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BREATHING FRESH: A COMPARATIVE ANALYSIS OF NATURAL V/S CONVENTIONAL AIR-PURIFIER

*Yash Patwardhan, **Jyoti Chaurasiya and ***Dr. Kranti Ozarkar

*,**Research Students, Department of Zoology, Department of Management Studies , B. K. Birla College (Empowered Autonomous), Kalyan

***Guide

Abstract:

Air pollution has become a pressing global issue. It is majorly due to urbanization and industrialization. It is impacting human health and environment severely. There have been innovations for the enhancement of air quality. Conventional air purifiers are one of such innovations. The convention air purifiers have proven efficacy in removing pollutants in the room. Conventional air purifiers, though effective in removing pollutants, have their limitations in energy consumption and environmental impact. This Sustainable plant-based air purifier offers an eco-friendlier alternative by utilization of natural processes. This research compares traditional air purifiers with sustainable air purifiers made from plants, examining their advantages, disadvantages, and real-world uses before determining which is more advantageous. The current study suggests a different model of air purifier which is sustainable yet effective.

Keywords: *Air pollution, Conventional Air-Purifier, Plant based Sustainable Air-Purifier.*

Introduction:

Air pollution remains a critical environmental challenge in the world. Case studies show a significant impact on both human health and environment. The air quality index (AQI) number is a numerical scale that represents the quality of air in a specific area, measuring the concentration of pollutants and including potential health impacts. India's current air quality index (AQI) status, as indicated by a value of 135. It is categorized as "Poor" across 1,238 monitoring stations that highlights a pressing environmental challenge. Poor AQI levels are associated with high concentration of harmful pollutants in the air [1].

Recent studies indicate that air pollution continues to be a leading cause of premature deaths in the country. A study published in Lancet Planetary Health in December 2024 found that long-term exposure to air pollution increased deaths by 1.5 million annually in India. Beyond human health, air pollution has severe environmental consequences. It contributes to the degradation of ecosystems, including damage to crops, forests, and water bodies [2].

An AQI pie-chart is shown below:

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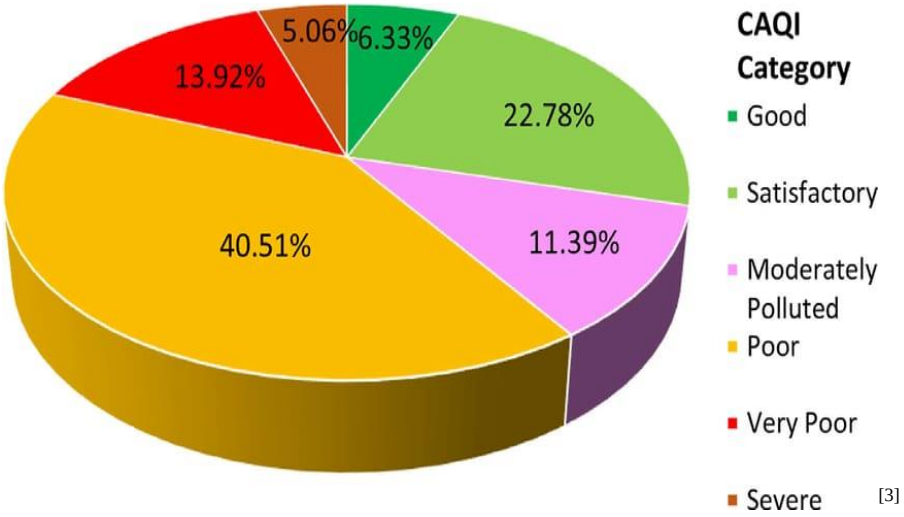

[3]

Some Case studies related to Air Pollution:

1. Bhiwadi's Air Pollution Crisis: Bhiwadi, an industrial city in Rajasthan, has been identified as one of the most polluted cities globally. In 2022, it recorded an Air Quality Index (AQI) of 228, significantly exceeding safe levels. The primary contributors to this pollution are the approximately 2,000 factories operating in the area, emitting large quantities of pollutants into the atmosphere [4].
2. Delhi has been grappling with severe air pollution, particularly during the winter months when a combination of factors leads to hazardous air quality levels.Recent Developments: Air Quality Index (AQI) Levels: In November 2024, Delhi's AQI reached alarming levels, with readings soaring above 1,000, categorizing the air quality as "hazardous." This has led to the city being ranked as the world's most polluted during that period [5].
3. A study examined the health effects of air pollution in different areas of Chennai, including Anna Nagar, Adyar, Kilpuak, T. Nagar, and Vallalar Nagar. The study found a relationship between air pollution levels and the percentage of affected people[14].
4. The AQI in Shivajinagar reached the "very poor" category on Monday. Experts have pointed out that the deteriorating AQI is not only due to construction dust and vehicle emissions but also to garbage burning. The Pune Municipal Corporation (PMC) has taken action by documenting 458 cases of garbage burning and imposing fines totaling Rs 2.5 lakh on violators. Moreover, the PMC has observed a significant increase in illegal garbage dumping, with 6,709 instances reported this month compared to 4,299 in November[14].
5. Air quality in Mumbai continued to remain in the 'poor' category on Thursday, even as it saw a marginal improvement from the previous day. The city's Air Quality Index reached 116, according to data from aqi.in. It was 1.05 times higher than the average in Maharashtra.

Impact of Polluted air on Environment:

Air pollution has a profound impact on the environment, affecting air quality, water bodies, soil, plants, and pollinators. It introduces hazardous substances like particulate matter (PM), nitrogen oxides (NOx), sulfur dioxide (SO_2), and volatile organic compounds (VOCs) into the atmosphere. These pollutants contribute to smog and haze, reducing visibility and posing serious health risks. For instance, the Harvard Six Cities study

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demonstrated a clear link between fine particulate air pollution and higher mortality rates in certain U.S. cities [6]. Airborne pollutants also contaminate water bodies through acid precipitation, leading to the acidification of lakes and rivers. This process harms aquatic ecosystems, disrupts biodiversity, and degrades water quality. Moreover, acid rain releases toxic heavy metals like aluminium, which are detrimental to aquatic organisms, including fish [7,8]. The impact of air pollution extends to soil degradation, where acid rain—resulting from sulphur dioxide and nitrogen oxides emissions—lowers soil pH and increases its acidity. This change reduces soil fertility, affects nutrient availability, and negatively impacts plant growth. Acidic soils also promote the movement of heavy metals into water systems, threatening both wildlife and aquatic habitats. Plants face further challenges as air pollution disrupts their growth and reproduction. By interfering with photosynthesis and nutrient uptake, pollutants such as smog and haze block sunlight, compromising plants' ability to photosynthesize effectively. This leads to poor plant health, diminished growth, and biodiversity loss [7,8]. Pollinators, such as bees and butterflies, are also significantly affected. Air pollution alters their behaviour and reduces their visitation to flowers, which in turn impacts pollination. For example, a study in southern England found that air pollution reduced pollinator visits to black mustard flowers by as much as 90% in polluted areas compared to regions with cleaner air. Collectively, these effects highlight the urgent need to address air pollution to preserve ecosystems and maintain environmental balancee [9].

Consequences of Air Pollution on Humans:

Air pollution poses significant health risks, impacting various systems of the human body and disproportionately affecting vulnerable populations. It exacerbates respiratory conditions such as asthma and Chronic Obstructive Pulmonary Disease (COPD), increasing the frequency and severity of attacks. Additionally, polluted air raises the risk of respiratory infections like pneumonia and bronchitis. The cardiovascular system is also at risk, as long-term exposure to air pollution is associated with an increased likelihood of heart attacks and strokes. Moreover, prolonged exposure to certain pollutants significantly elevates the risk of developing lung cancer [10,11]. Vulnerable populations, including children, the elderly, and pregnant women, are particularly susceptible to these health impacts. Children and the elderly face higher rates of respiratory and cardiovascular issues, while pregnant women exposed to polluted air are at increased risk of adverse pregnancy outcomes, including stillbirth and miscarriage. The global toll of air pollution is staggering, contributing to millions of premature deaths annually. Addressing air pollution is therefore essential to safeguarding public health and reducing mortality rates worldwide. [10,11]. Impact on Infrastructure and Cultural Heritage: Taj Mahal and Acid Rain: Air pollution has severely affected monuments like the Taj Mahal. Sulphur dioxide (SO_2) and nitrogen oxides (NO,) released from industries and vehicles react with water vapor to form acid rain. Acid rain corrodes marble, causing discoloration (marble cancer) and structural weakening. Regular cleaning with clay packs is required to mitigate damage**.** Building Corrosion:Pollutants, especially in urban areas, erode buildings, bridges, and statues made of stone, metal, or concrete, increasing maintenance costs.

Problem Statement:

Conventional air purifiers have been widely used to address indoor air pollution, offering effective solutions to improve air quality in the room. However, these devices often consume significant amounts of energy and can generate harmful by-

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products such as ozone, which may pose additional health risks to users. While these conventional methods are popular, their environmental impact and sustainability are becoming increasing concerns [12]. On the other hand, natural air purifiers, such as indoor plants, provide an eco-friendly alternative to improve air quality [13]. With an emphasis on aspects including energy consumption, air quality enhancement, health consequences, and long-term sustainability, this study compares the effectiveness, efficiency, and environmental impact of natural and conventional air purifiers.

Objective of the study

1. To examine the efficiency of sustainable plant-based air purifiers and conventional air purifiers.
2. To evaluate the differences in performance between sustainable plant-based air purifiers and conventional air purifiers.

Literature Review:

Conventional air purifiers and sustainable plant-based air purification systems offer distinct advantages and challenges in improving indoor air quality. HEPA filters, widely used in conventional systems, effectively capture particles as small as 0.3 microns, as noted by Smith and Brown (2021) in *Indoor Air Quality Solutions*. However, these filters are limited in addressing gaseous pollutants, which activated carbon filters can mitigate by adsorbing VOCs and odours, albeit with diminishing effectiveness over time (*Journal of Environmental Health*, 2020). Despite their efficiency, conventional systems contribute to waste through disposable filters, exacerbating landfill issues, as discussed in *Environmental Engineering Fundamentals* by Patel and Singh (2018). High energy consumption further increases their carbon footprint (*Energy Use in Modern Appliances* by Cheng et al., 2019). Additionally, recurring costs for filter replacement and energy make them less affordable, particularly for low-income households, as highlighted by Lee et al. (2019) in *The Economics of Home Appliances* and the *Journal of Public Health Policy* (2020).

In contrast, sustainable plant-based air purifiers, such as bioengineered plants and vertical green walls, utilize natural processes to absorb CO_2 and VOCs while producing oxygen. Research by Jones et al. (2020) in *Green Technology for a Sustainable Future* demonstrates their effectiveness in significantly reducing VOC levels. These systems also promote biodiversity, reduce urban heat, and integrate seamlessly into urban landscapes, enhancing aesthetics and sustainability (*Urban Sustainability Practices* by Chen et al., 2021; *Nature-Based Solutions for Urban Challenges* by Thakur, 2022). While initially cost-intensive, they require minimal maintenance, making them more economical over time, as supported by *Green Investments: Costs and Benefits* by D'Souza and Martin (2021). Together, these approaches highlight the need for a balanced strategy combining efficiency, sustainability, and affordability to address air quality challenges.

Suggested Model of Sustainable Plant Based Air-Purifier:

The model presents a sustainable, plant-based approach to air purification, combining natural filtration with innovative design. It features an air cleaner with a sleek plastic cover, divided into four sections, each housing a specific plant species: Spider Plant, Peace Lily, Snake Plant, and Aloe Vera. These plants are cultivated in coco coir, a sustainable growing medium. The air purifier functions by drawing air through a horizontal inlet pipe at the base, which then passes through the plant-filled sections. Each plant species contributes uniquely to air purification. Spider Plants are highly effective in removing formaldehyde and other volatile organic compounds (VOCs), while Peace Lilies excel at filtering benzene and trichloroethylene, common

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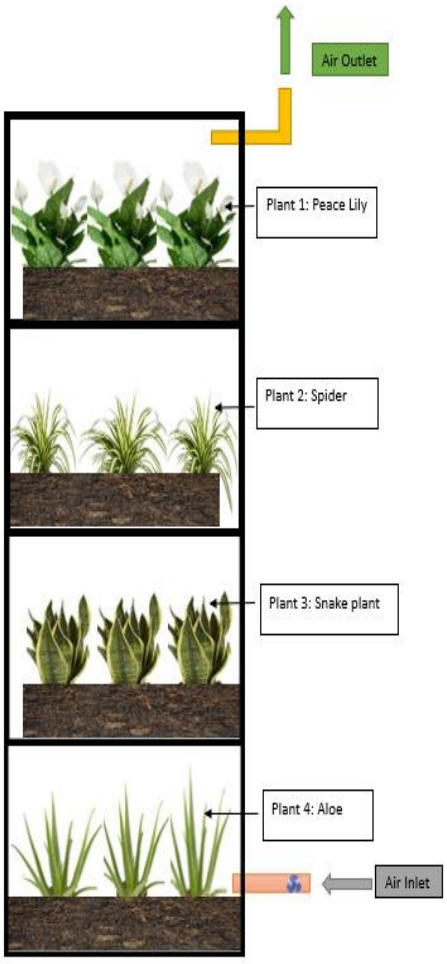
indoor pollutants. Snake Plants absorb carbon dioxide (CO_2) and release oxygen (O_2), enhancing air quality, and Aloe Vera further boosts oxygen levels during photosynthesis while also purifying the air. By leveraging the natural abilities of these plants, the air purifier transforms polluted air into clean, breathable air. This innovative model not only improves indoor air quality but also fosters a healthier living environment, exemplifying a seamless integration of nature and technology for sustainable living.



A few indoor plants for the plant-based air purifier

PLANT NAME	FIGURE	ADVANTAGES
SPIDER PLANT		Cleans the air by absorbing chemicals including formaldehyde, xylene, benzene and carbon monoxide. These plants are helpful to increase humidity level
PEACE LILY		Peace lilies are most effective for removing TEC from the air, removing 23% over 24 hours. It increases the level of humidity, helping you breathe better.
ALOE VERA		Aloe vera can remove some common chemicals found in households like detergent, plant and glues. It works by releasing Oxygen and observing CO2
SNAKE PLANT		It removes air pollutants such as formaldehyde and benzene. It helps to filter out impurities such as xylene trichlorethylene, toluene and ammonia. It can reduce the level of nitrate ions.
BOSS TEN FERN		Ferns are fantastic for removing common airborne pollutants including formaldehyde, xylene, and toluene. It reduces oxygen at night.
GOLDEN POTHOS		Pathos is best for purifying the air and removing toxins proving its efficacy in reducing formaldehyde, benzene and toluene

Benefits of the model:

1. Enhanced Performance: The purifier leverages the natural air-cleaning properties of plants to effectively eliminate pollutants, leading to significantly improved air quality.
2. Eco-Conscious Design: Crafted with environmentally friendly materials and powered by plants, this model supports sustainable practices while reducing dependence on synthetic purifiers.
3. Green and Safe: Unlike traditional purifiers, this model avoids releasing harmful substances or creating waste, ensuring a positive environmental impact.

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4. Affordable Solution: With easily accessible plants and a simple mechanical structure, the purifier is economical to produce and maintain.
5. Visually Pleasing: Incorporating greenery into its design, the purifier enhances the aesthetic appeal of both indoor and outdoor spaces, doubling as a decorative element.
6. Lower Carbon Emissions: By absorbing carbon dioxide and releasing oxygen, the plants help mitigate greenhouse gases, contributing to a cleaner atmosphere.
7. Urban Greening: This model encourages the integration of plants into cityscapes, increasing green spaces in areas dominated by concrete infrastructure.
8. Emotional Connection: For individuals, particularly elderly persons, who may find it challenging to care for pets, maintaining the plant-based air purifier model offers an alternative to reduce loneliness. By becoming "plant parents," they can dedicate their time to nurturing the plants within the model, fostering a sense of connection with nature. This activity not only supports emotional well-being but also contributes to improved indoor air quality, creating a healthier and more tranquil living environment.

Discussion:

Indoor air pollution demands sustainable purification solutions. Conventional air purifiers effectively filter pollutants using advanced technologies like HEPA filters but have significant drawbacks, including high energy consumption, carbon emissions, and potential ozone release (IRJMETS, 2023).

In contrast, plant-based air purifiers leverage natural processes to absorb pollutants. Most commonly absorbed ones are benzene and formaldehyde. Plants such as the snake plant, spider plant, aloevera and peace lily offer energy-efficient and eco-friendly alternatives. Their efficiency depends on factors like plant density and pollutant levels (NASA Clean Air Study). Recent advancements, like bioengineered plants from Neoplants, enhance pollutant absorption, making plant-based solutions more viable (Sustainable Brands).

While conventional systems provide immediate results, their environmental impact necessitates a shift toward plant-based or hybrid solutions for long-term sustainability.

This also increases the green cover in the urban areas.

Conclusion:

The sustainable plant-based air purifier provides a range of benefits. These make it a compelling choice for improving air quality. Utilizing plants provides a continuous and chemical-free filtration process. This not only enhances the air quality but also helps reduce the carbon footprint. The plants absorbs carbon dioxide and release oxygen, supporting a healthier environment.

Additionally, the system is cost effective. It relies on common plants and requires little maintenance unlike conventional purifier that inker on going costs for filter replacement. With its minimal power consumption, the sustainable air purifier is also an energy efficient solution. In summary the sustainable plant-based air purifier is an affordable, eco-friendly and efficient option for maintaining clean air in both residential and commercial spaces.

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