A Comprehensive Review of Phytoremediation Potential of Indoor Decorative Plants in Controlling Indoor Air Pollution (IAP) of Microenvironments and Sick Building Syndrome (SBS)

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Abstract

Indoor air pollution (IAP) has emerged as a critical global health concern, especially since people in modern societies spend approximately 70-90% of their time indoors. Studies show that indoor air can be two to five times more polluted than outdoor air, leading to a range of health issues, including ischaemic heart disease, stroke, respiratory infections, and lung cancer. The World Health Organization attributed 3.2 million premature deaths to IAP in 2020 alone. Common sources of indoor pollutants include building materials, furnishings, combustion appliances, biological contaminants, and electronic equipment. Sick Building Syndrome (SBS) describes a set of non-specific symptoms experienced by occupants of poorly ventilated buildings, which often alleviate after leaving the space. While conventional control methods rely on ventilation and air filtration systems, these are often costly, energy-intensive, and require careful maintenance. This review paper explores the potential of phytoremediation using common indoor decorative plants as a natural, sustainable, and cost-effective strategy for improving indoor air quality (IAQ). Various plant species have demonstrated the ability to absorb, degrade, or neutralize volatile organic compounds (VOCs), particulate matter, and even electromagnetic radiation. The paper synthesizes findings from NASA and other research organizations, presenting a comprehensive summary of effective plant species, their mechanisms of action, and practical guidelines for their use in homes and workplaces. The review concludes that integrating indoor plants offers a multifaceted solution for controlling IAP while providing psychological and physiological benefits to building occupants.

Keywords: *Indoor air pollution (IAP); Phytoremediation; Sick Building Syndrome (SBS); Indoor decorative plants; Indoor air quality (IAQ); Biofiltration; Environmental health*

INTRODUCTION

Air pollution is an issue that concerns all of us. While we can choose or reject certain foods, drinks, and comforts in life, we have little control over the air we breathe. People are forced to inhale smoke, exhaust fumes, and all the harmful pollutants in the surrounding air. Although most studies have concentrated on ambient (outdoor) air pollution from industrial and vehicular emissions, indoor air pollution (IAP) remains a significant risk factor for various health issues, including premature deaths globally. Air pollution accounted for 6.7 million premature deaths per year, of which 3.2 million were attributed to IAP alone in 2020 (WHO, 2024). A significant portion of deaths attributable to IAP exposure includes 32% from ischaemic heart disease, 23% from stroke, 21% from lower respiratory infections, 19% from chronic obstructive pulmonary disease (COPD), and 6% from lung cancer (WHO, 2024). These statistics highlight the serious health risks associated with breathing polluted air inside our homes and workplaces.

The problem of IAP is not new. Ever since people first built shelters for protection against harsh weather and began burning fuels indoors for cooking and heating, indoor air has been getting contaminated. An interesting historical example is the body of an Eskimo woman from the fourth century, discovered in 1972 on Saint Lawrence Island in the Bering Sea. An autopsy revealed that she suffered from black lung disease (Brenner, 1989). Researchers concluded that she must

have breathed very polluted air for many years, likely from lamps burning seal and whale blubber in her home.

According to the U.S. Environmental Protection Agency, indoor air is generally 2 to 5 times more polluted than outdoor air (EPA, 1991). In today's world, people spend between 70% to 90% of their time indoors—in homes, offices, restaurants, and other enclosed spaces. An average urban resident spends more than 20 hours each day inside buildings. This makes indoor air quality (IAQ) a more pressing issue than many realize. A study by Antikainen *et al.* (2008) found a direct link between air quality and job productivity: cleaner air helps people work better.

The common method of controlling IAP is proper ventilation. However, most ventilation systems are not specifically designed to remove certain indoor pollutants, and they require careful maintenance to keep working effectively. On the other hand, common indoor plants offer a natural way to absorb and remove harmful pollutants from the air inside modern buildings, while also making the space look better (NASA, 2007). NASA studies have shown that green plants are often better than many kinds of air filters at cleaning impurities from the air (Alam, 2002). NASA's findings also suggest that indoor plants can help fight "*Sick Building Syndrome*" (SBS)—a condition where residents complain of health problems like itchy eyes, skin rashes, drowsiness, breathing issues, headaches, and other allergy-related symptoms.

This paper aims to comprehensively review and synthesize existing scientific literature on the sources and health effects of indoor air pollution (IAP), the phenomenon of Sick Building Syndrome (SBS), and established indoor air quality (IAQ) standards. The primary objective is to critically evaluate the potential of common indoor decorative plants as a phytoremediation strategy for controlling IAP in microenvironments, and to provide practical, evidence-based recommendations for their use in improving indoor air quality.

SYMPTOMS AND HEALTH PROBLEMS ATTRIBUTED TO IAP

Recognizing indoor air pollution (IAP) is neither new nor difficult. It is common to feel suffocated in a closed room, which is often blamed on a lack of oxygen. While carbon dioxide from breathing can build up in a crowded, airtight space, such increases are usually small and temporary. However, a wide variety of unpleasant symptoms can result from exposure to indoor air pollutants (Deswal and Deswal, 2004; Klein, 2007). Some chemical pollutants cause irritation of the skin, eyes, nose, and throat. Others may lead to dizziness, nausea, shortness of breath, or coughing. For example, carbon monoxide (CO) causes breathlessness at low levels, and at higher levels, it can be deadly. Breathing 25 ppm or more of CO for just one hour is dangerous. Tissues like the brain, heart, and muscles are especially sensitive to CO. Other pollutants, such as radon, asbestos, and benzene, can cause long-term chronic health problems, including cancer. The key signs and symptoms linked to common indoor sources are summarized in Table 1.

SICK BUILDING SYNDROME (SBS)

Sick Building Syndrome (SBS) refers to a set of acute health symptoms that occur in people who spend time in a particular building, usually a poorly ventilated one like an office or residence (NASA, 2007). Common symptoms include a feeling of malaise, tiredness, headaches, dizziness, nausea, irritation of mucous membranes, breathing discomfort, eye and skin irritation, strange odours, itching, pain, and even depression. These symptoms are not linked to any single illness or cause, but they tend to go away once the person leaves the building. In some cases, illnesses are directly tied to a building's environment, such as outbreaks of *Legionnaires'* disease in convention centers or hospitals. Often, it is hard to pinpoint what exactly causes SBS because the symptoms can result from a mix of factors: air toxins in the building, poor management, worker morale, and psychological stress (EPA, 1992). However, researchers

Table 1: Signs/symptoms of health problems caused by indoor sources/activities.

S. No.	Source / activity	Key signs/symptoms of health problems
1	Combustion (stoves, space heaters, furnaces, fireplaces, etc.)	Dizziness or headache, confusion, nausea/emesis, fatigue, tachycardia, eye and upper respiratory tract irritation, wheezing/bronchial constriction, persistent cough, elevated blood carboxy-hemoglobin levels and increased frequency of angina in persons with coronary heart disease.
2	Animal dander, molds, dust mites and other biologicals	Recognized infectious disease, exacerbation of asthma, rhinitis, conjunctival inflammation, recurrent fever, malaise, dyspnea, chest tightness and cough.
3	Volatile organic compounds (formaldehyde, pesticides, solvents and cleaning agents)	Conjunctival irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnea, declines in serum cholinesterase levels, nausea, emesis, epistaxis (formaldehyde), fatigue and dizziness.
4	Airborne lead vapours	In adults: gastrointestinal discomfort, constipation, anorexia, nausea, fatigue, weakness, personality changes, headache, hearing loss, tremor and lack of coordination. In infants and small children: irritability, abdominal pain, ataxia, seizures/ loss of consciousness and chronic learning deficits, hyperactivity and reduced attention span.
5	Mercury poisoning caused by airborne mercury	Muscle cramps or tremors, headache, tachycardia, intermittent fever, acrodynia, personality change and neurological dysfunction.

Table 2: Factors affecting Sick Building Syndrome (SBS).

Personal Factor	Job Category	Type of Work	Psychological Factor	Building Factor	Building Related Factor	References Saini *et al.* (2020)
Y	Y	Y	Y	Y	Y	Skov *et al.* (1990)
				Y	Y	Morrice and Dennison (1995)
Y			Y		Y	Bholah and Subratty (2002)
Y					Y	Runeson *et al.* (2004)
			Y	Y	Y	Fisk *et al.* (2009)
Y			Y		Y	Crook and Burton (2010)
				Y	Y	Aruna (2004)

agree that IAQ is directly connected to building design and maintenance (Table 2), and that poor IAQ leads to more sick days and lower productivity (Bako-Biro *et al.*, 2004; Saini *et al.*, 2020).

SOURCES OF INDOOR AIR POLLUTION

Over the past few decades, the EPA has found measurable levels of over 107 known cancer-causing chemicals in modern offices and homes (NASA, 2007). The sources of these indoor pollutants are extremely varied. They can come from building materials, furniture, gadgets, heating and cooling systems, natural gases seeping into the building, and manufacturing processes for products like plywood or laminate cabinets (Deswal and Deswal, 2004; EPA, 1991). Table 3 provides a detailed overview of key indoor air pollutants and their common sources or activities.

One clear reason why indoor pollutant levels are often higher than outdoors is that there are so many potential sources inside a building. Another reason is somewhat ironic: the very steps we take to save energy—like adding insulation and sealing buildings tightly—trap pollutants inside. High temperature and humidity can also increase levels of some pollutants, especially microbial volatile organic compounds (MVOCs) from mould and bacteria growing in damp, warm conditions (EPA, 2025; McGinnis, 2004).

IAQ STANDARDS AND CHALLENGES

To prevent Sick Building Syndrome, various international organizations have set IAQ standards. These include the Illinois Department of Public Health (IDPH), the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the Occupational Safety and Health Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH), and the Indian Indoor Air Quality Standards (IIAQS). A summary is provided in Table 4. Good IAQ means having a comfortable temperature and humidity, a steady supply of fresh outdoor air, and control over pollutants coming from both inside and outside the building.

CONTROL OF INDOOR AIR POLLUTION

The range of indoor air pollution is very wide, and our options for controlling it are somewhat limited. Incense, candles, and "air fresheners" only add more chemicals to the air (Alam, 2002). One of the principal means for controlling the quality of indoor air is by dilution with fresh outdoor air via a ventilating air-conditioning system. Outside air is brought in and mixed with air in the return flow system from the building; the air is filtered, heated or cooled, and supplied to the building. A method that saves more of the heat in a building uses a counter-current heat-exchange system, which warms incoming, clean, outdoor air by exchanging the heat with outgoing, warm, dirty air. Thus, fresh air enters the building at a higher temperature, minimizing heat loss. In addition, various types of air-cleaning equipment for residential and non-residential buildings are available. To handle a variety of potential pollutants, such as particles, vapours and gases, a multistage system is used, consisting of mechanical filters, electronic air cleaners and gas- and vapour-removal devices (Nagda, 1987). These systems can be installed as part of the heating, ventilation and air-conditioning system or as stand-alone appliances. It is important to mention here that the commonly used ventilation systems are not generally designed to reduce some types of indoor pollution, such as radon gas. Other strategies include source removal, source modification and air cleaning (Nagda, 1987). But these strategies do not constitute a complete list, and some combination of them has to be adopted.

However, with a number of contributing factors/sources to indoor air pollution, it is no wonder people can become frustrated when trying to improve indoor air quality (EPA, 1991). A recent critical review of ventilation effectiveness in naturally ventilated spaces highlights that ventilation studies are relatively sparse and often poorly implemented, and that natural ventilation is not always reliable due to changing outdoor conditions and potential air pollution concerns (Mustafa *et al.*, 2025). One of the primary functions of a ventilation system is to improve IAQ and thermal comfort by diluting indoor air contaminants—but if the outside air is itself polluted, even well-designed natural ventilation may not help.

But there is a simple and very effective solution which will work regardless of the cause or source of "dirty" indoor air—that is "common indoor house plants". There are plenty of household decorative plants that are useful in tackling IAP, since in the process of photosynthesis, chemicals are absorbed by the plants and biologically degraded. Besides cleaning the air from chemicals, plants also absorb odours. In the ill-ventilated houses that dot most of the urban centers, the indoor decorative plants not only provide fresh clean air by removing indoor emissions but also increase the supply of much-needed oxygen in the micro-environment of the houses and workplaces. Also, during photosynthesis, plants release large amounts of water into the air as a result of evapotranspiration. Consequently, plants, when placed

Table 3: Sources/activity of key indoor air pollutants in microenvironments.

Source / Activity	Indoor air pollutants													References
	Benzene (C_6H_6)	Formaldehyde (CH_2O)	Trichloroethylene (TCE)	Xylene / Toluene	Alcohols	Acetone	Ammonia (NH_3)	Biological pollutants (Fungi, mods, mildews)	Particulate Matter (PM)	Carbon dioxide (CO_2)	Ozone (O_3)	EMR	+ve Ions	
Adhesives	√	√	√	√		√								Kraakman *et al.* (2021); Singh *et al.* (2016); Wolverton (1997)
Bioeffluents* of occupant and pets				√	√	√	√	√		√			√	Ding (2024); Wolverton (1997)
Carpets	√	√	√	√	√			√	√				√	Ding (2024); Najafabadi *et al.* (2022); Wolverton (1997)
Caulking compounds	√	√		√	√									Wolverton (1997)
Cleaning products			√				√		√					Maisey *et al.* (2013); Wolverton (1997)
Cosmetics			√		√	√	√		√					Tagesse *et al.* (2021); Wolverton (1997)
Draperies		√												Wolverton (1997)
Printers, Photocopiers, phones, computers, coffee m/c	√			√			√		√		√		√	Ding (2024); Maisey *et al.* (2013); Wolverton (1997)
Fabrics		√												Wolverton (1997)
Facial tissue		√												Wolverton (1997)
Floor coverings	√	√		√	√									Wolverton (1997)
Grocery bags	√													Wolverton (1997)
Nail polish remover			√			√								Kraakman *et al.* (2021); Singh *et al.* (2016); Wolverton (1997)
Office correction fluid			√			√								Kraakman *et al.* (2021); Singh *et al.* (2016); Wolverton (1997)
Paints, varnishes	√	√	√	√	√								√	Ding (2024); Kraakman *et al.* (2021); Liqun and Yanqun (2021); Singh *et al.* (2016), Wolverton (1997)
Building materials	√	√	√	√	√				√					EPA (2025); Kraakman *et al.* (2021); Liqun and Yanqun (2021); Singh *et al.* (2016)
Paper towels		√												Wolverton (1997)
Particleboard or chipboard	√	√		√	√									Wolverton (1997)
Pre-printed paper forms						√								Wolverton (1997)
Stains and varnishes	√	√		√	√								√	Ding (2024); Wolverton (1997)
Upholstery		√											√	Ding (2024); Wolverton (1997)
Wall coverings	√			√	√									Wolverton (1997)
Electronic equipment												√	√	Ding (2024); Lestari and Sutikno (2023)
Air Conditioners / Coolers								√	√				√	Ding (2024); HiCare (2026); Kumar *et al.* (2023)
Cooking	√							√	√	√				Kumar *et al.* (2023)
Bathroom							√	√	√	√				Kumar *et al.* (2023)
Diffusion of outdoor air	√	√	√	√	√	√	√	√	√	√	√			Singh and Deswal (2008)
Smoking		√												EPA (2025)

together increase the moisture content and, in the process, bring down the room temperature.

Recent scientific evidence strongly supports this approach. A couple of comprehensive reviews published in analyzed the multifaceted role of indoor plants in improving air quality, health, and perception. The authors concluded that botanical biofilters are a cost-effective and energy-efficient method for reducing indoor gaseous pollution, and that plants, along with their root-zone microorganisms, act as dynamic bio-filters, actively absorbing, degrading, and removing a wide spectrum of indoor air pollutants (Rasheed and Jayasree, 2025; Shubham, 2025). The review also highlighted that indoor plants help regulate humidity, reduce airborne microbes, and enhance psychological well-being and cognitive performance—benefits that go far beyond simple air cleaning (Shubham, 2025).

Another important contribution came from a 2025 study, which evaluated the air phytoremediation potential of four common indoor plant species: *Epipremnum aureum* (Money plant), *Chlorophytum comosum* (Spider plant), *Syngonium podophyllum* (Arrowhead vine), and *Cordyline fruticosa*. The study found that *Cordyline fruticosa* showed the highest VOC removal efficiency at 87.5%, while *Syngonium podophyllum* achieved 81.69% reduction. When these two

Table 4: IAQ Standards (*Source:* IDPH, 2025; IIAQS, 2024; Wijerathne, 2012).

PARAMETER	IDPH	ASHRAE	OSHA	ACGIH	IIAQS
Humidity	20 – 60 %	30 – 65 %	N/A	N/A	30 – 60 %
Temperature	68 - 75 °F (Win) 73 – 79 °F (Sum)	68 - 75 °F (Win) 73 - 79 °F (Sum)	N/A	N/A	24 – 30 °C
Carbon Dioxide	1,000 ppm	1,000 ppm (8-hr ave)	5,000 ppm	5,000 ppm	1,000 ppm
Carbon Monoxide	9 ppm	9 ppm (8-hr ave)	50 ppm	25 ppm	2.0 mg/m^3 (8-hr ave)
Hydrogen Sulfide	0.01 ppm	N/A	20 ppm	10 ppm	
Ozone	0.08 ppm	N/A	0.1 ppm	0.05 ppm	
Particulates	PM_{10} (24-hr ave): 150 µg/m^3 $PM_{2.5}$ (24-hr ave): 65 µg/m^3	PM_{10} : 50 µg/m^3 (annual ave):	Total: 15 mg/m^3 Resp.: 5 mg/m^3	Total: 10 mg/m^3 Resp.: 3 mg/m^3	Home – PM_{10} (24-hr ave): 60 µg/m^3 $PM_{2.5}$ (24-hr ave): 40 µg/m^3 Office, Commercial and Educational Institutions – PM_{10} (8-hr ave): 60 µg/m^3 $PM_{2.5}$ (8-hr ave): 40 µg/m^3
Formaldehyde	0.1 ppm (Office) 0.03 ppm (Home)	0.1 ppm (office) 0.04 ppm (home)	0.75 ppm	0.3 ppm	0.05 ppm (30-minute average)
Nitrogen Dioxide	0.05 ppm	N/A	5 ppm (8-hr ave)	3 ppm	N/A
Radon	4.0 pCi/L	N/A	100 pCi/L	4 WLM/yr (working level months/year)	N/A
Outdoor air floor rate	N/A	15 L/s per person	N/A	N/A	N/A

plants were combined in Plant-Based Bio-Filters (PBBFs), they significantly improved indoor air quality, reducing TVOC, CO_2, CO, $PM_{2.5}$, and PM_{10} levels dramatically—including 100% removal of $PM_{2.5}$ and PM_{10} (Elhadad *et al.*, 2025). The study concluded that air phytoremediation is a natural, cost-effective solution for VOC mitigation, offering a practical approach to sustainable indoor design.

A 2025 review examined biological methods for air pollution control and concluded that phytoremediation and microbial remediation—based on plant and microorganism activities—are sustainable, cost-effective, and public-friendly technologies for mitigating indoor VOCs (Kumar *et al.*, 2023). The review also noted that plant-based systems are particularly attractive because they are simple, potentially cheap, and easily implemented compared to traditional or advanced methods.

If a plant is placed in an artificially lit environment with no windows or fresh air, it will detoxify the ambient chemicals and increase the oxygen, but not infinitely. The plant has to be located in natural light and air at least once a week. Another option is to group several plants together so that humidity is increased and they stay healthier.

Removing chemicals, smells and releasing oxygen are not the only things that plants can do to lessen the toxicity in the indoor environment. An equally important service is 'de-ionization'. Our nervous system functions on small electric impulses in the form of ions being received and sent by the brain to various organs. Our body, therefore, is very sensitive to changes in ion concentrations in the ambient environment. Air that is overcharged with +ve ions has a negative effect on health; whereas, air balanced with –ve ions has a positive effect on health (Jiang *et al.*, 2018; Xiao *et al.*, 2023; Yaglou *et al.*, 1933). Our houses and workplaces often generate and trap so many +ve ions that the occupants complain of ill health without knowing why. Doesn't the air feel heavy, leaving the person lethargic and drowsy, just before a storm? That is because the air is full of +ve ions. Certain hot winds, such as the 'sirocco' of southern Europe or the '*looh*' that comes to north India, occasionally carry an extreme number of +ve ions, and they have very unpleasant effects on people. In general, +ve ions are emitted by metallic objects while non-metallic sources release –ve ions. Heating and air-conditioning systems deplete –ve ions and add +ve ions to the air during recirculation through metal ducts. In nature, -ve ions are manufactured by rain, lightning, sunshine and the breaking up of water droplets in surf, waterfalls and fountains. These clean out the air with –ve ions so one feel better after the storm and the air feels fresher and cooler.

Research has confirmed the health benefits of negative ions in indoor spaces. A 2025 study by Deng *et al.* (2025) found that negative air ions (NAIs) effectively reduce particulate contamination and gaseous pollutants, inhibit microorganisms, alleviate depression, enhance cognitive function, and even stimulate sympathetic activity. The study also recommends maintaining optimal NAI concentration thresholds to balance beneficial effects while avoiding contradictory impacts on cardiac and respiratory function. Another recent study by Zdražil and Roubal (2024) notes that lack of negative light ions can cause fatigue, health problems,

Table 5: Summary of reviewed indoor decorative plants that have been tested to reduce airborne pollutants.

Scientific name (Common name)	Benzene	Formal-dehyde	TCE	Xylene	Toluene	NH_3	O_3	Path-ogens	EMR	PM	Source
Aglaonema modestum (Chinese Evergreen)	√	√								√	Lohr and Caroline (1996); Wolverton and Wolverton (1993)
Aloe vera (Aloe vera)		√		√	√						Wolverton and Wolverton (1993)
Anthurium andreanum (Flamingo lily)		√		√	√	√					Wolverton and Wolverton (1993)
Asparagus densiflorus (Foxtail fern)	√ (2.61-5.54 mg m^{-3} m^{-2} h^{-1})		√ (5.79-11.8 mg m^{-3} m^{-2} h^{-1})		√ 5.81-9.63 (mg m^{-3} m^{-2} h^{-1})				√		Lestari and Sutikno (2023); Yang *et al.* (2009)
Betel leaf plant (Paan)									√		Bhattacharya *et al.* (2005)
Chamaedoreas seifrizii (Bamboo palm)	√ (1,420 µg/h)	√ (1,350-3,196 µg/h)	√ (688 µg/h)	√	√	√				√	Jhanji and Dhatt (2021); Pottorf (2010); Lohr and Caroline (1996); Wolverton and Wolverton (1993)
Chlorophytum comosum (Spider plant)	√ (88-95% in 7 days)	√ (11-60%)	√ (560 µg/h)		√		√		√	√ $PM_{2.5}$: 56.04 % PM_{10}: 10.74 %	Dingle *et al.* (2000); Gawronska and Bakera (2015); Giese *et al.* (1994); Lestari and Sutikno (2023); Wolverton and Wolverton (1993); Xu *et al.* (2011); Zhou *et al.* (2011)
Chrysalidocarpus lutescens (Areca palm)	√	√ (938 µg/h)	√	√	√	√		√			Bhargava *et al.* (2021); El-Sayed (2020); Jhanji and Dhatt (2021); Wolverton and Wolverton (1996)
Chrysanthemum morifolium (Florist's daisy, Garden mum, Guldaudi)	√ (81-96%; 3,205 µg/h)	√ (1,450 µg/h; 90%)	√	√	√	√					Aydogan and Montoya (2011); Pottorff (2010); Wolverton and Wolverton (1993)
Dieffenbachia camille (Dumb cane)				√	√			√			Sharma *et al.* (2018); Wolverton and Wolverton (1996)
Dracaena deremensis "*Warneckei*" (Warneckei)	√ (1,630 µg/h)	√ (760 µg/h)	√ (573 µg/h)	√	√			√			Godish and Guindon (1989); Pottorff (2010); Mosaddegh *et al.* (2014); Wolverton (1993); Wolverton and Wolverton (1996)
Dracaena fragrans '*Massangeana*' (Corn palm/plant)	√	√ (938 µg/h)	√ (421 µg/h)	√	√			√			Aydogan and Cerone (2021); Chauhan *et al.* (2017); Jhanji and Dhatt (2021); Pottorff (2010); Wolverton (1993); Wolverton and Wolverton (1996)
Dracaena marginata (Red-edged dracaena, Dragon tree)	√ (1,264 µg/h)	√ (853 µg/h)	√ (1,137 µg/h)	√ (90% in 5 days)	√ (2.2–549 mg m^{-3} d^{-1})					√	Pottorff (2010); Lohr and Caroline (1996); Orwell *et al.* (2006), Wolverton and Wolverton (1993)
Dracaena sanderiana (Lucky bamboo)	√ (66-70% in 24 h)										Treesubsuntorn and Thiravetyan (2012)
Epipremnum aureum (Money plant/ Devil's ivy / Golden pothos)	√	√ (90%)		√	√			√	√ (28%)	√ $PM_{2.5}$: 0.2-30 % $PM_{2.5}$ PM_{10}: 0.24-0.39 %	Aydogan and Montoya (2011); Cao *et al.* (2019); Gong *et al.* (2019); Pottorff (2010); Lestari and Sutikno (2023); Lohr and Caroline (1996); Peng *et al.* (2020); Wolverton and Wolverton (1996)

Table 5 *Contd.*: Summary of reviewed indoor decorative plants that have been tested to reduce airborne pollutants. Contd.

Scientific name (Common name)	Benzene	Formal-dehyde	TCE	Xylene	Toluene	NH_3	O_3	Path-ogens	EMR	PM	Source
Ficus alii (Alii ficus)								√			Wolverton and Wolverton (1993; 1996)
Ficus benjamina (Weeping fig)		√ (80%; 940 µg/h)		√	√			√			Pottorff (2010); Kim and Kim (2008); Schmitz *et al.* (2000); Weidener and Silva (2006); Wolverton and Wolverton (1993; 1996)
Ficus elastic (Rubber plant)		√	√ (9.8% h^{-1})								Cornejo *et al.* (1999); Pottorff (2010); Wolverton and Wolverton (1996)
Gerbera jamesonii (Barberton daisy)	√ (4,486 µg/h)	√	√ (1,622 µg/h)								Pottorff (2010); Wolverton and Wolverton (1993; 1996)
Hedera helix (English ivy)	√ (579 µg/h)	√ (402-1,120 µg/h; 90%)	√ (5.79-11.8 mg m^{-3} m^{-2} h^{-1}; 298 µg/h)	√	√	√					Aydigan and Montoya (2011); Jhanji and Dhatt (2021); Pottorff (2010); Wolverton and Wolverton (1993); Yang *et al.* (2009),
Hemigraphis alternata (Red ivy)			√ (5.79-11.8 mg m^{-3} m^{-2} h^{-1})								Yang *et al.* (2009)
Hoya carnosa (Wax plant)			√ (5.79-11.8 mg m^{-3} m^{-2} h^{-1})								Yang *et al.* (2009)
Nephrolepis exaltata '*Bostoniensis*' (Bosten fern)		√ (1,863 µg/h)		√	√					PM_{10}: 92.46 %	Jhanji and Dhatt (2021); Pottorff (2010); Pettit *et al.* (2017); Wolverton and Wolverton (1993)
Philodendron domesticum (Elephant ear philodendron)		√						√			Pottorff (2010); Sharma *et al.* (2018); Wolverton and Wolverton (1996)
Rhapis excelsa (Lady palm)	√	√	√	√	√	√		√			Aydogan and Cerone (2021); Pottorff (2010); Schmitz *et al.* (2000); Wolverton and Wolverton (1996)
Sansevieria hyacinthoides (Snake plant)	√	√	√	√	√ (85%)		√	√	√		Mahadevan and Young (2020); Sriprapat *et al.* (2014b)
Sansevieria trifasciata '*Laurentii*' (Snake plant / Mother-in-law tongue)	√ (1,196 µg/h)	√ (1,304 µg/h)	√ (405 µg/h)	√	√		√	√	√ (33-53.86%)		Pottorff (2010); Lestari and Sutikno (2023); Seminar (2012); Sharma *et al.* (2018); Wolverton *et al.* (1989); Wolverton and Wolverton (1993; 1996)
Spathiphyllum wallisii' (Peace lily)	√ (1,725 µg/h)	√ (674-939 µg/h)	√ (1,128 µg/h)	√	√	√		√	√		Pottorff (2010); Lohr and Caroline (1996); Parseh *et al.* (2018); Wolverton and Wolverton (1993; 1996)
Succulent									√ (10-27 %)		Lestari and Sutikno (2023)
Syngonium podophyllum (Arrohead vine)	√	√	√	√	√			√			Parseh *et al.* (2018); Wolverton and Wolverton (1996)
Tradescantia pallida (Purplr heart)			√ (5.79-11.8 mg m^{-3} m^{-2} h^{-1})								Yang *et al.* (2009)
Zamioculcas zamiifolia (Zanziber gem/ ZZ plant)				√ (95% in 72 h)	√ (95%)						Sriprapat and Thiravetyan (2013); Sriprapat *et al.* (2014a)

and reduced productivity in the workplace, and recommends that building design should consider its influence on the indoor ionic environment.

There are two ways to increase the –ve ions inside the buildings. One is to install an 'ionizer' which releases thousands of ions into the air and cleans the +vely charged dust, smoke and pollutants by attracting and –vely charging them. But this does not get rid of them permanently – it makes them heavier so that they sink rather than float where they will be breathed in. The second option is to use 'nature's ionizer' – a low-tech alternative. The presence of water as moisture released from plants is very effective in countering an increased concentration of +ve ions in the indoor air (Lyu *et al.*, 2025). What is more is the fact that in the presence of a higher number of –ve ions, human body is able to absorb a greater amount of oxygen. This will not only result in a healthier body metabolism but also increases an individual's working capacity.

PLANTS AS A POLLUTION CHECK

Instead of using high-tech solutions, bioremediation with plants can be a highly effective way to fight IAP. Through their normal physiological and biochemical activities, plants break down or neutralize pollutants. However, different plant species respond differently to various pollutants. Some may be sensitive to fluoride but resistant to sulfur dioxide. That's why it's important to choose the right plant for the right pollutant. Researchers look at factors like leaf shape and surface, stomatal conductivity, and levels of certain chemicals in the plant (like ascorbic acid and proline) to determine how well a plant will work.

Table 5 summarizes many common indoor decorative plants (Alam, 2002; Aruna, 2004; EPA, 1991; Gandhi, 1994) that have been scientifically tested for their ability to remove airborne pollutants. These plants are widely available in nurseries across India and are easy to care for.

Based on these findings, it is recommended to have about one plant for every 10 square yards (roughly 9 square meters) of floor space, assuming standard ceiling heights of 8 to 9 feet. This means two or three plants can make a noticeable difference in an average living room of about 20-25 square yards. For an 1,800 square foot home, about 15 to 20 Spider Plants or Money Plants can keep the air clean and fresh. Many indoor plants originally grew in the deep shade of tropical forests, so they don't all need to be placed right next to a window. They can do well in darker corners. However, try to avoid putting them in a strong draft, as this can reduce their air-cleaning effectiveness.

Benefits of Plants in Indoor Microenvironments

It is well documented that indoor plants not only improve IAQ by reducing airborne pollutants (Table 5), but they also offer several positive psychological, physiological, and cognitive benefits (Aydogan and Cerone, 2021). These include:

- Making building interiors more attractive and comfortable.
- Providing a calming effect, reducing stress and negative feelings.
- Improving mental health and boosting the morale of residents and workers.
- Making the air more pleasant to breathe, helping people feel better and work more productively.
- Increasing oxygen levels inside homes and workplaces.
- Adding moisture to the air, which can help cool down a room.
- Lifting people's mood by fighting sadness, fatigue, fear, and tension.
- Reflecting a company's positive image by showing that it cares about employees and visitors.
- Offering a natural way to combat Sick Building Syndrome (SBS) in modern buildings.

Using plants to control indoor air pollution is not only cost-effective but also environmentally friendly. Mechanical systems use more energy and add to outdoor pollution. Plants, on the other hand, are beautiful, natural, and clean the air without any negative side effects.

CONCLUSION

This review has examined the serious and often underestimated problem of indoor air pollution and the promising role that common houseplants can play in addressing it. The evidence is clear: indoor air in our homes, offices, and other microenvironments is frequently two to five times more polluted than the air outside. This is due to a combination of tightly sealed, energy-efficient buildings and a vast array of pollutant sources—from furniture and cleaning products to electronic devices and even our own breathing. The health consequences are severe, ranging from immediate symptoms like headaches, eye irritation, and fatigue to long-term chronic diseases including heart disease, stroke, respiratory infections, and lung cancer. The World Health Organization's estimate of 3.2 million premature deaths per year from IAP alone makes this a public health crisis that cannot be ignored.

Traditional approaches to improving indoor air quality—mainly ventilation and mechanical air filtration—have significant limitations. Ventilation systems are often not designed to capture specific chemical pollutants, and they require constant, costly maintenance to prevent them from becoming sources of biological contamination themselves. Air filters and electronic cleaners can be effective but consume energy and do nothing to address the psychological and physiological benefits that natural elements bring to a space.

This is where phytoremediation using indoor plants offers a compelling, low-tech, and nature-based solution. As summarized in Table 5, a wide variety of common decorative plants—including Snake Plant, Spider Plant, Peace Lily, Areca Palm, and Money Plant—have been scientifically shown to absorb, metabolize, or neutralize a broad spectrum of indoor air pollutants. These include volatile organic compounds like benzene, formaldehyde, and toluene; airborne microbes; particulate matter; and even some forms of electromagnetic radiation. The mechanisms involved include uptake through leaf stomata, degradation by root-

associated microorganisms, and even direct breakdown within plant tissues.

Beyond their pollutant-removing abilities, indoor plants provide additional, often overlooked benefits. They release oxygen and increase humidity through evapotranspiration, which can help regulate room temperature. They naturally generate negative ions, which have been shown to improve mood, alertness, and overall well-being. Studies have documented that the presence of plants in offices reduces stress, lowers blood pressure, increases pain tolerance, and improves productivity and concentration.

For practical application, the evidence suggests that placing one medium-sized plant per 10 square yards of floor space can provide meaningful air quality improvement. Even in spaces with low natural light, many suitable species (like Snake Plant and ZZ plant) thrive and continue to function effectively. Grouping plants together enhances their humidity-regulating effect and keeps them healthier.

In conclusion, while indoor air pollution remains a formidable challenge, the strategic use of indoor plants offers a safe, affordable, sustainable, and aesthetically pleasing mitigation strategy. No single solution will eliminate all indoor pollutants, but integrating plants alongside good ventilation practices and source control can create significantly healthier indoor environments. Future research should focus on understanding the synergistic effects of plant-microbe combinations, optimizing plant selection for specific pollutant profiles in different settings (homes, schools, hospitals, offices), and developing easy-to-use guidelines for building occupants and facility managers. For now, the evidence strongly supports a simple message: bringing nature indoors through common houseplants is one of the most effective and enjoyable things we can do to protect our health and improve the quality of the air we breathe every day.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy, have been completely observed by the authors.

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