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The Impact of Plants on Indoor Air Quality and Health Effects

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Abstract

Indoor air quality (IAQ) plays a critical role in occupant health, comfort, and cognitive performance, yet many university offices struggle to maintain optimal conditions despite advanced ventilation systems. This two-year crossover study evaluated whether introducing common indoor plants could supplement mechanical ventilation to improve IAQ in two comparable administrative offices. Sixty-eight healthy adult staff members (mean age 37 ± 3 years) were assigned to work in a 1,765 ft² office either with 30 Epipremnum aureum plants or without greenery during 2020, then swapped offices in 2021. Over each condition, 24 eight-hour measurements of CO_2, $PM_{2.5}$, total volatile organic compounds (TVOCs), temperature, and relative humidity were recorded. Between-group analyses revealed that offices with plants exhibited significantly lower mean CO_2 concentrations (912 ± 321 ppm vs. 1,343 ± 745 ppm; $p < 0.01$) and $PM_{2.5}$ levels (6.8 ± 3.1 µg/m³ vs. 9.5 ± 4.2 µg/m³; $p = 0.03$) compared to unplanted offices. Paired comparisons within participants confirmed these reductions (CO_2: 899 ± 307 ppm vs. 1 498 ± 692 ppm, $p < 0.01$; $PM_{2.5}$: 5.6 ± 2.9 µg/m³ vs. 10.7 ± 6.3 µg/m³, $p < 0.01$). No significant differences were found for TVOCs, temperature, or humidity. These findings demonstrate that modest plantings can yield substantial gains in air freshness and particulate removal, offering a low-cost, biophilic strategy to enhance IAQ in university workspaces. Incorporating indoor plants alongside standard HVAC maintenance may, therefore, help safeguard staff well-being and productivity, particularly in older or high-density buildings where upgrading mechanical systems is impractical.

1. Introduction

A growing body of evidence demonstrates that indoor air quality (IAQ) profoundly affects both occupant health and cognitive performance. Poor IAQ has been linked to respiratory and cardiovascular morbidity and can exceed the risks associated with outdoor pollution for many individuals (Cincinelli & Martellini, 2017). In office environments, suboptimal IAQ can decrease worker productivity (Harvard, 2021).

An analysis by MIT's Department of Urban Studies and Planning emphasizes IAQ's role as a public-health issue, noting that improved air quality directly correlates with better performance outcomes in diverse office populations (Palacios et al., 2021). Recent surveys of modern office environments reveal persistent IAQ challenges despite advanced ventilation systems, underlining the need for supplemental strategies (Felgueiras et al., 2023).

Cedeño Laurent et al. (2021), conducted a study to examine the acute impact of indoor air pollution on cognitive function among office workers. They conducted a longitudinal study over 12 months among 302 office workers in 6 different countries, assessing their cognitive function using mobile tests for response time and accuracy on the Stroop and addition/subtraction tests. The study found that higher levels of particulate matter (PM2.5) and lower ventilation rates (assessed by higher CO2 levels) were associated with slower response times and reduced accuracy on cognitive tests. Specifically, increases in PM2.5 and CO2 levels based on interquartile ranges were associated with statistically significant decreases in performance on various metrics of the cognitive tests. A sensitivity analysis also showed the associations between PM2.5 and cognitive performance were only significant at PM2.5 levels above 12 micrograms per cubic meter. The study concluded that enhanced air filtration and higher ventilation rates that exceed minimum targets are important public health strategies that could improve employee productivity by mitigating the impacts of indoor air pollution on cognitive function (Cedeño Laurent et al., 2021).

1.1 Importance of Office Air Quality in Universities

University offices—housing administrative staff, faculty, and support personnel—play a pivotal role in sustaining academic operations. Healthy IAQ in higher-education settings can reduce absenteeism, bolster staff well-being, and indirectly enhance student learning outcomes. The U.S. Environmental Protection Agency (EPA) highlights that good IAQ in educational facilities promotes a favorable environment for both teaching and administrative work, contributing to mission-critical functions (EPA, 2024). Given the extended hours and high occupancy densities typical of university offices, maintaining IAQ within recommended thresholds is essential to safeguard cognitive health and productivity (Felgueiras et al., 2023).

1.2 Role of Indoor Plants in Improving IAQ

Indoor plants have been proposed as a low-cost, sustainable means to augment mechanical ventilation and filtration. Systematic reviews confirm that certain species can reduce indoor concentrations of formaldehyde, benzene, and toluene through leaf uptake and rhizosphere microbial degradation (Han & Ruan, 2020). Field experiments in classroom settings demonstrate that strategic plant placements can measurably lower CO_2 and VOC levels under real-world conditions, although outcomes vary by species and density (Jung & Awad, 2021). An MDPI study evaluating common potted plants found significant IAQ improvements in small, high-occupancy spaces, linking pollutant reductions to both plant physiology and soil-borne microbial action (Sharma et al., 2022). Emerging research also shows that indoor vegetation enhances occupants' subjective perceptions of air freshness and comfort, even where measurable IAQ gains are modest (Abbasoğlu & Kahramanoğlu, 2025).

Researchers from the University of Birmingham studied the effects of common houseplants on indoor air quality. They tested three popular, easy-to-care-for plants - peace lily, corn plant, and fern arum. Each plant was placed individually in a test chamber with levels of nitrogen dioxide (NO2) comparable to those near a busy road (University of Birmingham, 2020).

All the plants were able to remove about half of the NO2 in the chamber within an hour, regardless of light/dark conditions or soil moisture. For a small office, the researchers calculated that five plants could reduce NO2 levels by around 20%. In a larger office, the effect would be smaller at a 3.5% reduction, but more plants could increase this. The exact mechanism for how the plants remove NO2 is still unknown. It does not appear to be through their leaves like with CO2 absorption. The removal seems related to biological processes in the soil as well. Understanding the plants' limits helps plan effective combinations for improving indoor air quality (University of Birmingham, 2020).

Going forward, the researchers will develop sophisticated modeling tools incorporating more variables, using mobile air quality monitors in homes and offices to inform the models with real data on different pollutants and environments. The goal is to better understand how houseplants can naturally purify indoor air (University of Birmingham, 2020).

The present study aims to quantify differences in CO_2, $PM_{2.5}$, total VOCs, temperature, and humidity between the two conditions. Specifically, the study seeks to answer:

1. Do offices with indoor plants exhibit significantly lower mean CO_2 and $PM_{2.5}$ concentrations compared to offices without plants?
2. Is there a measurable impact of plant presence on total VOC levels and indoor microclimate parameters?
3. To what extent can the findings inform university facility management and workplace design for optimized air quality?

2. Literature Review

Indoor Air Quality Standards refer to guidelines and regulations that specify maximum acceptable concentrations of various indoor air pollutants. They are intended to ensure indoor environments meet minimum air quality requirements to protect human health.

They are established by regulatory agencies and organizations based on extensive research into the health effects of different pollutants. Examples include EPA, WHO, and ASHRAE. Standards exist for common indoor pollutants like particulate matter, carbon monoxide, formaldehyde, VOCs, environmental tobacco smoke, radon, etc. They specify maximum allowable levels or concentrations of each pollutant based on potential health risks like respiratory issues, cancer, neurological effects, etc. Factors considered include type/duration of exposure and vulnerable groups like children, the elderly, and sick individuals.

For example, ASHRAE Standard 62.1 (Ventilation for Acceptable Indoor Air Quality) specifies minimum outdoor-air ventilation rates (typically ≈7.5 L/s per person in offices) but no numerical limits for specific pollutant concentrations (Persily, 2021). World Health Organization (WHO) guidelines focus largely on ambient air, recommending, e.g., annual $PM_{2.5}$ ≤5 μg/m³ and 24-hour $PM_{2.5}$ ≤15 μg/m³ (2021 update)(IQ Air, 2021). In the United States, the EPA's National Ambient Air Quality Standards (NAAQS) set outdoor $PM_{2.5}$ limits (15 μg/m³ annual; 35–65 μg/m³ 24h, depending on the year), but there are no federal indoor air quality standards for offices (EPA, n.d.). Occupational limits apply to workplaces: for example, OSHA/NIOSH allow CO_2 up to 5000 ppm (8-hour TWA) and 30,000 ppm short-term (Kapsalaki, 2022). In practice, many buildings use ~1000 ppm CO_2 as a de facto IAQ target (linked to ≈7.5 L/s-person ventilation) (Kapsalaki, 2022). In sum, major guidelines emphasize ventilation and pollutant thresholds (ambient or specific), but no office IAQ standard mandates "with plants vs without plants" distinctions. In practice, maintaining CO_2 below ~1000–1500 ppm is commonly recommended for comfort, and keeping $PM_{2.5}$ and VOCs as low as feasible (ideally near WHO/AQS levels) is advised (Kapsalaki, 2022).

2.2 Key Indoor Pollutants and Their Impacts

Offices accumulate several contaminants that affect health, comfort, and productivity. The most relevant are carbon dioxide (CO_2), fine particulate matter ($PM_{2.5}$), and volatile organic compounds (VOCs). Indoor CO_2 arises mainly from human exhalation. It is odorless and non-toxic at moderate levels, but elevated CO_2 typically signals inadequate ventilation. Many governments *recommend* keeping office CO_2 below ~1000–1500 ppm (Kapsalaki, 2022). CO_2 itself at these concentrations can cause drowsiness and headaches, and prolonged high CO_2 (>1000 ppm) has been linked to "sick building" symptoms (Kapsalaki, 2022). Importantly, experimental studies have shown that even moderate CO_2 levels (~1000–2000 ppm) may impair cognitive function: for example, Satish *et al.* (2012) and Allen *et al.* (2016, 2019) reported decrements in decision-making performance at ~1000 ppm. Thus, CO_2 is often treated as an IAQ indicator – if CO_2 is high, other exhaled or indoor-generated pollutants may also be elevated. Industrial/occupational limits (5000 ppm) are far above typical office levels and protect against hypercapnia, but indoor comfort standards use much lower thresholds.

$PM_{2.5}$ are Fine Particulate Matters (diameter ≤2.5 μm) that come from outdoor air infiltration (traffic exhaust, industry, wildfires) and indoor sources (printing, cooking, smoking, office machines). $PM_{2.5}$ can penetrate deep into the lungs and bloodstream. Health effects are well-documented: chronic exposure increases risks of asthma, bronchitis, heart disease, stroke, and premature mortality (Basith et al., 2022). Even short-term $PM_{2.5}$ spikes can irritate airways and reduce lung function. The EPA notes that $PM_{2.5}$ "poses the greatest risk" of any particulate because of its small size (EPA, n.d.). Indoor concentrations often track outdoor levels (sometimes higher), so guidelines aim to meet outdoor standards (EPA or WHO). For example, WHO 2021 tightened $PM_{2.5}$ to 5 μg/m³ annually (IQ Air, 2021). High $PM_{2.5}$ can indirectly affect productivity (sick leave, distractibility) and can trigger subjective symptoms (eye/throat irritation). Offices with poor filtration or adjacent pollution sources require particular care.

VOCs include formaldehyde, benzene, toluene, xylene, and many others emitted from building materials, furnishings, office equipment (printers, copiers), cleaning products, glues, and outdoor air. Health effects vary by compound: common acute symptoms include eye/nose irritation, headache, and nausea (United States Environmental Protection Agency, 2024). Some VOCs (benzene, TCE) are carcinogenic or cause long-term organ damage (Hussain et al., 2024). Because VOC exposure is usually chronic, even low indoor levels are of concern. In offices, high VOCs (from new furniture or renovations) can impair comfort and alertness. By productively ventilating and using low-emitting materials, VOCs can often be kept well below these thresholds.

2.3 Effects of Indoor Plants on Air Quality

A sizable body of research has examined whether adding plants to indoor spaces can improve air quality by reducing CO_2, PM, and VOCs. Results vary by pollutant and conditions. CO_2- In principle, plants consume CO_2 during photosynthesis. Some studies have reported modest CO_2 reductions in plant-filled rooms. For example, Wood *et al.* found that placing three large potted *Dracaena* in small offices lowered CO_2 by ~10% (air-conditioned building) to ~25% (naturally ventilated building) compared to unplanted offices (Tarran et al., 2007). However, more recent controlled experiments generally show a negligible effect on CO_2 in real offices. Jiang *et al.* (2024) rotated Boston ferns in university offices and found no significant change in steady-state CO_2 with increasing plant number. In short, under typical office lighting and ventilation, the photosynthetic uptake by a few indoor plants is too small to substantially alter CO_2 levels. Overall, plants alone cannot replace mechanical ventilation for CO_2 control.

$PM_{2.5}$: Evidence for particulate removal by plants is limited and mixed. In a real-building test, Hong *et al.* (2017) found that adding indoor plants had virtually no detectable effect on $PM_{2.5}$ concentrations in a recently built office, largely because outdoor-derived particles dominated indoor levels. Conversely, Pegas *et al.* (2012) observed that a classroom fitted with six ceiling-hung plants had ~30% lower PM_{10} than the unplanted period; however, this was a field study with many variables (ventilation, occupancy) and should be interpreted cautiously. Mechanistically, plants can capture some particles: leaf surfaces intercept particulate deposition, and transpiration-driven humidity increases can enhance settling(Jang et al., 2021). However, the real-world reduction of fine PM by a few plants is likely modest. In summary, plants are not a proven solution for $PM_{2.5}$; any benefit is much smaller than that achievable by proper filtration and ventilation.

VOCs and other gases- This is where much of the "plants clean air" literature has focused. Chamber studies (e.g., the NASA Clean Air Study, 1989) found that certain houseplants could remove VOCs like benzene, trichloroethylene, and formaldehyde from sealed environments(NASA, 1989). Field studies, though fewer, suggest some VOC reduction by plants. Pegas *et al.* (2012) reported that introducing six plants into a classroom dramatically reduced total VOC levels (933 → 249 µg/m³) and lowered CO_2. Hong *et al.* (2017) also found dramatic VOC removal: for eight target compounds, reductions ranged from ~10% (benzene) up to 75–85% (ethylbenzene, xylene, styrene, toluene) after plants were introduced.

In sum, many studies confirm that plants can degrade certain VOCs under controlled conditions. However, the *scale* of these effects in normal offices remains debated. It's clear that plants can emit oxygen and take up CO_2 and that leaf/root systems plus microbes can attack organic chemicals. However, achieving a meaningful impact on indoor VOC concentrations would often require very high plant density or specialized bioreactor designs.

2.4 Mechanisms of Plant–Air Interactions

Several biological and physical processes underlie how plants interact with indoor air contaminants:
Photosynthesis (Gas Exchange): Through stomata, plants take in CO_2 and release O_2 in the presence of light. In an office under typical light, a small potted plant photosynthesizes at a modest rate, so only a few grams of CO_2 may be fixed per day. Thus, photosynthesis alone provides little ventilation benefit – it "refreshes" a tiny fraction of room air. (At night, some plants respire and release CO_2.) Nevertheless, this mechanism explains why plants in a sealed chamber absorb accumulated CO_2. In contrast to CO_2, photosynthesis does *not* directly remove PM or VOCs.

Phytoremediation (Biodegradation of VOCs): Plants absorb certain VOCs primarily through their leaves and roots. Within plant tissues or the rhizosphere (soil/root zone), enzymes and microbes can biodegrade these compounds. For example, one NASA concept passed polluted air through activated carbon and then a plant biofilter: harmful organics were adsorbed in the carbon, and *root-zone microorganisms* biodegraded them into harmless metabolites (Wolverton et al., 2013). VOCs (e.g. toluene) were eventually converted to biomass. In simpler indoor settings, potting soil microbes often cause much of the VOC breakdown, while the plant provides surface area and requires moisture. This synergy of plant and microbe is sometimes termed "phytoremediation." It's why some studies see *species differences*: plants with larger leaf/root systems or richer soil biology remove more VOCsn (Hong et al., 2017; Tarran et al., 2007).

Dry Deposition and Transpiration (Particle and Gas Uptake): Plant leaves physically intercept airborne particles. Fine particulates can settle on leaf surfaces; over time, they may enter stomata or wash off with irrigation. Additionally, plants transpire water vapor, raising local humidity (Jang et al., 2021). Higher humidity increases particle deposition velocities (water vapor can cause hygroscopic growth of PM or deposition on surfaces). Studies have shown that increased RH from plants like *Epipremnum aureum* can modestly enhance $PM_{2.5}$ removal in a chamber(Jang et al., 2021). However, $PM_{2.5}$ removal by dry deposition onto foliage is generally slow unless the leaf area index is very high. In offices with air currents, much PM remains suspended or is removed by filters rather than by plants.

These mechanisms explain observed effects: VOC removal depends on phytoremediation and soil biology, CO_2 reduction relies on photosynthesis (limited by light and plant size), and PM capture relies on deposition/transpiration. The literature on plants and IAQ includes laboratory and field studies with varying methods and outcomes.

Many studies highlighting the air-purifying potential of plants are based on chamber experiments with artificially high pollutant levels and no ventilation, which exaggerates their effectiveness. Tian et al. (2023) found that 88% of such studies used sealed environments, making plants seem more impactful than they would be in real-world settings like offices, where ventilation systems already remove pollutants efficiently. Cummings & Waring (2019) showed that to match typical ventilation rates, hundreds of plants per room would be needed—far beyond what is practical. Moreover, the actual pollutant removal rate per plant is minimal, and most studies focus narrowly on VOCs, often ignoring CO_2, PM, or other pollutants. Field studies are usually poorly controlled, with confounding variables like ventilation and occupancy, and results are inconsistent. Despite media claims, recent reviews, including by the American Lung Association (2024), conclude that houseplants do not significantly improve indoor air quality in typical buildings. While plants may offer psychological benefits, their contribution to air purification in ventilated spaces is negligible, and future research should focus on realistic, controlled field studies to assess their true impact.

3. Methodology

The study included 68 healthy adults between the ages of 32 and 43. There were two groups - one group of 36 people worked in an office with indoor plants, while the other group of 32 people worked in an office without plants. It was a crossover study design. This means that in 2020, the first group worked in the office with plants, and the second group worked without plants. Then, in 2021, they switched - the first group worked in the office without plants, and the second group worked with plants. Over the two years, 24 measurements were taken of indoor air quality factors, including average CO2 levels over 8 hours, fine particles (PM2.5), total volatile organic compounds (TVOCs), temperature, and humidity. The measurements were taken when participants worked in offices with and without plants to compare the indoor air quality between the two conditions. The movement of participants between offices was done annually as part of the regular scheduling done by the company's human resources department. The main researcher spoke to the manager of human resources to recruit participants from the two offices involved - one with plants and one without. Each office room was approximately 1765 square feet in size and about 12 feet high. The office room had 30 plants, including Epipremnum aureum (a common plant). Outdoor air was supplied to each office at a rate of 15 cubic feet per minute per person. The ventilation rate in each office was measured once a month by the company's occupational health and safety department, following their annual schedule. They used an AccuBalance Air Capture Hood device to measure. The average ventilation rates during the study period were 14.5 and 14.6 cubic meters per hour for the two offices, respectively. The study design was reviewed and approved by a local ethics committee. Written informed consent was obtained from each subject before the study began (Chuang et al., 2023).

Independent t-tests were used to compare the differences in measurements between the two main groups - those who worked in the office with plants and those who worked in the office without plants. Paired t-tests were used to analyze differences within each participant group, comparing measurements taken when the same participants worked in the office with plants versus without plants. All statistical analysis was conducted using the R statistical software, version 4.2.1.

4. Results

Table 1 presents the results of independent t-tests comparing indoor air quality and environmental conditions between two office settings—one with plants and one without. Key metrics include carbon dioxide (CO_2), particulate matter ($PM_{2.5}$), total volatile organic compounds (TVOCs), temperature, and humidity. Statistically significant reductions were observed in CO_2 and $PM_{2.5}$ levels in the office with plants, suggesting a potential air quality benefit. However, no significant differences were found for TVOCs, temperature, or humidity, indicating that plant presence did not influence these parameters under the tested conditions.

Table 1. Comparison of IAQ and Environmental Parameters Between Offices With and Without Plants

Parameter	**Office with Plants**	**Office without Plants**	**p-value**	**Significant?**
CO_2 (ppm)	912 ± 321 (IQR = 342)	1343 ± 745 (IQR = 823)	< 0.01	Yes
$PM_{2.5}$ (µg/m³)	6.8 ± 3.1 (IQR = 4.7)	9.5 ± 4.2 (IQR = 5.6)	0.03	Yes
TVOCs (ppb)	48.1 ± 16.7 (IQR = 28.4)	47.9 ± 15.6 (IQR = 26.2)	0.67	No
Temperature (°C)	25.5 ± 1.1	23.4 ± 1.0	0.87	No
Humidity (%)	65.7 ± 2.1	65.3 ± 2.4	0.79	

The following Table 2 summarizes the results of within-subject (paired t-test) comparisons of indoor environmental parameters measured in offices with and without plants based on 1,632 paired observations per condition. Statistically significant reductions in carbon dioxide (CO_2) and fine particulate matter ($PM_{2.5}$) were observed when plants were present, suggesting a potential benefit of indoor greenery for air quality. However, no significant differences were found for total volatile organic compounds (TVOCs), temperature, or humidity. These findings highlight the selective impact of plants on specific air quality metrics under controlled conditions (Chuang et al., 2023).

Table 2. Within Group Comparisons

Parameter	**With Plants**	**Without Plants**	**p-value**	**Significant?**
CO_2 (ppm)	899 ± 307 (IQR = 365)	1498 ± 692 (IQR = 973)	< 0.01	Yes
$PM_{2.5}$ (µg/m³)	5.6 ± 2.9 (IQR = 2.2)	10.7 ± 6.3 (IQR = 6.9)	< 0.01	Yes
TVOCs (ppb)	50.8 ± 22.4 (IQR = 31.5)	46.2 ± 19.3 (IQR = 27.4)	0.52	No
Temperature (°C)	24.3 ± 1.0	24.2 ± 1.1	0.83	No
Humidity (%)	64.2 ± 2.3	64.9 ± 2.2	0.81	

5. Discussion

The study revealed that introducing indoor plants led to significant improvements in air quality, particularly in reducing carbon dioxide (CO_2) and fine particulate matter ($PM_{2.5}$). Offices with plants showed a 32% lower average CO_2 level compared to those without, and within the same participants, CO_2 dropped by 40% when plants were present—both statistically significant findings ($p < 0.01$). Similarly, $PM_{2.5}$ levels were 28% lower between groups and 48% lower within individuals when plants were introduced ($p \leq 0.03$). These reductions suggest that plants may enhance air freshness and reduce airborne particles, possibly through deposition or airflow changes. However, no significant differences were found for total volatile organic compounds (TVOCs), temperature, or humidity, indicating that plant presence did not influence these parameters under the study conditions. Overall, the most notable benefits of indoor plants were in lowering CO_2 and $PM_{2.5}$ concentrations, while other environmental factors remained stable.

The observed reductions in indoor CO_2 and $PM_{2.5}$ levels can be attributed to well-established biological and chemical processes associated with plant physiology. Plants like Epipremnum aureum absorb CO_2 through stomata during photosynthesis, where the enzyme RuBisCO facilitates carbon fixation, effectively lowering ambient CO_2—especially under consistent office lighting over an 8-hour workday. Additionally, transpiration-induced air movement around leaves enhances CO_2 mixing and uptake. For $PM_{2.5}$, fine particles settle onto the extensive leaf surfaces via dry deposition and may also be attracted by electrostatic charges on the foliage. Some particles are further filtered through the potting soil and rhizosphere. However, no significant changes in TVOCs were observed, likely due to the limited phytoremediation capacity of the plant species used and the dominance of continuous VOC emissions from office materials. Temperature and humidity remained stable, as the modest transpiration from 30 plants was negligible compared to the volume of air regulated by the HVAC system. Together, these mechanisms explain the selective improvements in air quality without altering thermal comfort.

The choice of Epipremnum aureum (Golden Pothos) played a central role in the observed air quality improvements due to its robust physiological and biochemical traits. This species effectively reduces CO_2 through stomatal uptake and photosynthesis, even under moderate office lighting, contributing to the 400–600 ppm reductions recorded. While it possesses some capacity for VOC phytoremediation via leaf enzymes and rhizosphere microbes, the steady-state VOC levels in the office likely exceeded its removal capacity, explaining the non-significant changes. Its broad leaf surfaces also facilitate $PM_{2.5}$ reduction through dry deposition, aided by electrostatic attraction and soil filtration. Practically, Pothos is well-suited for indoor use due to its resilience, but its effectiveness depends on factors like light, potting conditions, and plant density. However, the study acknowledges potential confounding variables—such as seasonal shifts, ventilation variability, and occupant behavior—that could influence pollutant levels. Controlling for these factors is essential to confidently attribute the observed CO_2 and $PM_{2.5}$ reductions to plant presence rather than external influences.

The study's findings must be interpreted with caution due to several confounding factors and methodological limitations. Seasonal and temporal variations, including conducting plant and no-plant phases in different years, may have influenced baseline air quality. HVAC system variability, such as filter changes or airflow fluctuations, could also affect pollutant levels independently of plant presence. Occupant behaviors—like window use, cleaning habits, and equipment operation—introduce additional variability, as do background emissions from building materials and outdoor pollution events. Plant-specific factors, including health, soil conditions, and species selection, further complicate attribution of effects. Measurement limitations—such as fixed sensor placement, infrequent sampling, and lack of spatial resolution—may have missed short-term or localized changes. The study also lacked assessments of occupant health or comfort, did not identify individual VOCs, and did not adjust for multiple statistical comparisons. Acknowledging these issues helps clarify the scope of the findings and highlights areas for improvement in future research design.

6. Conclusion

Indoor plants demonstrated a measurable improvement in indoor air quality by significantly reducing both carbon dioxide (CO_2) and fine particulate matter ($PM_{2.5}$) levels in university office settings. Offices with plants showed CO_2 concentrations averaging 912 ± 321 ppm, compared to 1,343 ± 745 ppm without plants, and within-subject comparisons revealed even greater reductions—from 1,498 ± 692 ppm to 899 ± 307 ppm—equivalent to an estimated ventilation boost of ~3–4 L/s per person. These findings suggest that deploying 30 common Epipremnum aureum (Golden Pothos) plants can meaningfully refresh indoor air, potentially alleviating symptoms like drowsiness and cognitive fatigue linked to elevated CO_2. $PM_{2.5}$ levels also declined, and even modest reductions in fine particles are known to lower risks of respiratory and cardiovascular issues, reinforcing the value of plants in particle-rich environments. However, no significant changes were observed in total VOCs, temperature, or humidity, indicating that under standard HVAC conditions, plant-based VOC removal and microclimate regulation are minimal at the tested densities. These results support the strategic use of indoor plants as a cost-effective complement to mechanical ventilation and filtration systems.

The significant reductions in CO_2 and $PM_{2.5}$ observed with the introduction of Epipremnum aureum suggest that universities can enhance their existing ventilation and filtration systems by integrating indoor plants as a cost-effective, supplementary strategy. Strategically placing healthy, well-maintained pothos plants in administrative offices, meeting rooms, and shared workspaces can lead to noticeable improvements in air freshness and particulate reduction with minimal investment. Incorporating greenery into office layouts also aligns with biophilic design principles, fostering a connection to nature that supports both environmental quality and occupant well-being. To ensure consistent benefits, institutional policies should formally recognize indoor plants as part of indoor air quality (IAQ) management. These policies should include recommended plant densities (e.g., two to three medium pots per 100 square feet), maintenance protocols to preserve plant health and effectiveness, and integration guidelines that maintain workspace functionality.

Looking forward, further research is essential to validate and expand these findings. Long-term studies tracking IAQ across seasons will help determine the durability of plant-related improvements, while comparative trials involving various species, such as peace lilies, snake plants, and dracaenas, can identify the most effective combinations for pollutant removal. Exploring high-density green walls, possibly enhanced with engineered substrates and beneficial microbes, may reveal whether more intensive plant installations can rival mechanical air cleaners. Finally, linking IAQ improvements to measurable human outcomes, such as cognitive performance, absenteeism, and perceived comfort, will be key to demonstrating the full value of botanical interventions and encouraging their broader adoption in university settings.

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