air samples were withdrawn at 0, 6, and 24 h post-injection using a gas-tight Hamilton syringe and analyzed using a SHIMADZU GC-2010 PLUS gas chromatograph equipped with a flame ionization detector (FID).

The gas chromatograph used a non-polar BP5 column (30 m length, 0.25 mm inner diameter, and 0.25 µm film thickness). The column was programmed for thermal analysis, starting at 60 °C and ramping up to 220 °C at a rate of 7 °C min^{-1}, with a hold time of 3 min. Nitrogen gas with 99.9% purity was used as the carrier. The injection port and detector temperatures were both set at 250 °C (Kim et al., 2014; Irga et al., 2013).

Table 1. Research treatments.

Treatment	Abbreviation
25 µL L^{-1} Acetone with Sansevieria	Ac 25P1
50 µL L^{-1} Acetone with Sansevieria	Ac50P1
25 µL L^{-1} Benzene with Sansevieria	B25P1
50 µL L^{-1} Ethanol with Sansevieria	Et50P1
50 µL L^{-1} Methanol with Sansevieria	Met50p1
25 µL L^{-1} Acetone with Pothos	Ac25p2
50 µL L^{-1} Acetone with Pothos	Ac50P2
25 µL L^{-1} Benzene with Pothos	B25P2
50 µL L^{-1} Ethanol with Pothos	Et50P2
50 µL L^{-1} Methanol with Pothos	Met50P2

Data analysis

To analyze the residual gases inside the chambers, the retention times of each pollutant were first determined by injecting them into the gas chromatograph. The characteristics of the treatments used in this study are summarized in Table 1. Data analysis included ANOVA and mean comparisons performed using Duncan's multiple range test (P≤0.05). Statistical analysis was conducted using SAS 9.1 software.

Results

All traits evaluated showed significant differences based on plant species, the duration of exposure to pollutants, and the type of gaseous pollutant (Table

2). These findings indicate that the absorption capacity of the plants was influenced by these factors. The amount of absorbed gaseous pollutants varied depending on the pollutant type and plant species. Overall, *Epipremnum aureum* (Pothos) demonstrated significantly higher pollutant absorption than *Sansevieria trifasciata*. After injecting 25 µL L^{-1} of acetone into the chambers, the residual pollutant concentration was 11.53 µL L^{-1} in the Pothos chamber, compared to 19.85 µL L^{-1} in the Sansevieria chamber—indicating that Pothos absorbed nearly double the amount of acetone (Fig. 1). When exposed to 50 µL L^{-1} of acetone, Pothos reduced the residual pollutant concentration to 21.83 µL L^{-1}. In contrast, Sansevieria showed a 46% lower absorption capacity, leaving a residual concentration of 40.65 µL L^{-1}. Similarly, Pothos outperformed Sansevieria in absorbing benzene. The residual concentration in the Pothos chamber was 7.85 µL L^{-1} compared to 10.45 µL L^{-1} for Sansevieria.

Ethanol treatments revealed the most pronounced differences between the two species. Pothos demonstrated a six-fold greater absorption capacity compared to Sansevieria. For methanol, Pothos again exhibited superior performance, with a residual pollutant concentration of 1.08 µL L^{-1} in its chamber compared to 2.53 µL L^{-1} in the Sansevieria chamber, further underscoring its higher efficiency in pollutant absorption (Fig. 1). These results suggest that Pothos has greater potential for the phytoremediation of indoor air pollutants, especially for VOCs such as acetone, ethanol, and methanol, making it an effective choice for improving indoor air quality.

Table 2. Results of ANOVA for the effects of treatments on the absorption of gaseous pollutants.

Source of change	Degree of freedom	Mean squares: Pollutant absorption
Plant	1	3580.7**
Time	2	526.8**
Treatment	4	2201.6**
Plant × Time	2	154.8*
Plant × Treatment	4	792.3**
Treatment × Time	8	133.6**
Plant × Treatment × Time	8	135.2**
Error	55	30.56
(%) CV		10.2

* and ** indicates, significant at $P \leq 0.05$ and $P \leq 0.01$, respectively.

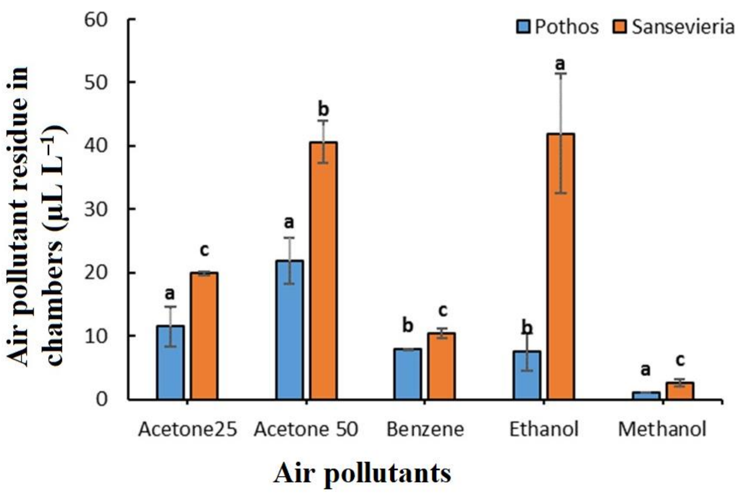

Fig. 1. Air pollutant (acetone, benzene, ethanol, and methanol) absorption by Pothos and Sansevieria in the chambers, showing that Pothos absorbed pollutants more than Sansevieria (values marked by different letters are significantly different $P \leq 0.05$).

Figure 2 illustrates the impact of time on pollutant absorption. The data show a steady increase in absorption over time, with approximately 19.7% of environmental pollutants removed in the first 6 h and 30.3% removed within 18 h. For Pothos, the rate of pollutant absorption remained relatively consistent during the initial 6 h and then increased slightly thereafter. In contrast, Sansevieria exhibited a higher absorption rate during the first 6 h, which then leveled off to a more uniform rate over time. Overall, both Pothos and Sansevieria demonstrated comparable pollutant absorption efficiencies over a 24 h period (Fig. 3). By the end of 24 h, Pothos reduced VOC concentrations in the chambers by 52%, while Sansevieria exhibited a 35% reduction.

In addition to evaluating the total pollutant reduction over 24 h and highlighting the high efficiency of Pothos and Sansevieria, the study also examined the reduction patterns for each pollutant individually. A decrease in concentration was observed across all tested pollutants. For acetone, ethanol, and methanol, a gradual reduction was observed over the 24 h period. However, benzene exhibited a distinct pattern: its absorption rate was slow during the initial 6 h but increased significantly thereafter.

After 24 h, the concentration of 25 µL L^{-1} acetone was reduced by 45.7%, indicating effective pollutant removal by both plants. Interestingly, the absorption efficiency for 50 µL L^{-1} acetone was notably higher, with a reduction of approximately 65%, demonstrating a direct correlation between the initial pollutant concentration and its absorption rate in phytoremediation. Similarly, significant reductions were observed for ethanol and methanol. Their concentrations decreased by 62.8% and 46.6%, respectively, within 24 h of injection (Fig. 4).

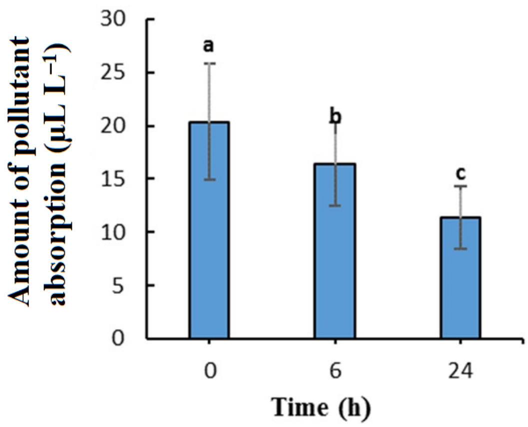

Fig. 2. Total air pollutant (acetone, benzene, ethanol, and methanol) absorption by Pothos and Sansevieria in the chambers, showing that absorption increased over time (values marked by different letters are significantly different $P \leq 0.05$).

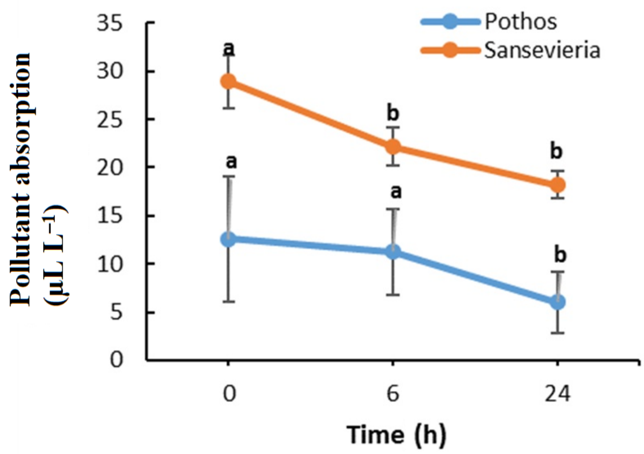

Fig. 3. Air pollutant (acetone, benzene, ethanol, and methanol) absorption rate by Pothos and Sansevieria in the chambers in 24 h, showing that Pothos and Sansevieria absorbed the gaseous pollutants similarly during 24 h (values marked by different letters are significantly different $P \leq 0.05$).

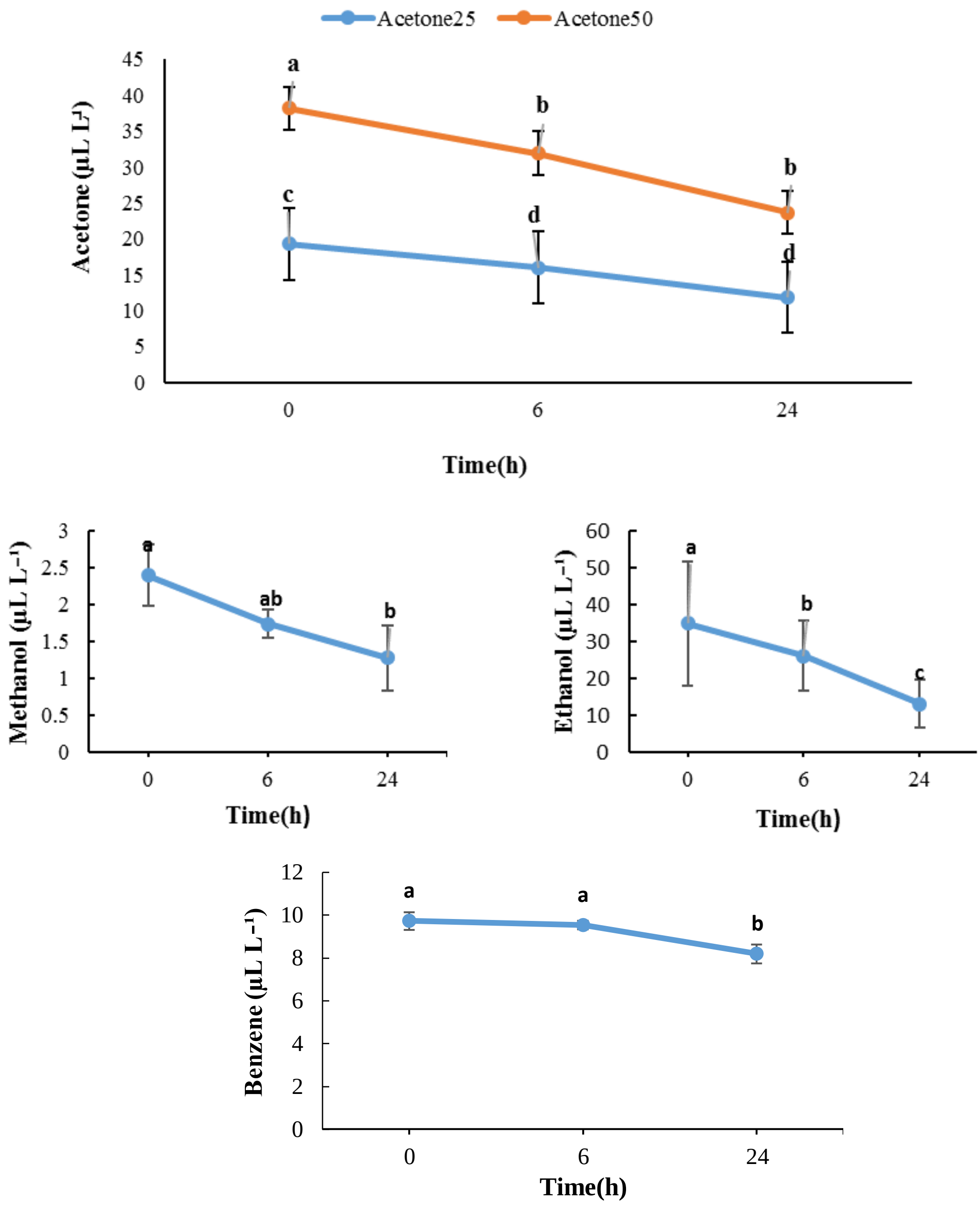

Fig. 4. Reduction rate of each air pollutant (acetone, benzene, ethanol, and methanol) in the chambers during 24 h, showing that the amount of all pollutants decreased over time but the process of decrease differed (values marked by different letters are significantly different $P \leq 0.05$).

Figure 5 illustrates the three-way interaction effects of plant species, exposure time, and pollutant treatment on pollutant concentration. The data indicate a consistent decrease in pollutant concentrations over time, highlighting the phytoremediation capacity of both Pothos and Sansevieria to absorb indoor air pollutants. A direct correlation was observed between pollutant concentration and absorption efficiency, with higher initial concentrations resulting in greater pollutant absorption. Among the tested pollutants, the highest absorption percentages were recorded for 50 µL L^{-1} ethanol, followed closely by 50 µL L^{-1} acetone, both exhibiting similar trends in both plant species. Additionally, the concentrations of benzene, ethanol, and methanol steadily declined, reaching their lowest levels by the end of the analysis. Comparatively, Pothos demonstrated superior efficiency in the phytoremediation of indoor air pollutants when compared to Sansevieria (Fig. 5).

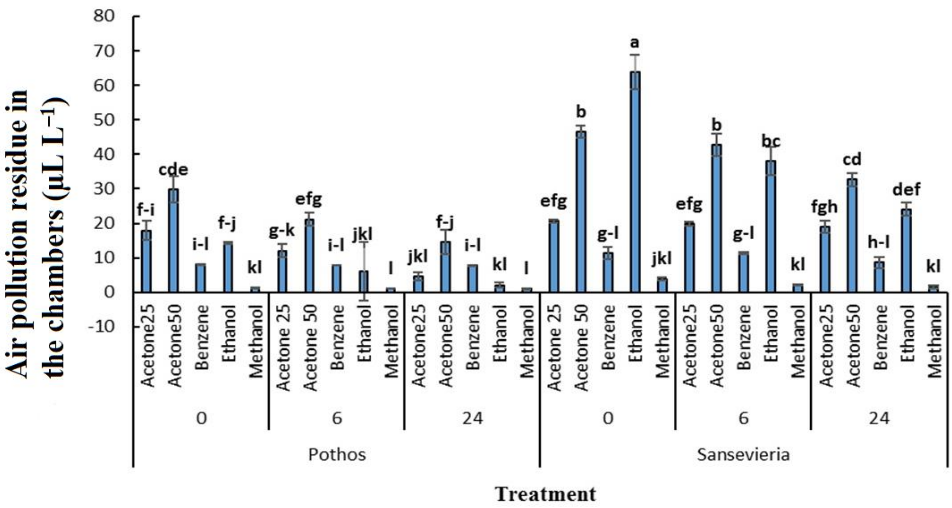

Fig. 5. Comparison of air pollutant (acetone, benzene, ethanol, and methanol) absorption by Pothos and Sansevieria in the chambers in 24 h, showing that the concentrations of all pollutants decreased over time. Compared to Sansevieria, Pothos had higher efficiency in the absorption of indoor air pollutants (values marked by different letters are significantly different $P \leq 0.05$).

Discussion

Numerous reports indicate that indoor air pollution levels can be 5-7 times higher than outdoor air, often contributing to sick building syndrome (SBS). Consequently, identifying effective methods to purify and improve indoor air quality is essential. Phytoremediation has emerged as a promising approach to address this issue, utilizing plants to remove VOCs from the indoor environment. Both leaf and root systems of plants play crucial roles in pollutant removal, while plants also help regulate temperature and relative humidity through evaporation and transpiration, further mitigating airborne pollution.

Additionally, the integration of nature into indoor spaces enhances air quality and provides physiological benefits to occupants, reflecting humans' intrinsic connection with the natural world (Nisitha et al., 2023). Our study demonstrated that Pothos (*Epipremnum aureum*) and *Sansevieria trifasciata* effectively reduced indoor air pollutants, with Pothos exhibiting greater efficacy. VOC absorption was influenced by pollutant type, concentration, exposure duration, plant species, and leaf characteristics, aligning with prior findings. Khaiwal and Mors (2022) reported that indoor pollutant removal efficiency depends on plant species and characteristics, such as leaf size, thickness, area, photosynthetic activity, light intensity, and the plant parts involved—leaves, roots, wax, cuticle, and stomata. Similarly, Saxena and Sonwani (2020) found that *Dracaena deremensis* and *Lilium candidum* significantly reduced environmental pollutants. These plants, characterized by thick, waxy cuticles, effectively accumulate lipophilic toxins, such as ozone and benzene. Collins et al. (2000) attributed this ability to cuticles composed of long-chain hydrocarbons like aldehydes, ketones, and alcohols, which facilitate pollutant accumulation. In another study, Abbass et al. (2017) recorded a maximum ozone removal rate of 5.6 m h^{-1} for golden Pothos. Suárez-Cáceres and Urrestarazu (2021) evaluated the efficiency of five plant species in living walls for VOC removal. They observed higher formaldehyde reduction compared to n-hexane, with *Chlorophytum comosum* demonstrating the highest efficiency and *Spathiphyllum wallisii* the lowest. Interestingly, no correlation was found between leaf area, fresh weight, or dry weight and contaminant reduction.

Setsungnern et al. (2017) reported that *Chlorophytum comosum* absorbed substantial amounts of benzene, with maximum absorption observed under blue and red LED lighting at a 1:1 ratio, significantly outperforming conventional white fluorescent lighting (P<0.05). Liu et al. (2022) investigated the impact of plants and ventilation on air pollutants in tobacco smoke using three experimental chambers simulating smoking environments. They found that pollutant concentrations were lowest in chambers with plants, reinforcing the role of plants in reducing indoor air pollution. These findings collectively underscore the potential of phytoremediation as a sustainable solution for improving indoor air quality, with plant species selection playing a pivotal role in optimizing pollutant removal.

Snake plants are among the few plants capable of absorbing carbon dioxide and releasing oxygen both during the day and at night, utilizing a process known as Crassulacean Acid Metabolism (CAM) photosynthesis. They exhibit the highest carbon dioxide absorption rate, measured at 0.201 ppm cm^{-2} of leaf area. Research by Kavya et al. (2017) demonstrated that snake plants possess nearly double the photosynthetic potential of dracaena and exhibit greater oxygen-releasing efficiency under both light and dark conditions. These characteristics make them a superior choice as indoor plants, particularly for pot transplantation in cold climates to improve indoor air quality. Gholami Borujeni et al. (2013) evaluated 10 species of ornamental plants and identified *Alternanthera hedera*, *Tradescantia* and *Hosta* as the most effective in removing total VOCs. Alternanthera proved especially efficient, eliminating four of the five tested pollutants—benzene, TCE, toluene, and octane. Across all ornamental plants studied, the average removal rate of pollutants ranged from 8 to 44 $\mu g\ m^{-3}\ h^{-1}$. Additionally, Hedera helix effectively eliminated alpha-pinene, and all flower species studied contributed to VOC reduction.

Further research by Gong et al. (2019) revealed a significant decrease in benzene concentration when using ornamental plants such as *Epipremnum aureum*, *Chlorophytum comosum*, *Hedera helix*, and *Echinopsis tubiflora*. Echinopsis, a C4 plant, reduced various initial benzene concentrations by 80%, attributed to its high transpiration rate and chlorophyll concentration. Similarly, Pothos (*Epipremnum aureum*) achieved a benzene removal efficiency of 72%, primarily due to its waxy leaf surface and numerous stomata, which facilitate benzene absorption. Gong et al. (2019) noted that transpiration rate and chlorophyll concentration are valuable parameters for selecting ornamental plants to improve indoor air quality. Kvesitadze et al. (2009) and Treesubsuntorn et al. (2015) emphasized the importance of both the waxy cuticle and stomatal function in benzene absorption. In C3 plants, the waxy cuticle remains active in the dark, compensating for closed stomata, thereby enhancing benzene uptake.

Both aboveground and belowground plant structures contribute to indoor air purification. Stomata on leaf surfaces serve as natural entry points for gaseous pollutants, while the cuticle plays a key role in adsorbing contaminants. For instance, in *Zamioculcas zamiifolia*, cuticular absorption accounted for 20% of benzene, 23% of toluene, 25% of ethylbenzene, and 26% of xylene uptake. Once absorbed, pollutants may be degraded, retained or excreted, either at the site of uptake or after translocation to other plant sections. Khaiwal and Mors (2022) highlighted that increased stomatal conductance in *Nerium indicum* corresponded linearly to greater formaldehyde removal from the surrounding air. Additionally, benzene, with its hydrophobic nature, penetrates more effectively through the cuticle, while formaldehyde primarily enters through stomatal openings. Nisitha et al. (2023) identified Golden Pothos, Snake Plant and Areca Palm as the most popular and effective indoor plants for improving indoor air quality. These plants were noted for their ability to reduce a broad spectrum of indoor pollutants, including formaldehyde, toluene, PM2.5, PM10, xylene, ozone, ketones and CO_2, outperforming other indoor plants.

Taemthong et al. (2022) observed the highest CO_2 reduction rate of 1.74 ppm min^{-1} when green walls incorporating Golden Pothos were positioned perpendicular to windows, maximizing light exposure. Deng et al. (2018) reported that Golden Pothos could reduce formaldehyde levels by 81–96% within 24 h. Additionally, Ibrahim et al. (2018) demonstrated its effectiveness in mitigating particulate matter, with reductions of 85% in total suspended particles, 75.2% in PM2.5, and 71.9% in PM10. The reviewed literature confirms the general capacity of plants to remove volatile organic compounds (VOCs). For instance, seven plant species collectively removed 59–337 ppm $m^{-2}\ d^{-1}$ of benzene, which, in a chamber with a volume of 0.216 m^3, corresponded to a benzene removal rate of 43.8–205.6 mg $m^{-2}\ d^{-1}$ (Orwell et al., 2004).

Conclusion

Gas chromatography results from this research, based on residual pollutants in the plant test chambers, confirmed that both houseplant species, Pothos (*Epipremnum aureum*) and Sansevieria (*Sansevieria trifasciata*), effectively purify volatile organic compounds in indoor air. However, *Epipremnum aureum* demonstrated a higher absorption capacity (52%) compared to *Sansevieria trifasciata* (35%). The concentration of volatile organic compounds significantly influenced the rate of absorption. While both plants exhibited a relatively low absorption rate for benzene during the initial hours after volatile organic compounds injection into the test chambers, they absorbed other pollutants—acetone, ethanol, and methanol—more rapidly within the first 6 h. Factors such as the concentration, duration, and type of indoor air pollutants, along with plant species and the amount of green surface area, were critical in determining pollutant removal efficiency. Both

Pothos and Sansevieria proved to be effective indoor plants for improving indoor air quality.

Conflict of Interest

The authors indicate no conflict of interest in this work.

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