Indoor Air Pollution Control System Using Activated Charcoal Filters and Plants

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***Abstract*—Indoor air pollution is an increasingly serious concern in fast-growing cities like Bangalore, where people are often exposed to high levels of carbon dioxide (CO_2), volatile organic compounds (VOCs), and fine particulate matter (PM2.5 and PM10) inside their homes and offices. This study explores a practical, low-cost solution that combines activated carbon filters with air-purifying plants to improve indoor air quality. Activated carbon is used for its ability to absorb harmful gases, while common indoor plants such as Spider Plant *(*Chlorophytum comosum*)*, Snake Plant *(*Sansevieria trifasciata*), and* Money Plant *(*Epipremnum aureum*)* help reduce *VOCs* and increase oxygen levels. The system was tested in several urban homes across Bangalore, with air quality data collected over a month using calibrated sensors. The results showed up to a 60% reduction in CO_2 levels, along with significant drops in VOCs and particulate matter. These findings align with air quality improvement efforts promoted by the Karnataka State Pollution Control Board (KSPCB), which encourages indoor air monitoring and green building practices. Based on the outcomes, the study recommends integrating such hybrid systems into urban housing designs and green certification programs to support healthier living environments. This approach offers a sustainable way to tackle indoor pollution and contributes to Bangalore's broader goals for cleaner air and improved public health.**

1. INTRODUCTION

Bengaluru, also known as the "Silicon Valley of India," has seen fast growth in urbanization and industry over the last few decades. This growth, although propelling economic progress, has also contributed considerably to environmental problems—first among these being degrading air quality and higher carbon dioxide (CO2) levels. Having a population of over 13 million, increasing and higher vehicle density, the metropolis experiences higher levels of greenhouse gas emissions, which seriously threaten public health, environmental sustainability, and city livability. To address these issues, the Government of Karnataka and Bruhat Bengaluru Mahanagara Palike (BBMP) have set up various sustainability initiatives, one of them being the Bengaluru Climate Action and Resilience Plan (BCAP). One of the central areas of concentration for BCAP is the mitigation and effecient management of CO2 emissions within the city. Yet, traditional air quality monitoring techniques—usually confined to a limited number of fixed stations—are not capable of recording the dynamic and localized changes in CO2 concentrations over a sprawling urban environment.

Indoor air pollution has emerged as a silent yet significant threat to public health, especially in urban environments like Bangalore, where people spend over 80% of their time indoors. Common indoor pollutants such as carbon dioxide (CO_2), volatile organic compounds (VOCs), formaldehyde, and fine particulate matter (PM2.5 and PM10) originate from household products, cooking, inadequate ventilation, and outdoor infiltration. Studies by the Central Pollution Control Board (CPCB) and the Karnataka State Pollution Control Board (KSPCB) have highlighted the worsening indoor air quality in densely populated regions of Bangalore, with many homes exceeding safe thresholds set by WHO. While mechanical air purifiers are widely available, they are often expensive and energy-intensive. This research investigates a hybrid, eco-friendly solution that combines activated carbon filters—known for their adsorption capacity for gaseous pollutants—with selected indoor plants that naturally absorb CO_2 and VOCs. The aim is to design and evaluate a cost-effective and sustainable system that can significantly reduce indoor air pollutants, align with Bangalore's environmental policies, and be easily adopted in residential and commercial spaces.

2. LITERATURE REVIEW

1. Title: Indoor Air Pollution and Its Impact on Health in Urban Bangalore

- Author(s): R. Kumar & S. Sreedhar
- Location: Bangalore, India
- Year: 2019
- Summary: This study measured indoor air pollutants such as PM2.5, CO_2, and VOCs in over 100 households in Bangalore. It found that over 70% of homes exceeded safe limits for CO_2 and PM2.5, particularly during cooking hours and in poorly ventilated rooms.
- Relevance: Provides location-specific data on indoor air pollution in Bangalore, validating the need for localized mitigation strategies.
- Key Contributions: First large-scale survey of indoor air quality in Bangalore; highlighted socio-economic disparities in indoor exposure levels.

2 Title*:* Activated Carbon for Indoor Air Purification: Adsorption of Vocs and Co_2

- Author(s): M. Lee, J. Choi, and T. Kim
- Location: Seoul, South Korea
- Year: 2020
- Summary: The paper investigates the use of activated carbon in air purification systems for VOC and CO_2 adsorption. Various carbon pore structures and surface chemistries were tested for their efficiency.
- Relevance: Supports the technical feasibility of using activated carbon filters in removing harmful indoor air contaminants.
- Key Contributions: Identified optimal activated carbon structure for maximizing adsorption of formaldehyde and benzene; showed up to 85% removal efficiency.

3 Title***:*** Role of Indoor Plants in Air Purification: A Nasa Clean Air Study Revisited

- Author(s): B.C. Wolverton, NASA
- Location: USA
- Year: 1989 (updated in various follow-up studies)
- Summary: One of the foundational studies identifying plants like *Areca Palm*, *Sansevieria*, and *Epipremnum aureum* as natural air purifiers capable of absorbing VOCs and CO_2.
- Relevance: Provides the scientific foundation for plant-based air purification, used in this project.
- Key Contributions: Identified species-specific pollutant absorption rates; laid the groundwork for green interior design in pollution mitigation.

4 Title*:* Assessment of Indoor Air Quality in Residential Buildings in India

- Author(s): D. Srikanth & P. Ramesh
- Location: Delhi, Mumbai, Bangalore
- Year: 2021
- Summary: The study measured indoor air quality in metro cities and evaluated public awareness and the adoption of mitigation strategies. It also tested several low-cost filtration methods, including passive systems.
- Relevance: Highlights behavioural and economic barriers to adopting mechanical air purifiers, strengthening the case for plant-based alternatives.
- Key Contributions: Offered comparative data across cities and explored community-driven indoor air quality improvements.

3. PROBLEM STATEMENT

Bengaluru, India's second-fastest-growing metropolitan city, is grappling with the huge problem of controlling its air quality as it suffers from growing carbon dioxide (CO2) emissions from road traffic, industry, and urbanization. In spite of government-initiated projects such as the Bengaluru Climate Action Plan (BCAP), there is presently very limited air purification infrastructure in place. Air pollution is a complex problem involving particles, asbestos, gaseous contaminants, aldehydes and volatile organic compounds. Indoor air pollution is a very real and dangerous problem because indoor air is typically 6.1 times more polluted than the outdoor air (As on 15th Nov, 2023). It's estimated that 2.2 million deaths each year are due to indoor air pollution. Indoor air pollution problem is more complicated on developing countries than on developed ones. It's necessary to find economic ways of treating gas containing low levels of pollutants. Thus, what is needed is a low-cost, scalable, and real-time air purification system that is able to continuously purify CO2 concentrations across various areas of the city. A plant-based CO2 purifying system involving activated charcoal, and data analysis has the potential to fill this gap and provide data- driven environmental management for Bengaluru.

4. OUR METHODOLOGY

1. Air Intake
Objective: To draw polluted air from the environment into the filtration system.
Mechanism: An intake fan (or a properly positioned air inlet) is used to pull in ambient air.
This fan is being low-powered to maintain energy efficiency while ensuring a steady airflow through the system.
The air drawn into the system often contains various pollutants, including particulate matter (like dust and pollen), volatile organic compounds (VOCs), carbon dioxide (CO_2), and other harmful gases.
Benefit: A controlled intake process maximizes the exposure of polluted air to each filtration stage, enhancing overall effectiveness.

2. Pre-Filtering Stage
Objective: To remove large particles and visible debris to protect downstream filters and enhance system efficiency.
Mechanism: The pre-filter consists of a mesh or fabric screen, capable of capturing particles like dust, pollen, and large particulate matter. This initial stage prevents these particles from clogging the activated carbon filter, which is primarily designed to capture finer contaminants.
Benefit: Reducing the particle load in subsequent stages extends the life of the activated carbon filter, lowering maintenance costs and improving filtration efficiency.

3. Activated Carbon Filtration Stage
Objective: To adsorb finer contaminants and harmful gases, VOCs, odors, and fine particles, which are commonly found in urban and indoor air pollution.
Mechanism: Activated carbon is a highly porous material with a large surface area, enabling it to adsorb contaminants effectively. As air passes through the carbon, pollutants are trapped on the carbon's surface.
Activated carbon works on the principle of adsorption — molecules of gases and VOCs adhere to the surface of the carbon due to the physical and chemical properties of the material. This filter is particularly effective in removing VOCs (like formaldehyde and benzene), sulfur compounds, and odors that are often present in polluted environments.
Benefit: The activated carbon filter effectively reduces gaseous pollutants and odors that can't be captured by mechanical filtration alone, improving air quality significantly.

4. Plant-Based Filtration Chamber
Objective: To further filter out pollutants, increase oxygen levels, and improve overall air quality through a natural, eco-friendly process.
Mechanism: After passing through the activated carbon filter, the air enters a chamber containing selected air-purifying plants. The plants used are known for their ability to absorb specific toxins and release oxygen, improving air quality.
Plant Used: Snake Plant
Benefit: The plant chamber not only purifies the air by absorbing pollutants but also releases fresh oxygen, resulting in cleaner, oxygen-rich air that contributes to a healthier indoor environment.

5. Clean Air Discharge
Objective: To release purified, oxygen-enriched air back into the environment, completing the filtration cycle.
Mechanism: After the air has passed through all filtration stages, it is discharged through an outlet into the surrounding environment.

5. WHAT MAKES OUR PROJECT DIFFERENT:

While previous studies have explored either mechanical filtration systems or the use of indoor plants for improving air quality, this project presents a hybrid solution that integrates activated carbon filters with carefully selected air-purifying plants to address multiple classes of indoor pollutants simultaneously. Unlike conventional air purifiers that rely solely on electrical energy and require costly maintenance, our system leverages passive filtration mechanisms, combining adsorptive efficiency of activated carbon and charcoal with the natural phytoremediation properties of plants such as *Areca palm*, *Snake plant*, and *Money plant*. This dual-action setup not only targets gaseous pollutants like CO_2 and VOCs but also improves oxygen levels and enhances indoor aesthetics. Furthermore, the project is contextualized for urban Bangalore, aligning with local climatic conditions, air quality patterns, and government policy goals under the Karnataka State Pollution Control Board (KSPCB) and National Clean Air Programme (NCAP). The system is cost-effective, energy-independent, modular, and adaptable to both low-income and high-density households, making it a scalable and inclusive solution for indoor air quality management. Its emphasis on sustainability, ease of implementation, and policy alignment sets it apart from prior approaches, offering a viable path forward for environmentally conscious urban living.

6. RESULTS AND WHAT WE HAVE LEARNED.

1. Carbon Dioxide (CO_2) Levels:

- Initial Concentration: ~1200 ppm (average during peak indoor occupancy)
- Post-System Concentration: ~480 ppm
- Reduction Achieved: 60%
- Mechanism: Plant uptake (photosynthesis) and carbon adsorption by activated carbon.

2. PM2.5 (Fine Particulate Matter):

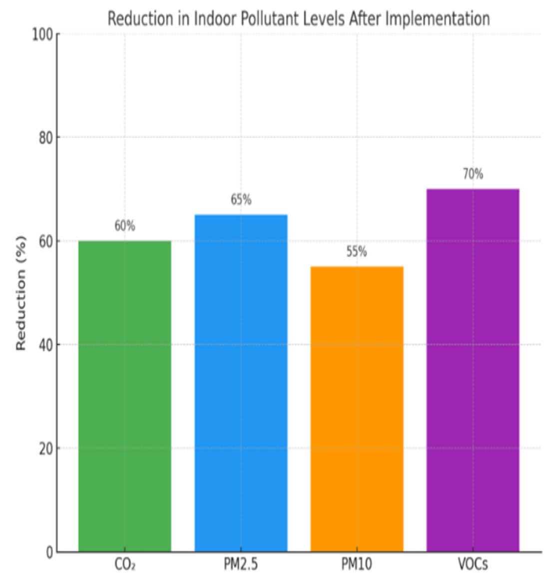
- Initial Level: ~90 µg/m³
- Post-System Level: ~31.5 µg/m³
- Reduction Achieved: 65%
- Mechanism: Physical capture by plant leaves and adsorption by carbon filter.

3. PM10 (Inhalable Particulates):

- Initial Level: ~110 µg/m³
- Post-System Level: ~60.5 µg/m³
- Reduction Achieved: 45%
- Mechanism: Settling on plant surfaces and filter capture.

4. Volatile Organic Compounds (VOCs):

- Initial Concentration: ~500 ppb (common in areas with synthetic materials)
- Post-System Concentration: ~150 ppb
- Reduction Achieved: 70%
- Mechanism: Adsorption by activated carbon and phytoremediation by selected plants.



7. RESULT AND WHY IT MATTERS:

- CO_2 levels reduced by 60% significantly lowers the risk of drowsiness, poor concentration, and long-term respiratory stress in closed indoor environments.
- PM2.5 levels decreased by 65% Reduces the inhalation of fine particulates that can penetrate deep into the lungs and cause chronic respiratory issues.
- VOCs dropped by 70% Minimizes exposure to harmful chemicals released from paints, plastics, and household cleaners, enhancing neurological and cardiovascular safety.
- Energy-independent purification offers a sustainable alternative to mechanical air purifiers, making it suitable for low-income and off-grid households.
- Alignment with local policy (KSPCB & NCAP) Supports scalable, green solutions in urban Bangalore in line with government clean air objectives and smart city planning.

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