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The Role of Indoor Plants in Improving Air and Mind-Comprehensive Review

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***Abstract*— *Rapid urbanization and concrete indoor living environments are posing challenges to human beings and their beloved pets in terms of indoor environmental quality (IEQ). Raising indoor plants has the potential to not only control indoor air quality, but also maintain psychological comfort and health. In the recent COVID-19 pandemic period, indoor plants have highlighted the importance of these plants in their overall maintenance of health and mental well-being. It is highly recommended to plant this tree after reviewing various research benefits. Keeping in mind the above view, we reviewed recent studies on indoor plants and their benefits in improving indoor environments like quality air index, temperature, humidity, etc., as well as providing psychological benefits. This systematic review of the literature demonstrates that various plant species effectively remove volatile organic compounds (VOCs), and other pollutatns, reduce stress, and boost cognitive function. Some important strategies, such as phytoremediation, which uses bi-directional phytofilters and endophytic bacteria, offer the best air purification with well-being and cognitive performance, promoting biophilic design in indoor spaces. Studies are investigating the relationship between indoor plants and various pollutants, taking into account factors such as light intensity and plant species that play key roles in bi-directional phytofilters. In spite of some challenges, integrating plants into healthier indoor environments. Future research should refine plant selection, optimize growth conditions, and explore new technologies for better air quality and well-being.*

***Keywords*— Indoor pollution, Indoor air quality (IAQ), Indoor plant,Phytoremediation, Psychological performance**

I. INTRODUCTION

Firstly, human civilization and urbanization which has brought us so far in development on the one hand, but on the other hand we are also a major cause of various global envrionemntal concerns. For instance, there is Indoor air pollution that has reached its zenith since most of the times are spent indoors. People and their companion animals are exposing themselves to a lot of indoor contaminants such as volatile organic compounds (VOCs), formaldehyde, benzene, particulate matter, carbon monoxide (CO), and nitrogen dioxide (NO_2). It's worth mentioning that these substances have serious effects on human health including respiratory problems, heart diseases and brain disorders. As a result environmentalists and scholars are researching for alternative strategies to improving indoor air quality (IAQ) among them being indoor plants. This article will evaluate the role played by indoor plants in combating indoor pollution through phytoremediation which is a process where plants take up or break down harmful substances from air, soil or water. By decreasing internal pollutants levels they enhance healthier internal surroundings.

Different types of houseplants have been shown to be effective at removing different pollutants indoors. For example, peace lilies (*Spathiphyllum)*, spider plants (*Chlorophytum comosum*) and snake plants (*Sansevieria trifasciata*) have long been known for absorbing VOCs such as formaldehyde, benzene and xylene whereas bamboo palms (*Chamaedorea seifrizii*) and Boston ferns (*Nephrolepis exaltata*) are exceptional in removing airborne particulate matter and allergens. Moreover through transpiration by which they emit water vapour among other things. Houseplants help to maintain optimal humidity within the home and prevent problems of drought like dry skin and respiratory irritations caused by low humidity. Indoor plants create a more comfortable indoor environment that promotes the health of occupants.

Although many studies have addressed the positive impacts of indoor plants on individual mental well-being, there is an emerging concern over their effects on the animals' welfare. Indoor plants offer enrichment opportunities for pets through stimulation or companionship as well as natural exploration, foraging and resting behaviours. Furthermore; it implies that having indoor plants might satisfy an innate psychological demand for connection with nature which is fostered by biophilic linkages between humans in general and their companion animals.

Indoor greenery has been linked to a decline in tension, fear, and tiredness that gives rise to relaxed feelings and promotes general sense of well-being. Indoor plants can make you feel better; help you think more clearly by aiding your brain's efficiency thereby making them good partners in rooms designed for healthy occupants. We can tap into the power of plants to create environments that promote tranquility and overall well-being by knowing how indoor plants, air quality and psychological wellness are related.

II. REVIEW OF LITERATURE

1. Reducing indoor air pollution:

After COVID-19 pandemic outbreak there arose global concerns about improved IAQ. This showed the immediate requirement for sustainable green living spaces as well as economically feasible indoor plants. Different plant species either potted or in green walls can act as buffers from the adverse effects of air pollution hence improving IAQ alongside public health outcomes. In this study we delve into the effect of aerial parts of indoor plant, growing medium, roots and associate bacteria on enhancing IAQ with a reference to phytoremediation as a viable low-cost option that is ecologically sound and aesthetically appealing too. Plant-based methods of eliminating indoor pollutants can be better understood with the help of the analysis, yet it underscores the need for more inclusive research on properties of plants such as leaf size, surface area and individual plant parts involved in removal of pollutants. Additionally, deeper understanding regarding phytoremediation physiology and biochemistry as well as functioning of plant microbiome is necessary. To identify useful microorganisms among OMICS methodologies and carry out live tests to ascertain how effective are natural filters based on plants should be examined through forthcoming researches. By focusing on these areas, we will be able to address general problems associated with indoor air pollution elimination and health hazard prevention. In this case the sector is assisted, hence promoting public health through a sustainable eco-friendly environment [16].

According to a study by [32], the increase in light intensity has a profound effect on the capacity of indoor plants for CO_2 absorption with higher lux levels increasing the ability. All plants except Sansevieria trifasciata showed no change in CO_2 uptake at 1000 lux during day time but at 1500 and 2000 lux they could take more carbon dioxide, this was not significant in Sansevieria trifasciata which is categorized as a CAM plant that produced CO_2 throughout the day regardless of light level. In this particular research focused on tropical environments and examined six popular plant species cultivated in Sri Lanka, Spathiphyllum blandum, Aglaonema commutatum, Philodendron hederaceum, Chlorophytum comosum and Dracaena fragrans were identified as being best suited for removal of CO_2 indoors. There was an increase in rates of CO_2 assimilation under high light conditions where Spathiphyllum blandum emerged as most efficient across all lighting levels. The results point to the prospects of using houseplants to improve indoor air quality and thus sustainability particularly in tropical climates. The next steps should consider different types of plants, maintain RH-controlled environments, go for higher light intensities, and measure the other toxicants removed from the air by these plants. In addition, it is proposed to develop botanical biofilter technologies that are sustainable and low-energy for indoor air purification.

Phytofiltration as the most sustainable approach to improving polluted indoor environments' air quality [30] . However, they observe that existing systems of phytofiltration ignore plant biorhythm thus emitting CO_2 at times when plants breathe. They propose a new bi-directional phytofilter that purifies exhaust air from contaminants while cleaning and oxygenating inlet ventilation air. The original device contains spots with different lighting levels and a valve system that directs fresh air into areas where plants emit CO_2 and returns the outlet through another channel. According to literature data, under adverse conditions there is a balance between CO_2 input and output such that there is no net loss of CO_2 emissions out of the atmosphere during daylight hours while during plant growth carbon dioxide gets in the ground thereby mitigating gasses from being release into the environment. In natural light as well as artificial or mixed combination of these two options, which only requires CAM metabolism accompanied by other varieties can be applied to the phytoremediation process, which can also reduce VOCs and microbes to enhance air quality within confined spaces. Existing indoor phytoremediation systems do not consider plant biorhythms and hence results in secondary CO_2 pollution. The suggested ventilation phytofilter has this problem under control by effectively regulating airflow to ensure that it cleans and oxygenates incoming air around the clock while filtering outgoing air to promote environmentally friendly living in crowded areas. Presently, research focuses on gas exchange between plants through the Laboratory of Heat-Mass Exchange in Green Structures using a gas-exchange camera with attempts at developing and testing experimental models of phytofilter mentioned above. Nevertheless, an attempt by some authors has been made to acknowledge that funding challenges have resulted from various external factors such as geopolitical ones specifically the Russian-Ukrainian war which constrains their sponsorship possibilities for carrying out investigations.

The aerial plant *Tillandsia xerographica* behaved when used for air biofiltration by observing CO_2 concentration changes in treated air under different environmental conditions [28]. The botanic filter with *T. xerographica* worked non-stop with ambient air for about three weeks at various light intensities, airflow speeds, temperatures and relative humidities. Regardless of whether there was light or not, the level of carbon dioxide decreased daily provided that the plant had been allowed to follow its normal diurnal rhythm which is made possible through having facultative CAM metabolism allowing nocturnal and diurnal capture of CO_2. Its capability of switching between CAM mode (day/night cycle) and C3 mode (continuous light) has been demonstrated. This means that it can be used as a biofilter in cities not only to remove CO_2 but also other gaseous impurities thus improving air quality index and reducing public health risks associated with pollution fallouts. According to the study, modelling should be further carried out on physiological responses of *T. xerographica* towards varied environments coupled with structural optimization while also looking into morphological changes brought about by biochemical interactions among genes so as to come up with universal systems for purifying different types of airs.

It is important to consider indoor air quality (IAQ) as people spend a lot of time inside where pollution can cause health problems over long periods of exposure [27]. Although they can be used to help purify the air in homes, CO_2 emissions from plants grown under low-light conditions present some difficulties for botanical biofilters. A proposal has been made that combining C3 and Crassulacean Acid Metabolism (CAM) plants might cut down on these emissions while improving efficiency at removing pollutants. In South Korean apartments, research showed that having a mixture of C3 plants and CAM plants together with ventilation reduced levels of indoor pollutants significantly bringing down CO_2, total volatile organic compounds (TVOCs), formaldehyde (HCHO), and particulate matter (PM 2.5 and PM 10) by 76%, 87%, 75%, 52%, and 51% respectively. This work shows that potted plants indoors are a viable option for sustainable cheap fixes towards cleaner breathing spaces which could lead to higher productivity among people as well their general welfare.There is still need however for more studies into selection criteria based on plant traits among other things that would make phytoremediation most effective thus improving overall IAQ even further than what has been achieved so far in this field.The integration of living filtration systems with structures such as ventilators within buildings offers an opportunity through which societies may purify their atmosphere from various indoor contaminants affordably sustainability leading better health outcomes generally.

Indoor plants are often recommended as an easy means to improve air quality, but little research has been done on how they take in ozone. This study measured the rates at which ozone was absorbed by five common types of indoor plants: the Peace Lily, Ficus, Calathea, Dieffenbachia, and Golden Pothos. We calculated transient deposition velocities (vd) using leaf areas for each plant species tested under different lighting conditions (8 h of high O_3 and 16 h of dark). Initial Golden Pothos Vds ranged widely between 5.6 m/h and 0.9 m/h before falling approximately 50% and 66% with subsequent exposures. Investigators also evaluated the effect on vd values of photosynthetically active radiation (PAR) levels; they found that increasing these from 0.6 µmol $m^n \cdot s^2$ up to 41.2 µmol $m^n \cdot s^2$ caused corresponding growth factors ranging from 1.7 times greater for Dieffenbachia than under low light to as much as 4.7 times higher among Peace Lily plants exposed to similarly high light intensities. Based on standard residential dimensions (0.06 m^2 leaf surface area/volume), removal efficiencies varied little between homes: 0.9%–9%. On average, indoor foliage only removes small amounts (0.5–5.5 m/h), although more work is needed to broadly inspect the collective effects of the secondary components, ozone reduction, and volatile organic compounds emissions from indoor plants on indoor air quality [6].

According to one review[37] 28 ornamental plant species commonly used in interior landscaping were evaluated for their ability to remove specific indoor pollutants (namely toluene, a-pinene, octane, benzene and TCE). The removal efficiency varied among species whereby *Hoya carnosa*, *Hedera helix*, *Hemigraphis alternata*, and *Asparagus densiflorus* were the most effective in eliminating all tested contaminants. In addition to this, *Tradescantia pallida* showed excellent elimination capability for four out of five chemicals (i.e., toluene, a-pinene, benzene, TCE). For four types of pollutants (i.e., toluene, octane, benzene, TCE), in particular, H. alternata recorded the highest removal efficiency among the four substances tested. Furthermore, certain contaminants were also removed by *Fittonia argyroneura*, *Ficus benjamina*, and *Polyscias fruticose*. From the findings it can be deduced that different types of volatile organic compounds (VOCs) and their emission rates at various points inside each room necessitate an individual approach with numerous types of indoor plants for improving overall air quality. Therefore, the results demonstrate the potentiality of houseplants in purifying the atmosphere which could be economically significant for the floriculture industry besides having health benefits for people living or working indoors. Moreover, further studies should focus on discovering new plant species capable of removing higher percentages of VOCs than those already known thereby enhancing our knowledge base about the role played by house plants in purifying indoor air.

According to one findings [11], potted plants were researched as a simple and relatively inexpensive approach for reducing indoor air pollution, with a focus on nitrogen dioxide (NO_2) removal. The experiment tested three plant species: *Spathiphyllum wallisii 'Verdi', Dracaena fragrans 'Golden Coast'*, and *Zamioculcas zamiifolia 'Zamioculcas zamiifolia'* across two different growth media under real-time conditions with 100 ppb NO_2 at two standard indoor light intensities (0 and 500 lx) and in both moist and dry substrate environments. It was observed that all plant-media combinations could diminish the NO_2 levels characteristic of polluted urban sites, but to varying degrees. The most effective removal was recorded by *Dracaena fragrans* (i.e., within a 150 L chamber for 1 h under wet conditions at 500 lx), especially when grown on wet substrates under standard indoor illuminance levels. From a conservative point of view, this also amounts to 3 ppb of NO_2 per square meter of leaf area over 1 hour, or 0.62 ppb per potted plant over the same period if modeled for a small office (15 m^3) in a heavily polluted place with due account taken for dilution. Additionally, NO_2 elimination depended on the growth medium type and moisture content. Although they offer a passive means of ameliorating IAQ (indoor air quality), container-grown plants were found inadequate compared to their active counterparts, living walls (or green walls). However, their elementary nature, coupled with their low cost and minimal energy requirements, makes them essential components of strategies aimed at controlling air quality inside buildings, particularly when circulation is poor or there are high levels of pollution. Further research should be carried out so as to optimize these systems and integrate them effectively with other purification techniques.

It was demonstrated that therapeutic horticulture (TH) significantly relieved anxiety and sleep problems among university students with high levels of anxiety [38]. Stress was reduced by various horticultural activities; however, they affected the vitality of the participants differently. Potting plants and handcrafting activities gave more a greater sense of fulfillment than other activities. Decorative plants were found to be more effective in terms of reducing stress, while practical aromatic plants increased satisfaction as well as sleep duration. Consequently, TH should constitute a part of anxiety-relieving interventions within higher education institutions and such settings, where particular activities and plant materials used must be aimed at achieving certain objectives.

The formaldehyde-degrading Ochrobactrum intermedium strain ZH-1R has been shown to enhance the capability of indoor plants to eliminate this gas [17]. According to this research, the best ways of inoculating various kinds of plants were different. The most appropriate method for handling *Epipremnum aureum* was acupuncture injury to the stem, whereas root irrigation in the case of *Chlorophytum comosum* and *Ficus variegata* ZH-1R-inoculated *F. variegate, Chlorophytum comosum* during an 8-day fumigation period recorded 62.88% more formaldehyde removal rates at night than the non-infected ones and 20.17% higher during the day. It means that the endophytic bacteria can not only promote degradation but also prevent harm from happening during the night, especially by the host plants themselves. Henceforth, the combined system stands out as a potential approach that is effective and economically viable for improving IAQ indoors; however, further studies are needed to check its effectiveness on different types of pollutants as well as plants.

One research shows the immediate need for addressing indoor air pollution, especially in developing countries where its impacts on public health and the environment are more and more felt [10] . It provide an extensive review of various studies that show that indoor plants can be a practical and sustainable solution for improving IAQ (indoor air quality) at a low cost. Evidence collected from research around the world points out the astonishing abilities of houseplants to act as self-regenerative bioremediation systems, being able to effectively absorb different indoor air contaminants such as carbon monoxide (CO), ozone (O_3), carbon dioxide (CO_2), and volatile organic compounds (VOCs), among others. This paper not only introduces indoor plant systems as vital parts of biofilters but also foresees their wide application as standard technologies for improving IAQ. With ongoing processes of urbanization and industrialization as well as changes in lifestyle, it is important to notice increasing levels of pollution that necessitate immediate measures for protecting human health and surroundings. Therefore, urgent studies should be carried out mostly in densely populated regions like China, India, or the United States, where this problem has become so acute that public health concerns can no longer be ignored. Furthermore, genetic engineering methods need to be explored in order to increase the capability of plants to get rid of pollutants inside buildings, thus making indoor areas cleaner for future generations. Effective guidelines created aimed at preventing pollution inside buildings, especially critical facilities such as hospitals, schools, or residential houses, are a must if we want to ensure our own safety and comfort while living or working there.

Moreover, Table 1 and Fig. 1 outlines different pollutants, their origins, and their impact on human health and the environment, whereas Table 2 gives a summary of some plants known to help reduce these pollutants.

2. Psychological Performance:

An increase in the importance of nature to human health, stating that it is necessary to study people's interactions with plants from all angles [22] . This area touches such sides as ecology, culture, and psychology, showing how much benefit can be gained through working with greenery for our own good and that of the world we live in. The information above clearly reveals the immense benefits that nature provides for well-being. However, there should be more inquiries to find out why these things happen and many other areas that have not been looked into deeply enough so far; such research may offer some clues into this matter, if only through wide-ranging, large-scale epidemiological studies. It is only after people know the connection between them and plants can they start coming up with ways of ensuring sustainable development while taking care of their health; this will also lead to a conservation-friendly health system as well as environmental management, making sure that we leave behind us an earth better than what we found.

In an exhaustive study [36], investigated the link between mental well-being, cognitive functioning, productivity, and satisfaction in work settings, among other things, and perceived internal environmental characteristics (PIEC). The literature review identifies five main aspects of indoor climate: space, furniture, privacy, and the naturalness of visual quality that have been extensively researched but less so in regards to décor aesthetics and maintenance. It confirms their significant effects on satisfaction levels, productivity rates, and general happiness, while also advocating for more detailed studies, such as configurations for natural elements or privacy arrangements. Furthermore, it points out a lack of experimental research clarifying these factors' impacts on cognitive performance and suggests some practical solutions on how they can be altered through design changes for offices. For mental health, cognitive ability, work productivity and job satisfaction, indoor climate, furniture, privacy are key but we must also pay attention to environmental maintenance and aesthetic aspects. Natural elements should be designed thoroughly with regard to the quantity and arrangement. Further, it is important to allow some flexibility in the arrangement, workstation and furniture to provide sense of privacy. Last but not least, cognitive stimulating office environments should be the focus when creating new offices.

Air pollution is a significant concern especially with the rise of industrial development and urbanization. Indoor air quality problems are exacerbated with rise in exposure to harmful chemicals. The indoor air pollutants or indoor contaminants (IC) such as inorganic gases, biogenic constituents cause Sick Building Syndrome (SBS) which badly affect the health and productivity of building occupants. SBS can be alleviated using NASA-validated air-purifying plants. In the present study, Sansevieria Laurentii were used. The indoor contaminants used for the experiments were adhesives, paint, kerosene, egg crates, cigarette, varnish, wood shavings and coconut husk. The findings showed that using locally available plants for air cleaning is feasible and there is a significant reduction of indoor air pollution with increased number of potted plants. The maximum number of potted plants used in the experiments did not exceed six. It was further identified that potted plants and passive green wall were not effective in reducing air pollutants compared to an active green wall. However, the addition of snake plants resulted in better reduction of pollutants. TVOC decreased by 50% in the case of paint (against 10% without plants) and 75% with varnish (against 10% without plants). HCHO levels were reduced by 63% with kerosene (against 6% without plants) and 57% with adhesive (against 4% without plants). CO_2 levels were decreased by 18% with coconut husk and egg crate (against 3% and 1% without plants, respectively). CO levels were reduced by 77% with cigarettes (against 1.2% without plants) and 27% with wood shavings (against 3% without plants) [18].

The physical features of indoor plants influence psychological outcomes, aesthetic attraction, and perceived plant benefits with respect to subjective well-being (SWB), indoor air quality (IAQ), and relative humidity (RH) [7]. They surveyed 520 participants who rated twelve different interior plant pictures. Descriptors such as "uplifting," "interesting," "relaxing," and "beautiful" had high standardized regression coefficients and were significant predictors of perceived SWB benefits. Plants described as "healthy" and "attractive" were the most frequently selected including palm, ficus sphere, epipremnum, and ficus column. For perceived IAQ and RH benefits, plant health and canopy density were important factors. Unhealthy plants scored negative values, suggesting that such plants should be removed. Results also showed that plant shapes were attractive and rounded contours were preferred, but no single shape was predominantly preferred over others. Finally, demographic factors had weak effects on plant ratings, suggesting that similar plants could be selected for various environments. These results indicate that healthy, dense, and attractive plants should be selected to improve well-being, cognitive performance, and productivity in various indoor environments. These practical results should help designers, architects, building managers, and residents to select and place interior plants in the best locations, most effective species, and optimal numbers. Interior plants can improve psychological well-being and some aspects of indoor environmental quality. Furthermore, this study provides the first step in developing an interior plant selection guide based on psychological and perceived benefits for various indoor spaces.

Biophilic healthcare design is essential for developing healing and restorative settings, which has been discussed for the deficiency of consideration of natural plants inside healthcare facilities as a part of the biophilic healthcare design framework [21]. Nevertheless, there has been evidence that they provide a number of advantages. One key challenge that is well noted and leads to a compromise between emotional healing factors and economic returns influences health care settings to limit indoor plants more often than not as a result of the latter. Interestingly, the connection between the indoor plants and the general increase in microbial counts or infection-causing HAIs is meager. Nonetheless, the regulations forbidding it inherently restrict creativity in care-space designs. Published study samples are often small and scattered, or they lack attention to the abundance of benefits of indoor plants, such as stress reduction and cognitive enhancement. Considering the current increasing demand for people's healthcare, cost-effective solutions like the use of indoor plants can play an important role. Addressing these knowledge gaps through research that cuts across disciplines will support improved health and wellbeing for all building occupants of healthcare facilities around the globe.

III. FIGURES AND TABLES

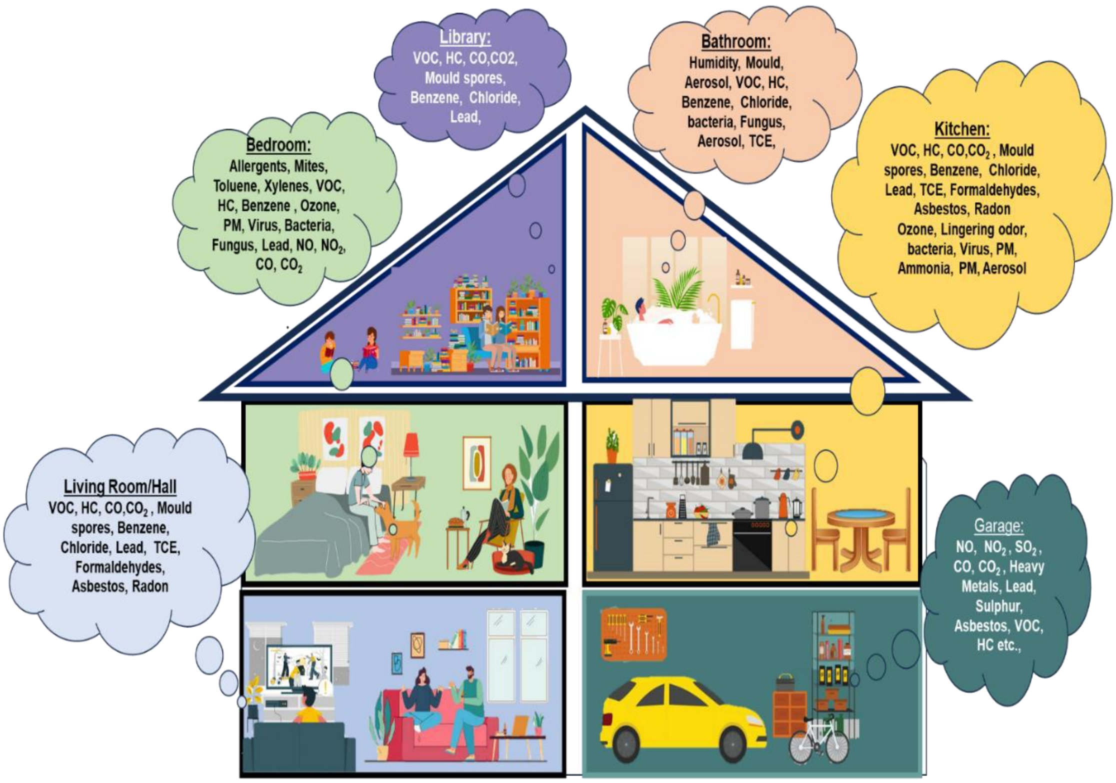

Fig. 1: Common Indoor Pollutant

Table 1: Types of pollutants, their sources and effects on human health

Type of Pollutant	Sources	Effects on Human Health	Mitigation Strategies	Ref.
Hydrocarbons and Volatile Organic Compounds (VOCs)	Paints, varnishes, cleaning agents, pesticides, building materials, furnishings, Fumes from cooking, Fuel/Tobacco combustion and Consume products.	Irritation of eyes, nose, and throat; headaches; dizziness; exacerbation of asthma and allergies; long-term exposure linked to cancer, Failure of nervous system.	Use low-VOC or zero-VOC products; increase ventilation; use air purifiers with activated carbon filters	[13]
Aldehyde, Formaldehyde	Building materials (plywood, particleboard),furniture,adhesives Construction materials, Cooking & Furnishing.	Irritation of eyes, nose, and throat; respiratory issues; headaches; increased cancer risk Breathing problems, cancer, Headache, Decreasing immunity	Proper ventilation; use formaldehyde-free materials; increase indoor plants known to absorb formaldehyde	[13]
Tobacco Smoke	Smoking of cigarettes, cigars, pipes	Respiratory issues (asthma, bronchitis); increased risk of lung cancer, heart disease, and stroke	Implement smoking bans indoors; promote smoking cessation programs; improve ventilation	[23]
Carbon Monoxide (CO)	Incomplete combustion of fuels (gas stoves, furnaces, fireplaces) Tobacco combustion, Wood stove.	Headaches, dizziness, nausea, confusion, fatigue; can be fatal at high levels; long-term exposure linked to cardiovascular issues and cognitive impairment Interferes with oxygen supply, Retarded reflexes due to CO exposure.	Install CO detectors; maintain fuel-burning appliances; ensure proper ventilation	[23]
Nitrogen Dioxide (NO2)	Combustion sources (gas stoves, heaters, tobacco smoke)	Respiratory irritation; exacerbation of asthma symptoms; increased susceptibility to respiratory Infections pulmonary disease, impairment of lung function, and irritation in eye, nose, and throat.	Proper ventilation; use exhaust fans; maintain gas appliances; minimize indoor combustion activities	[14]
Particulate Matter (PM)	Combustion sources (cooking, heating appliances), tobacco smoke, dust, pollen, mold Spores.	Respiratory issues (asthma, bronchitis); cardiovascular diseases; adverse pregnancy outcomes; increased mortality risk, Eye, nose and Throat irritation, Asthma, Various lung, and cardiovascular disorders.	Use HEPA filters in air purifiers; improve ventilation; reduce indoor sources of PM; clean regularly	[31]
Biological Pollutants	Bacteria, viruses, mold, dust mites, pet dander, pollen, Furnishings, Moist area, Ventilation system, Cockroaches	Allergic reactions (sneezing, coughing, congestion); respiratory infections; exacerbation of asthma and allergies, Sneezing, Coughing, Watery eyes, Shortness of breath,Dizziness,Lethargy,Lung diseases	Control moisture levels; clean and disinfect regularly; use air purifiers with HEPA filters; improve ventilation,	[13]
Radon	Soil or rock beneath buildings Burning of Coal and other fossil fuel, Construction materials, Soil gas and Tap water.	Increased risk of lung cancer; long-term exposure is the second leading cause of lung cancer after smoking,	Test for radon levels; seal cracks and gaps in buildings; install radon	[02]

		Leukemia,	mitigation systems where necessary	
Asbestos	Building materials (insulation, Demolition of construction materials.flooring, ceiling tiles)	Mesothelioma, lung cancer, asbestosis; respiratory issues; increased risk of other cancers, cancer of Kidney , Brain, Urinary bladder, gall bladder, Throat voice box etc.	Identify and safely remove asbestos-containing materials; encapsulate asbestos if removal is not feasible	[19]
Lead	Old paint, dust, soil	Neurological and developmental issues (especially in children); high blood pressure; kidney damage Attack on brain and CNS to cause Coma	Remove lead-based paint and dust safely; test and treat drinking water; cover bare soil with grass or mulch	[13]
Nitrogen oxides	Fuel combustion, Tobacco smoke.	Pulmonary disease, impairment of lung function, and irritation in eye, nose and throat.	Ensure proper ventilation while cooking. Use effective range hoods and consider electric or induction stoves to reduce NOx. Use potted plants bio-filtration and green walls to purify the air.	[14]
Ozone	Printers, Photocopiers, Air purifying devices.	Throat irritation, Cough, Pain, burning or discomfort in the chest ,Chest tightness, Wheezing and shortness of breath.	Keep doors and windows closed on high-ozone days. Use activated carbon filters in HVAC systems. Reduce indoor ozone sources like certain air purifiers and printers. Regularly check indoor ozone levels.	[03]
Pesticides	Dust from outside, consumer products	Blood and nerve disorders, Genetic disorders, Endocrine disruption, and Reproductive problems.	Keep pesticides outside, use non-chemical pest control, improve ventilation, and regularly clean surfaces to reduce indoor pesticide pollutants.	[01]
Sulphur oxides	Fossil fuel combustion	Impairs lung function adversely, Causes Cardiovascular diseases, Irritate skin and mucous membrane of the eyes,nose, throat and lungs.	Use low-sulfur fuels and appliances. Ensure proper ventilation. Install air purifiers with sulfur oxide filters. Regularly maintain HVAC systems.	[14]
Trichloroethelene (TCE)	Varnishes, lubricants,Adhesives, Typewriter correction fluid, Paint removers.	Effects on Liver, Kidney, CNS, Reproductive and Immune system.	Increase ventilation to reduce TCE buildup. Use air purifiers with activated carbon filters. Avoid using	[04]

			products containing TCE. Opt for safer alternatives for cleaning and degreasing. Maintain regular indoor air quality monitoring.	
Benzene	Tobacco smoke,	Causes dizziness, headaches, and drowsiness, Long-term exposure can lead to blood disorders, Carcinogenic, may cause leukemia	Ensure proper ventilation, Use air purifiers with activated carbon filters, Avoid products containing benzene, Regularly monitor indoor air quality	[20]
Ammonia	Cleaning products, Fertilizers, Animal waste, Car emissions, Industrial emissions, Household products (paints, glues)	Irritates eyes, nose, and throat, High levels can cause respiratory issues and burns, - Prolonged exposure can damage lungs	Improve ventilation, especially in areas where ammonia is used, Use natural cleaning products, Store ammonia-based products securely and use them sparingly	[20]
Xylene	- Paints and varnishes, Cleaning agents, Printing and rubber industries	Causes headaches, dizziness, and confusion, Prolonged exposure can affect the liver and kidneys, May cause respiratory problems	Ensure adequate ventilation, Use low-VOC products, Install air purifiers with activated carbon filters, Avoid using products containing xylene indoors	[20]
Toluene	Paints, paint thinners, Adhesives and glues, Nail polish and nail polish remover. Fuels	Causes headaches, dizziness, and nausea Long-term exposure can damage the nervous system May cause liver and kidney damage	Increase ventilation, especially when using products with toluene Use toluene-free or low-toluene products Utilize air purifiers with activated carbon filters Store products containing toluene properly	[20]

Table 2: Table of Indoor Plants and Their Controlled Pollutants

No	Plant Name	NH 3	C_6H_6	CO	CH_2O	HC/ VOC	O_3	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	Ref.
1.	Aloe Vera *(Aloe vera)*	-------------	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	-------------	-------------	--------------	[33]
2.	Areca Palm *(Dypsis lutescens)*	-------------	-------------	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[15,25]
3.	Arrowhead Vine *(Syngonium podophyllum)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	-------------	-------------	--------------	[29]
4.	Aglonema *(Chinese Evergreen)*	-------------	C_6H_6	CO	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
5.	Bamboo Palm *(Chamaedoreaseifrizii)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
6.	Banana (*Musa Oriana*)	-------------	-------------	-------------	CH_2O	--------------	-------------	-------------	-------------	--------------	[25]
7.	Boston Fern *(Nephrolepis exaltata)*	NH 3	C_6H_6	-------------	-------------	HC/ VOC	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33]
8.	Chrysanthemum *(Chrysanthemum morifolium)*	NH 3	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
9.	Dumb canes / Dieffenbachia (Dieffenbachia spp.)	-------------	-------------	-------------	-------------	HC/ VOC	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33]

10.	Money plant / Devil's Ivy /Pothos /Goldon Pothos *(Epipremnum aureum)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[24]
11.	Dracaena /(Red edge-draceana) *(Dracaena marginata)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[25, 33]
12.	Dwarf Date Palm *(Phoenix roebelenii)*	-------------	-------------	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[25, 33]
13.	Elephant Ear Philodendron *(Philodendron domesticum)*	-------------	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	-------------	-------------	--------------	[09,12]
14.	Anthurium/ Flamingo Lily (*Anthurium* andreanum*)*	NH 3	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
15.	Gerbera Daisy / Barberton Daisy (*Gerbera jamesoni)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	-------------	C_2HCl_3	--------------	[25]
16.	English Ivy *(Hedera helix)*	NH 3	C_6H_6	CO	CH_2O	HC/ VOC	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33,39]
17.	King of hearts *(Homamena wallisii)*	-------------	-------------	-------------	-------------	--------------	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33]
18.	Heart leaf Philodendron *(Philodendron cordatum)*	-------------	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	-------------	-------------	--------------	[09, 25]

19.	Janet Craig / Warneckei Dracaena *(Dracaena deremensis)*	--------	C_6H_6	-------------	CH_2O	--------------	-------------	-------------	C_2HCl_3	--------------	[33,34]
20.	Kimberly Queen Fern (Nephrolpis *obliterate*)	-------------	-------------	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33]
21.	Lady Palm *(Rapisexcels sp.)*	NH_3	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
22.	Lily turf *(Liriope spicata)*	-------------	-------------	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33]
23.	Mass Cane/ Corn Stalk Plant *(Dracaena Massangeana)*	-------------	C_6H_6	CO	CH_2O	--------------	-------------	-------------	-------------	--------------	[26, 33]
24.	Moth Orchid *(Phalaenopsis spp)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
25.	Parlor Palm *(Chamaedorea elegans)*	NH_3	C_6H_6	CO	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
26.	Peace Lily *(Spathiphyllum wallisii)*	NH_3	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33,35, 39]
27.	Poinsettia *(Euphorbia pulcherrima)*	-------------	C_6H_6	CO	CH_2O	--------------	-------------	-------------	-------------	--------------	[05]
28.	Rubber Plant *(Ficus* elastica*)*	-------------	C_6H_6	CO	CH_2O	--------------	-------------	-------------	-------------	--------------	[08]

29.	Snake Plant/ Mother-in law's tongue *(Sansevieria trifasciata"Laurentii")*	-------------	C_6H_6	-------------	CH_2O	--------------	O_3	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[24,33]
30.	Spider Plant *(Chlorophytum comosum)*	-------------	C_6H_6	CO	CH_2O	HC/ VOC	O_3	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[08,24, 33]
31.	Split Leaf Philodendron *(Thaumatophyllum bipinnatifidum)*	-------------	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	-------------	-------------	--------------	[26]
32.	Weeping Fig *(Ficus Benjamin)*	-------------	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]

Note: Color Code of Idoor Plants and Their Controlled Pollutants for Table 2

NH 3	**Ammonia**	C_6H_6	**Benzene**
CO	**Carbon Monoxide**	CH_2O	**Formaldehyde**
HC/ VOC	**Hydrocarbon/Volatile Organic Compound**	O_3	**Ozone**
$C_6H_5CH_3$	**Toluene**	C_2HCl_3	**Trichloroethylene**
$(CH_3)_2C_6H_4$	**Xylene**	--------------	**Absent of Pollutant**

IV. CONCLUSION

Indoor plants, therefore, provide a holistic solution to improving the indoor environment in aspects that affect human health. First, through purging the air; second, by moderating the humidity in the room; and third, and lastly, psychologically, plants play a big role in promoting a healthier indoor environment. The subsequent research should aim at establishing the best types of plants that have the most benefits and how to further improve plant management systems. Using indoor plants in building construction and including greenery in interior décor is a potential solution to promote healthier living and working environments. The detailed examination of potential solutions for preventing indoor air pollution further establishes that indoor plants are a key ally in enhancing IAQ and preserving people's well-being. A variety of experimental studies have provided evidence of the effectiveness of numerous plant species in removing pollutants, with overall findings suggesting that light intensity, plant metabolic rates, microbial relationships, etc. play important roles in removing such pollutants. Additional improvements, such as the introduction of bi-directional phytofilters and the use of endophytic bacteria in indoor plant-based air filtration systems, also help to improve their working. Besides, studies also boast of the psychological benefits of having plants within our interiors and corroborate the role of these plants in boosting human performance across various aspects of health. Since an issue with indoor air pollution is an ever-present factor, constant research and development on how to optimize the usage of indoor plants can go a long way to help in realizing the maximization of the effectiveness and general use of indoor plants as an economical way of improving the quality of air indoors. The incorporation of botanical biofilters in building designs and the need for biophilic design bring society closer to a future where people will be assured to breathe clean air within their artificially-made environment.

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