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Review Article

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# Effects of potted plants in the removal of indoor air pollutants: A review

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**Abstract**

**Background:** Indoor plants that are used for decorative purposes can remove pollutants that are harmful to humans. This study aimed to compile information to give a broad picture of how indoor plants enhance indoor air quality.

**Methods:** The information sources for this study were Science Direct, PubMed, Web of Science, and Google Scholar. The eligibility criteria included studies with (i) interventions using any indoor plant, (ii) comparators included within the same experimental treatment, (iii) results that included air quality effects objectively measured using any instrument, (iv) research using a controlled study design, and (v) articles published in English. A total of 17 research articles reporting quantitative empirical research published between 2011 to 2022 were selected. The reviewed articles were compiled according to (i) Inferences, (ii) intervention, (iii) plant name, (iv) type of pollutant, (v) experimental setup, (vi) research environment.

**Results:** The effects of indoor plants on air quality were reduced pollutant levels (particularly volatile organic compounds, formaldehyde, Toluene, and ethylbenzene), followed by smoke particles, Nitrogen dioxide, Carbon dioxide, and Carbon monoxide.

**Conclusion:** This study showed that indoor plants have a significant potential to reduce indoor air pollutants and improve indoor occupant comfort, and overall improve public health.

**Keywords:** Indoor air quality, Indoor plants, $PM_{10}$, $PM_{2.5}$, Volatile organic compounds

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## Introduction

One of the primary issues in towns and cities, particularly in developing nations, is air pollution. Indoor environments are a combination of indoor contaminants, which originate inside the building, and outside contaminants, which are frequently associated with industrial activity and automobile traffic. Outside pollutants can enter through natural and mechanical ventilation systems, infiltration, or other means (1). The exposure to air pollutants imposes different health effects on humans, depending on the composition, exposure level, exposure duration, exposure frequency, and toxicity of the pollutant of interest (2). In 2018, the World Health Organization (WHO) reported that about 90% of people around the world breathe polluted air (3). Chemical complexes found in common household cleaning products, fungicides, insecticides, textiles and clothing, paints, couches, and other pesticides are another form of air pollution (4). The primary cause of indoor pollution in public spaces like restaurants, cafes, and other closed public areas is cigarettes. When compared to comparable public spaces where smoking is prohibited, the levels of $PM_{2.5}$ in areas where smoking is permitted are significantly (5). The necessity for air pollution controls has been brought to light by growing concern over the harmful impacts of air pollution on health (6). In the industrialized world, the quality of the indoor environment has become a major health problem since individuals who live in cities usually spend 80–90% of their time indoors (7). People may experience ailments like sick building syndrome, which is characterized by headache, eye, nose, and throat irritation, weariness, dizziness, and nausea, if indoor air quality is inadequate (8) About 1.2 million people died in India in 2017 as a result of indoor and outdoor air pollution (Health Effects Institute 2019). This is mostly because energy-saving measures such as sealing up naturally occurring apertures in buildings, utilizing unproven new materials, and inadequate air circulation significantly reduce indoor air quality. The interference is causing a rise in indoor concentrations of many pollutants, including CO, $CO_2$, $PM_{10}$, $PM_{2.5}$ and total volatile organic compounds (9). Recent studies have shown that indoor plants may dramatically reduce most forms of urban air pollution (10). Through mechanisms like rhizosphere biodegradation (by microorganisms), phytoextraction (plant-liquid extraction), stomatal uptake (plant-gas extraction), phytodegradation (via enzymatic catalysis inside tissues), and phytovolatilization (directly by evaporation from leaves or indirectly by plant transpiration). Ornamental plants have the capacity to absorb, distribute, and transport organic pollutants. This study aimed to compile information to give a broad picture of how indoor plants enhance indoor air quality.

## Materials and Methods

The databases like Science Direct, PubMed, Web of Science, and Google Scholar were searched for any available scientific literature published in the previous 10 years (2011–2022). The search terms entered alone and in combination included Indoor Air Pollution, Indoor plants, Volatile Organic Compounds, Environmental Exposure, $PM_{10}$, and $PM_{2.5}$.

Literature was screened using the subsequent search parameters: (i) treatments utilizing any indoor plant; (ii) comparators incorporated into the same experimental treatment; (iii) outcomes including objectively measurable air quality impacts using any instrument; (iv) studies employing any study design; and (v) publications written in English (vi). Only Journal publications with quantitative empirical research were used for this study. Thus, works such as "Vegetated Facades as Environmental Control Systems, Filtering Fine Particulate Matter ($PM_{2.5}$) for improving indoor air quality and unpublished theses and dissertations were excluded. Real data and analysis are usually used in empirical research, whereas statistical, mathematical, and computational techniques are used in quantitative research. Furthermore, because they must undergo peer review, Journal publications published in the public domain are subject to stricter publication requirements. Also, compared to laboratory trials, field studies carried out in real ecosystems have more ecological validity.

Electronic databases were searched using the keywords and the paper titles and abstracts were examined based on the previously indicated eligibility requirements. If the article titles and abstracts were not enough to make a decision, the full contents were evaluated. After the articles were examined based on the qualifying criteria, their entire texts were retrieved.

## Results

After performing a keyword-based search in databases such as Web of Science and PubMed, a total of 185 research and review papers were identified. Among these, 17 research articles involving experimental setups (controlled chamber studies) and published between 2011 and 2022 were selected for detailed analysis, as presented in Table 1.

In the 17 research articles selected, 37 plant species were tested for their effects on air quality. To avoid misjudgments during data compilation, Journal articles containing incomplete or unrecognizable species, non-specified scientific names, or incorrect names were excluded (6). Table 2 shows the most frequently tested indoor plant species was Epipremnum aureum (Pothos), which appeared four times, followed by Chlorophytum

**Table 1.** Summary of reviewed studies of indoor plant effects on air quality

| Author | Inferences | Interventions | Plant name | Type of pollutants | Experimental setup | Research environment |
|---|---|---|---|---|---|---|
| Jinhee Lee et. al. 2015 (11) | The plant can remove 29-35% tobacco pollutants in 60 minutes. | 30 air-filtering plants that can grow at a minimum temperature of 10°C and minimum light of 500 LUX all year are selected | *Spathyphyllurm* spp., *Samsevieria trifasciata,* Rhapis excels, Fatsia japonica, Cupressus macrocarpa 'Gold crest' | particle pollutant | Closed chamber (0.9 × 0.6 × 0.6 m volume 0.32 $cm^3$) for almost ground cover plants. | Minimum temperature of 10°C and minimum light of 500 LUX. |
| Fraser Torpy and Michael Zavattaro 2018 (12) | Air pollutant reduction with two commonly used indoor species. | For each test, a single plant module was placed, and three replicate planted modules were used in every trial. | Chlorophytum comosum (Spider Plant) and Epipremnum aureum (Pothos). | Particulate matter (PM) and volatile organic compounds (VOCs) | Sealed bench-top test-chamber (0.6 × 0.6 × 0.6 m; 0.216 m3) | In-built substrate ventilation fans with 100 mm diameter produced airflows of 4.5 or 9.0 L/s. Temperature maintained at 23–26°C. light intensity:100 µmol/ $m^2$/s |
| P.J. Irga, F.R. Torpy, M.D. Burchett 2013 (13) | With a moderate increase in indoor light intensity, Syngonium podophyllum removed significant amounts of $CO_2$ | 8 pots for each treatment. Plants were grown for 133 days before testing. The growing conditions were: temperature: 23.0; relative humidity: 45 | Syngonium podophyllum | Volatile organic compounds (VOCs) and $CO_2$ | Eight glass test chambers, 26 × 20 × 30.5 cm (interior volume 15 L), equipped with a portable Infrared Gas Analyser (IRGA) and $CO_2$ monitor | Fans with a 50 mm diameter were fitted to maintain air circulation. The temp. in the chambers was maintained at 23°C throughout the experiments using an internal copper coil (i.d. 4 mm) that circulated water from a thermostat-regulated water bath. |

**Table 1.** Continued.

| Author | Inferences | Interventions | Plant name | Type of pollutants | Experimental setup | Research environment |
|---|---|---|---|---|---|---|
| Suya Zhao et. al. 2018 (14) | The results show that two plants have strong tolerance to formaldehyde in the air and possess good formaldehyde removal ability. | Uniform seedlings were individually selected and transplanted into 4-L containers filled with 1/5-strength Hoagland nutrient solution. The plants were grown hydroponically for two weeks before the experiment. | Wild Taraxacum mongolicum Hand.-Mazz. and Plantago asiatica L | Formaldehyde | Transparent glass container (50 × 30 × 35 cm) filled with 1000 mL of a solution containing varying formaldehyde contents. | The container (pot) was sealed and placed into a plant growth room (with a 14-h light period) with temperatures of 25°C during the day and 20°C at night, and 50–70% relative humidity. |
| Zhiqiang Wang et. al. 2014 (15) | The role of the plant was to introduce and maintain a favorable microbial community that effectively degraded the VOCs. | Golden Pothos plants (one or two), with their status just like how it is placed in homes and offices, were placed in the chamber. | Golden Pothos Epipremnum aureum | Formaldehyde | Tests were conducted in an air-tight 5.1 $m^3$ stainless steel chamber with interior dimensions of 1.83 m × 1.68 m × 1.68 m. | Temperature and relative humidity can be controlled. |
| Zhongjun Xu et. al. 2011 (16) | Spider plant–soil system had the highest formaldehyde removal capacity compared to others. | Three pots of each plant were planted in the porcelain pots with an inner diameter of 15 cm and a height of 10 cm, and have been cultivated in a light intensity of 240 μ mol/$m^2$/s (12 h in light) for more than 5 months. | Spider plant (Chlorophytum comosum), Aloe (Aloe vera) and golden pothos (Epipremnum aureum) | Formaldehyde | Cylindrical plexi glass chamber with an inner diameter of 40 cm and a height of 60 cm. | Potted plant species placed into each dynamic chamber were subjected to the light intensities of 80, 160, 240 μ mol/$m^2$/s (12 hours in light). |
| Suya Zhao et. al. 2019 (17) | The removal rate of plants in the plant-only systems was ordered as Helianthus annuus Linn > Lycopersicon esculentum Miller > Oryza sativa > Sansevieria trifasciata Prain > Bryophyllum pinnatum > Mesembryanthemum cordifolium L. f. | Uniform plant seedlings were transplanted into glass bottles containing 50mL of a nutrient solution. Glass bottles were amended with 40 mL of nutrient solution and 10mL of soil microorganism solution. The bottles were wrapped with dark paper, and the space between the cap and plant shoots was sealed with a sponge wrapped in aluminum foil. | Helianthus annuus Linn, Lycopersicon esculentum Miller, Oryza sativa, Sansevieria trifasciata Prain, Bryophyllum pinnatum, Mesembryanthemum cordifolium L. f. | formaldehyde | Transparent glass container (50 × 30 × 35 cm) filled with 1 L of solution containing varying formaldehyde concentration. | The container (pot) was sealed and placed in a plant growth room with a 14 h light period (260–350 μmol/$m^2$/s) at temperatures of 25 OC during the day and 20°C during the night, and 50–70% relative humidity. |
| Bhavya Bhargava et. al. 2020. (18) | Areca palm potted plants offer an efficient, cost-effective, self-regulating, sustainable solution for improving indoor air quality. | (12-month-old), free from any insect-pest attack, potted (30 × 30 × 20 cm) in a standard growing media (5 kg per pot) containing soil, sand, and well-decomposed Farm Yard Manure (1:1:1) was selected. | Areca palm | Total volatile organic compounds (TVOCs), Carbon dioxide ($CO_2$), and Carbon monoxide (CO). | Site I: Floriculture laboratory (122.1 $m^3$), Site II Chemistry laboratory (256.5 $m^3$), Site III canteen (153.4 $m^3$), and Site IV (library, 197.2 $m^3$). | Ambient atmosphere. Natural ventilation (ceiling and exhaust fans) without any additional air conditioning systems. |
| Hakimeh Teiri et. al. 2018 (19) | Plants efficiently removed formaldehyde from polluted air by 65-100%, Depending on the inlet concentration, for a long-time exposure. | | Chamaedorea elegans | Formaldehyde | Test chamber with a volume of 375 liters (84 cm × length × 62 cm width × 72 cm height). | The temperature and relative humidity of the chambers were controlled by digital hygro-thermometers. The light intensity, supposed to be natural indoor environment light four times a day over the experimental period. |
| Todd A. Wetzel & William J. Doucette 2014 (20) | Plant leaves to be used as cost-effective, real-time indoor air VOC samplers. | Plants were kept under a 400-W metal halide grow lamp with a 10-h photoperiod and were watered as needed to maintain health. | Ficus benjamina, Epipremnum aureum Chlorophytum comsosum 'vittatum' and Schlumbergera truncate 'harmony'. | Volatile organic compounds | Actual residence room | The residence was equipped with a forced air (HVAC) system and had a total air volume, including the basement of 600 $m^3$. House thermostat set at 25.6. |

**Table 1.** Continued.

| Author | Inferences | Interventions | Plant name | Type of pollutants | Experimental setup | Research environment |
|---|---|---|---|---|---|---|
| Curtis Gubb et. al. 2022 (21) | Potted plants offer clear potential to improve indoor air quality. | 3 L containers (width: 19 cm wide and height: 15 cm, with 227 $cm^2$ surface area). Plants were kept at room temperature (21–22°C) and light levels (~ 500 lx). | Dracaena fragrans ‘Golden Coast’, Spathiphyllum wallisii ‘Verdi’, and Zamioculcas zamiifolia. | Nitrogen dioxide ($NO_2$). | 150 L (45 × 45 × 75 cm, 0.15 $m^3$) Perspex chamber. ‘No’ light (0 lx) was achieved by undertaking except. at night. | Initial $NO_2$ concentration of 100 ppb (± 15%). Experiments were conducted for 1 hour. |
| Elham F. Moha et. al. 2015 (22) | The removal rate was found to be more than 67% in the treated chamber. | Storage bottle (250 mL) containing liquid formaldehyde, an air pump, a gas flow meter, and a set of two plastic chambers with an inside volume of 0.512 $m^3$. | Sugarcane bagasse waste raw materials with four well-established potted plants (petunias) | Formaldehyde gas | Two plastic chambers with an internal volume of 0.512 $m^3$, with 0.8 m each side. HCHO concentration was in the range of 15 -20 mg/$cm^3$. | The plants were exposed to HCHO gas for 18 hours over several time intervals that increased gradually during the experiment progress. The total period of plants exposure was 7 days. |
| Majbrit Dela Cruz et.al. 2018 (23) | All gasoline VOCs were reduced when H. helix was present. Total VOC removal was in the range of 11-32%. | Plants were 6 weeks old, grown in 11 cm pots, and consisted of 6-7 plantlets. Plants were allowed to acclimate for 14 days. After the first 15 days, the epigeous plant material was abscised, and for the last eight days, only the pot with soil and the hypogeal part remained. | Hedera helix ‘Shamrock’ | Volatile gasoline compounds | The plant was placed in two of four glass chambers (57.5 L). Light intensity was set to 37 ± 3 μ mol / $m^2$/s, and the day length was 12 h. The temperature was controlled at 20.8 ± 0.5. | The entire potted plant was exposed to gasoline. The mixing chamber was supplied with a 200 mL bottle with gasoline, which could diffuse through a 1.7 cm 12-gauge needle in the lid of the vial. The air flow was regulated at 4.3 ± 0.1 L/min by a pressure regulator. |
| Vanessa Hormann et. al. 2017 (24) | A rapid decline in the toluene as well as in the 2-ethylhexanol concentrations was observed when plants were present in the chamber. | Three plants of either D. maculata or S. wallisii or three pots without plants filled with unused potting soil only, were tested per Biobox under continuous light. All experiments were replicated four times. | Dieffenbachia maculata and Spathiphyllum wallisii | Toluene and 2-ethylhexanol | Two individual gas-tight chambers 80 × 60 × 50 cm with a total volume of 240 L, consist of two parts: a metal base 15 × 60 × 50 cm and a Plexiglas hood (65 × 60 × 50 cm). | $CO_2$ = 500 ppm, RH = 70%, temperature = 22, light = 180 ± 10 μmol/$m^2$/s. |
| Kwang Jin Kim et. al. 2018 (25) | The root zone is a major contributor to the removal of formaldehyde. | Two-year-old plants were transplanted to 19 and 15-cm-diameter pots. Plants were kept in an indoor environment for more than one month at 23℃ ± 2, 40% ± 5% relative humidity, and a light intensity of 20 ± 2 mol/ $m^2$/s. | Fatsia japonica Decne and Ficus benjamina. | Formaldehyde | Air air-tight chamber of 1.0 $m^3$ (90 cm × 90 cm × 123 cm), in which the air was circulated (6 L/min) and released at the bottom of the chamber. | |
| Wararat Sriprapat et. al. 2014 (26) | The highest toluene removal was found in S. trifasciata, while ethylbenzene removal from air was with C. comosum. | Twelve plant species with a leaf area of 0.013 $m^2$ were chosen for the experiment. Cultures of plants were maintained in plastic pots (0.1X 0.1 $m^2$) containing 200 g of soil and coco coir 1:1 as growth media. The pot was covered by aluminum foil to avoid other factors, such as soil and pot absorption. | Aloe vera, Sansevieria masoniana, Sansevieria trifasciata, Sansevieria hyacinthoides, Sansevieria ehrenbergii, Kalanchoe, blossfeldiana, Dracaena deremensis Codiaeum variegatum, Chlorophytum comosum, Dracaena sanderiana Cordyline fruticosa Aglaonema commutatum. | Toluene, ethylbenzene and volatile compounds. | Glass chambers with a volume of 15.6 L were used for plant fumigationThree replicate chambers were used in each treatment. | Toluene or ethyl benzene was injected to generate a concentration of 20 ppm or 12 μmol inside the chamber. The plant was placed into each chamber at room temperature (32) and a pressure of 760 mmHg with 12 h of light and dark cycles. |

**Table 2.** Most frequently studied plant families and species

| Plant Family | Frequency |
|---|---|
| *Epipremnum aureum (Pothos)* | 4 |
| *Chlorophytum comosum (Spider Plant)* | 3 |
| *Fatsia japonica* | 2 |
| *Syngonium podophyllum* | 2 |
| *Aloe vera* | 2 |
| *Areca palm* | 2 |
| *Ficus benjamina* | 2 |
| *Spathiphyllum spp* | 1 |
| *Samsevieria trifasciata* | 1 |
| *Rhapis excels* | 1 |
| *Cupressus macrocarpa* | 1 |
| *Wild Taraxacum mongolicum Hand* | 1 |
| *Plantago asiatica L* | 1 |
| *Helianthus annuus Linn* | 1 |
| *Lycopersicon esculentum Miller* | 1 |
| *Oryza sativa* | 1 |
| *Sansevieria trifasciata Prain* | 1 |
| *Bryophyllum pinnatum* | 1 |
| *Mesembryanthemum cordifolium L. f* | 1 |
| *Chamaedorea elegans* | 1 |
| *Christmas cactus (Schlumbergera truncate 'Harmony')* | 1 |
| *Dracaena fragrans 'Golden Coast'* | 1 |
| *Spathiphyllum wallisii 'Verdi'* | 1 |
| *Zamioculcas zamiifolia* | 1 |
| *sugarcane bagasse* | 1 |
| *Hedera helix 'Shamrock'* | 1 |
| *Dieffenbachia maculata* | 1 |
| *Spathiphyllum wallisii* | 1 |
| *Sansevieria masoniana* | 1 |
| *Sansevieria trifasciata* | 1 |
| *Sansevieria hyacinthoides* | 1 |
| *Sansevieria ehrenbergii* | 1 |
| *Kalanchoe, blossfeldiana* | 1 |
| *Dracaena deremensis 'Lemon lime'* | 1 |
| *Codiaeum variegatum,* | 1 |
| *Cordyline fruticosa* | 1 |
| *Aglaonema commutatum* | 1 |
| *Dracaena sanderiana* | 1 |

comosum (Spider Plant) three times, Fatsia japonica, Syngonium podophyllum, Aloe Vera, Areca palm, and Ficus benjamina two times each, and the rest of the plant species appeared only once.

Figure 1 shows that in the reviewed Journal articles, volatile organic compounds were removed by 16 plants, followed by Formaldehyde gas 13, Toluene and ethylbenzene 13, smoke particles 5, Nitrogen dioxide 3, Carbon dioxide 2, and Carbon monoxide (CO) by 1 plant. In most cases, experiments are done at 23 to 25°C with relative humidity of 50 to 70% and tested in a controlled environment by making air-tight chambers of varying size from 26 × 20 × 30.5 cm to 183 cm × 168 cm × 168 cm internal dimensions. Some tests in the reviewed articles are also performed in the natural environment.

## Discussion

This study encompasses several ornamental plants with varying capacities of pollutant removal. The lab values of closed and controlled chambers show a great decline in the variety of pollutants under study, namely smoke particles, particulate matter, volatile organic compounds VOCs, $CO_2$, Formaldehyde, TVOCs, CO, $NO_2$, toluene, and 2-ethylexanol. The study shows that snake plants and their variants can remove 29 to 35% of tobacco pollutants in an hour at 10°C with a minimum light intensity of 500 lux.

Spider plant and pothos are found to be effective in removing PM and volatile organic compounds in a sealed chamber. Eight pots of arrowhead plants removed a significant amount of VOCs.

Two plants, namely wild Traxacum and Plantago, exhibit strong tolerance and good formaldehyde removal ability in a glass container. Golden pothos plant with just status, like how it is placed in homes and offices, can maintain a favorable microbial community to degrade VOC.

The spider plant soil system had the highest formaldehyde removal capacity compared to others.

Areca palm offers a cost-effective solution for improving indoor air quality under natural ventilation. F. benjamina /epipremum aureum, chlorophytus cosmos remove VOCs in a room that was equipped with an HVAC system. The root zone of Japonica F Benjamin contributes to the removal of formaldehyde.

The present review study shows that indoor plants that are usually used for ornamental purposes can also be used as substantial air pollutant removers.

## Conclusion

According to several studies, potted plants may significantly reduce indoor air pollution by eliminating a variety of important pollutants. For these reasons, potted plants are a portable, affordable, self-regulating, adaptable, flexible, attractive, and sustainable bio-filtration system. The majority of the plants under study are capable of eliminating volatile organic chemicals, mainly followed by smoke particles, carbon dioxide, nitrogen dioxide, ethylbenzene, formaldehyde gas, and carbon monoxide (CO). Additional empirical research and field trials are necessary to determine the precise link between the plants and pollutants, even if the above-mentioned results were mostly acquired in labs. Nevertheless, they have significant reference and application value for policymakers and

**Formaldehyde**

↓

*Epipremnum aureum (Pothos), Chlorophytum comosum (Spider Plant), Fatsia japonica, Wild Taraxacum mongolicum Hand, Plantago asiatica L, Helianthus annuus Linn, Lycopersicon esculentum Miller, Oryza sativa, Sansevieria trifasciata Prain, Bryophyllum pinnatum, Mesembryanthemum cordifolium L. f Chamaedorea elegans, sugarcane bagasse.*

**Smoke Particle**

↓

*Fatsia japonica, Spathyphyllurm spp, Spathyphyllurm spp, Rhapis excels, Samsevieria trifasciata,*

**Volatile Organic Compounds**

↓

*Syngonium podophyllum, Aloe vera, Areca palm, Ficus benjamina, Christmas cactus, Hedera helix 'Shamrock', Sansevieria masoniana, Sansevieria trifasciata, Sansevieria hyacinthoides Sansevieria ehrenbergii, Kalanchoe, blossfeldiana, Dracaena deremensis 'Lemon lime', Codiaeum variegatum, Cordyline fruticosa, Aglaonema commutatum, Dracaena sanderiana*

**Toluene**

↓

*Aloe vera, Dieffenbachia maculata, Spathiphyllum wallisii, Sansevieria masoniana, Sansevieria trifasciata, Sansevieria hyacinthoides, Sansevieria ehrenbergii, Kalanchoe, blossfeldiana, Dracaena deremensis 'Lemon lime', Codiaeum variegatum, Cordyline fruticosa, Aglaonema commutatum, Dracaena sanderiana*

**Carbon Dioxide And Carbon monoxide**

↓

*Syngonium podophyllum*, *Areca palm*

**Nitrogen Dioxide.**

↓

*Dracaena fragrans 'Golden Coast', Spathiphyllum wallisii 'Verdi' Zamioculcas zamiifolia*

**Figure 1.** Type of pollutant removed by the plant species in this study

environmental planners. Furthermore, it is advised to do laboratory tests to look into causal linkages, with field experiments following to validate the lab results. This study has shown that indoor plants have a significant potential to reduce air pollution, improve indoor occupant comfort, and overall improve public health.

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## Authors' contribution
**Conceptualization:** Nusrat Ali.
**Data curation:** Nusrat Ali.
**Formal analysis:** Saba Imdad.
**Investigation:** Nusrat Ali, Saba Imdad.
**Methodology:** Nusrat Ali, Saba Imdad.
**Project administration:** Syed Aqeel Ahmad.

**Resources:** Sohail Ayub.
**Software:** Sohail Ayub.
**Supervision:** Syed Aqeel Ahmad, Sohail Ayub.
**Validation:** Saba Imdad.
**Visualization:** Saba Imdad.
**Writing–original draft:** Nusrat Ali.
**Writing–review & editing:** Nusrat Ali, Saba Imdad.

## Competing interests

The authors declare that they have no conflicts of interest.

## Ethical issues

The author hereby certifies that all data collected during the study are as stated in the manuscript, and no data from the study has been or will be published separately elsewhere.


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