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Investigating the Effectiveness of Plant Powders (Eucalyptus, Orange, and Pomegranate) as Air Purifiers

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ABSTRACT

Indoor air pollution poses significant health risks globally, with millions of deaths attributed to poor air quality annually. This study investigates the effectiveness of eco-friendly plant powders, including orange, eucalyptus, and pomegranate, as air purifiers. A prototype air filter was developed utilizing these plant powders, aiming to reduce indoor pollutants such as formaldehyde, volatile organic compounds (VOC_s), particulate matter (PM_{10} and $PM_{2.5}$), carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). The research involved installing the prototype filters in households, assessing pollutant levels before and after filtration. Results revealed varying effects of each plant powder on pollutant levels. While orange powder decreased SO_2 and NO_2 but increased HCHO, TVOCs, and PM, eucalyptus powder showed minor reductions across pollutants. Pomegranate powder effectively reduced SO_2 and NO_2 but showed slight increases in PM. These findings highlight the potential of plant powders in indoor air purification, though further research is needed to optimize their effectiveness and assess real-world applicability. Integration of eco-friendly materials offers promising avenues for sustainable indoor air quality improvement.

Keywords: plant, filters, adsorption, air purifier.

1. INTRODUCTION

Indoor environmental conditions play a crucial role in human wellbeing, given that people typically spend approximately 90% of their time indoors, primarily in residential or occupational environments (Leech *et al*., 2002). Alarmingly, indoor air pollution (IAP) contributes to the deaths of 3.8 million people annually (Balmes, 2019). Sources of indoor air pollution are diverse, stemming from activities such as cooking, smoking, use of electronic appliances, and emissions from building materials, among others (Kumar & Imam, 2013). Over the past decade, research emphasis has shifted from outdoor to indoor air quality control, reflecting lifestyle changes associated with increased urbanization (Ekmekcioglu & Keskin, 2007). Poor indoor air quality (IAQ) has been linked to building-associated illnesses, underscoring the imperative of understanding and mitigating indoor pollutants (Hromadka *et al*., 2017).

Key pollutants such as carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) pose significant health risks. CO_2 emissions result from combustion processes, while NO2, a major source of nitrate aerosols, is predominantly released during heating, power generation, and vehicle operation, causing severe respiratory issues, particularly in children (Madiraju *et al*., 2020). Indoor sources of NO2 include gas stoves, wood stoves, gasoline engines, and outdoor air infiltration (Samet *et al*., 1987). Malfunctioning or poorly vented combustion appliances, such as space heaters, can lead to elevated levels of NO_2 and carbon monoxide (CO) (Hedberg *et al*., 1989).

While numerous studies have investigated indoor air pollution, comprehensive assessments remain limited. Biersteker *et al.* (1965) conducted a notable study measuring indoor and outdoor chemical concentrations in 60 homes in Rotterdam, Netherlands, revealing varying levels of pollutants. Interestingly, indoor concentrations of smoke and SO_2 were found to be significant, albeit lower than outdoor levels on average. However, certain households exhibited substantially higher indoor concentrations, suggesting potential health risks during smog episodes. Additionally, Spedding *et al.* (1974) highlighted variations in indoor materials' capacity to absorb SO_2, identifying emulsion paint as a significant sink for this pollutant.

Recognizing the grave health implications of indoor air pollution, efforts to mitigate its effects have gained traction. Recommendations include employing air filters to reduce allergens and adopting adsorption techniques using organic and inorganic adsorbents for heavy metal sequestration (Vijayan *et al*., 2015; Ifelebuegu & Chinonyere, 2016). Furthermore, the integration of natural filters such as ornamental plants and green spaces has shown promise in reducing respiratory illnesses and hospital visits (Reshma *et al*., 2017; Nguyen *et al*., 2019; Oluyinka *et al*., 2022).

The primary objective of our research endeavors is to evaluate the efficacy of eco-friendly filtration mechanisms in mitigating the concentrations of airborne pollutants. This investigation is motivated by the imperative to address escalating concerns regarding air quality degradation and its adverse ramifications on public health and the environment. Through rigorous experimentation and analysis, we seek to ascertain the extent to which environmentally sustainable filtration methods can attenuate the presence of pollutants within atmospheric matrices. By elucidating the effectiveness of such interventions, our study aims to contribute to the development of strategies aimed at fostering cleaner air environments, thereby fostering advancements in sustainable urban living and ameliorating the detrimental impacts of pollution on global ecosystems.

2. MATRIALS AND METHODS

Sustainability is at the forefront of this air purifier. The main body, constructed from Novopan, an eco-friendly wood alternative, takes the form of a cuboidal box. As illustrated in Figure 1, this design leverages a unique two-sided functionality. One entire side serves as a dedicated compartment for the exhaust fan, ensuring efficient air flow through the unit. The fan's impressive specifications - 220 Volts AC, 50Hz single-phase, with a speed of 2250 RPM and a sweep of 150 mm - guarantee powerful suction. On the opposing side, multiple compartments of equal size are meticulously arranged to house the natural filter media. These filters are the heart of the air purification process, utilizing plant extracts derived from orange peels, eucalyptus leaves, and pomegranate peels. Through the process of adsorption, these natural materials effectively capture airborne pollutants, creating a cleaner and healthier breathing environment. The separation of the fan and filter media compartments optimizes performance by preventing dust buildup within the fan mechanism and ensuring maximum filter efficiency (Madiraju *et al*., 2020).

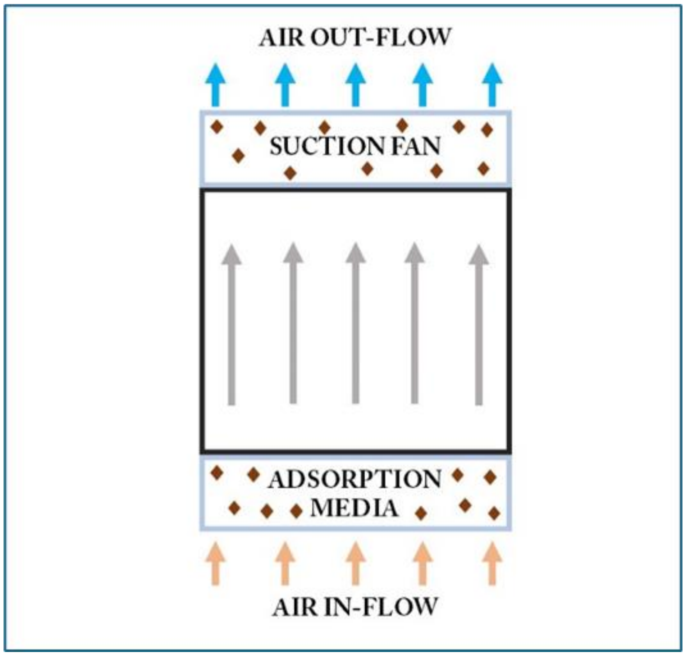

Fig. 1: Workflow of prototype air purifier

In this study, a prototype air filter was developed to reduce indoor air pollutants, including Formaldehyde (CH_2O), Total Volatile Organic Compounds (TVOCs), Particulate Matter (PM_{10} and $PM_{2.5}$), Carbon Dioxide (CO_2), Sulfur Dioxide (SO_2), and Nitrogen Dioxide (NO_2). The experimental design involved installing the prototype filters in selected households at specified locations. Prior to installation, pollutant levels were assessed at the air outlet using a gas analyzer. Following installation, measurements were taken again to evaluate the filter's effectiveness on February 2024. The gas analyzer used for measurement was specified, including details such as make, model, measurement range, accuracy, and calibration procedures. Ethical considerations, if applicable, were addressed regarding any involvement of human subjects or privacy concerns. Data analysis involved comparing pre- and post-installation measurements to assess pollutant removal efficiency and performing statistical analyses where appropriate (Nishihama *et al.,* 2021).

All laboratory experiments were conducted under controlled conditions with a room temperature of 20 ± 5°C. The research employed gas analyzers and air quality detectors to monitor NO_2 and SO_2 levels throughout the testing process. These instruments were meticulously calibrated before use to ensure accurate data collection. Additionally, the fabrication process for the prototype strictly adhered to the use of eco-friendly materials, excluding any chemicals or hazardous substances. The spent adsorbent powders (pomegranate pale powder, orange pale powder, and Eucalyptus globulus leaf powder) can be disposed of through incineration once they reach their saturation point (Madiraju *et al*., 2020).

3. Results and Discussion

The results of the study revealed changes in pollutant levels before and after the implementation of the orange pale powder air filter (Table 1). Prior to the installation, levels of Formaldehyde (HCHO) were measured at 0.031 mg/m³, which increased to 0.105 mg/m³ after the filter was installed. Similarly, Total Volatile Organic Compounds (TVOCs) saw a substantial rise from 0.196 mg/m³ to 0.747 mg/m³ post-installation. Particulate Matter ($PM_{2.5}$ and PM_{10}) levels also exhibited increases, with $PM_{2.5}$ rising from 27 µg/m³ to 35 µg/m³, and PM_{10} increasing from 48 µg/m³ to 59 µg/m³. Carbon Dioxide (CO_2) levels showed a slight increase from 915 ppm to 978 ppm after the filter was installed. Conversely, there were notable decreases observed in Sulfur Dioxide (SO_2) levels, dropping from 0.35 mg/m³ to 0.19 mg/m³, and Nitrogen Dioxide (NO_2) levels decreasing from 0.202 mg/m³ to 0.173 mg/m³ after the implementation of the air filter.

The observed changes in pollutant levels suggest that while the orange pale powder air filter effectively reduced certain pollutants such as SO_2 and NO_2, it led to increases in other pollutants like HCHO, TVOCs, and particulate matter. These findings indicate that the effectiveness of the air filter may vary depending on the type and concentration of pollutants present in the indoor environment. Further investigation is warranted to understand the mechanisms behind these changes and to optimize the design and performance of air filters for better indoor air quality. Additionally, it's essential to consider the potential health implications of increased levels of certain pollutants despite decreases in others, highlighting the importance of comprehensive air quality management strategies. Moreover, considering the results, it is speculated that the efficacy of the orange pale powder air filter could be improved by compacting the powder into blocks, as this may enhance its filtration capabilities. Further research into this modification could lead to more efficient air purification solutions (Reshma *et al.,* 2017).

Table 1: Pollutant Levels Before and After Filtration with Orange Pale Powder

Parameter	**Before**	**After**
HCHO	0.031 mg/m^3	0.105 mg/m^3
TVOC	0.196 mg/m^3	0.747 mg/m^3
$PM_{2.5}$	$27 \mu g/m^3$	$35\ \mu g/m^3$
PM_{10}	$48\ \mu g/m^3$	$59\ \mu g/m^3$
CO_2	915 ppm	978 ppm
SO_2	0.35 mg/m^3	0.19 mg/m^3
NO_2	0.202 mg/m^3	0.173 mg/m^3

The results for Eucalyptus globulus leaf powder indicate slight reductions in pollutant levels after filtration (Table 2). Formaldehyde (HCHO) levels decreased from 0.099 mg/m³ before filtration to 0.094 mg/m³ after filtration. Similarly, Total Volatile Organic Compounds (TVOCs) decreased from 0.704 mg/m³ to 0.687 mg/m³ post-filtration. Particulate Matter (PM2.5 and PM10) levels showed minor reductions, with PM2.5 decreasing from 27 µg/m³ to 32 µg/m³, and PM10 decreasing from 46 µg/m³ to

57 µg/m³ after filtration. Carbon Dioxide (CO_2) levels also decreased slightly from 1003 ppm to 979 ppm post-filtration. Noteworthy reductions were observed in Sulfur Dioxide (SO_2) levels, dropping from 0.74 mg/m³ to 0.63 mg/m³, and Nitrogen Dioxide (NO_2) levels decreasing from 0.254 mg/m³ to 0.249 mg/m³ after filtration with Eucalyptus globulus leaf powder.

The observed reductions in pollutant levels suggest that the Eucalyptus globulus leaf powder filter has the potential to effectively mitigate indoor air pollutants. However, the magnitude of reductions varies across pollutants, indicating differing filtration efficiencies. While some pollutants such as SO_2 and NO_2 exhibit significant reductions, others like HCHO and TVOCs show only slight decreases. Further research is needed to elucidate the mechanisms behind these variations and to optimize the performance of Eucalyptus globulus leaf powder filters. Additionally, the minor reductions observed in $PM_{2.5}$ and PM_{10} levels may warrant exploration into potential modifications or enhancements to improve the filter's particulate matter removal efficiency. Overall, these findings highlight the potential of natural leaf powder filters like Eucalyptus globulus in contributing to indoor air quality improvement efforts, though continued refinement and evaluation are necessary to maximize their effectiveness (Farhadi *et al.,* 2017).

Table 2: Pollutant Levels Before and After Filtration with Eucalyptus globulus Leaf Powder

Parameter	**Before**	**After**
HCHO	0.099 mg/m^3	0.094 mg/m^3
TVOC	0.704 mg/m^3	0.687 mg/m^3
$PM_{2.5}$	27 $\mu g/m^3$	32 $\mu g/m^3$
PM_{10}	46 $\mu g/m^3$	57 $\mu g/m^3$
CO_2	1003 ppm	979 ppm
SO_2	0.74 mg/m^3	0.63 mg/m^3
NO_2	0.254 mg/m^3	0.249 mg/m^3

The results for the third powder, Pomegranate pale powder, demonstrate changes in pollutant levels before and after filtration (Table 3). Formaldehyde (HCHO) levels decreased from 0.145 mg/m³ before filtration to 0.105 mg/m³ after filtration. Total Volatile Organic Compounds (TVOCs) also exhibited a decrease, from 1.041 mg/m³ before filtration to 0.747 mg/m³ after filtration. Particulate Matter ($PM_{2.5}$ and PM_{10}) levels showed slight increases, with $PM_{2.5}$ rising from 30 µg/m³ before filtration to 35 µg/m³ after filtration, and PM_{10} increasing from 54 µg/m³ to 59 µg/m³ post-filtration. Carbon Dioxide (CO_2) levels decreased slightly from 1003 ppm before filtration to 978 ppm after filtration. Notably, significant reductions were observed in Sulfur Dioxide (SO_2) levels, dropping from 0.73 mg/m³ before filtration to 0.34 mg/m³ after filtration, while Nitrogen Dioxide (NO_2) levels decreased from 0.282 mg/m³ to 0.228 mg/m³ post-filtration with Pomegranate pale powder.

The observed changes in pollutant levels suggest that the Pomegranate pale powder filter effectively mitigated indoor air pollutants. However, varying degrees of reduction were observed across different pollutants. While pollutants such as SO_2 and NO_2 exhibited substantial decreases, others like HCHO and TVOCs showed relatively smaller reductions. This variation in pollutant removal efficiencies may be attributed to the specific characteristics and filtration mechanisms of the Pomegranate pale powder filter. Further research is warranted to elucidate these mechanisms and optimize the filter's performance for enhanced pollutant removal.

Additionally, the slight increases observed in $PM_{2.5}$ and PM_{10} levels suggest that the Pomegranate pale powder filter may require modifications to improve its particulate matter filtration efficiency. Overall, these findings underscore the potential of the Pomegranate pale powder filter in contributing to indoor air quality improvement efforts, highlighting the importance of continued research and development to optimize its effectiveness (Ben Amor *et al.,* 2023).

Table 3: Pollutant Levels Before and After Filtration with Pomegranate Pale Powder

Parameter	**Before**	**After**
HCHO	0.145 mg/m^3	0.105 mg/m^3
TVOC	1.041 mg/m^3	0.747 mg/m^3
$PM_{2.5}$	30 $\mu g/m^3$	35 $\mu g/m^3$
PM_{10}	54 $\mu g/m^3$	59 $\mu g/m^3$
CO_2	1003 ppm	978 ppm
SO_2	0.73 mg/m^3	0.34 mg/m^3
NO_2	0.282 mg/m^3	0.228 mg/m^3

4. Conclusion

In conclusion, the study demonstrates the potential of eco-friendly powders, including pomegranate pale powder, orange pale powder, and Eucalyptus globulus leaf powder, as effective air filtration media for removing nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) from indoor environments. These natural powders exhibit promise in capturing gaseous pollutants, indicating their suitability for indoor air purification. Moreover, the integration of a two-stage filtration system into the prototype addresses the challenge of fine particulate matter ($PM_{2.5}$ and PM_{10}) accumulation, thereby enhancing overall air pollutant removal efficiency. However, it is important to recognize that this research was conducted in a controlled indoor environment at a single location. Further exploration is warranted to assess the effectiveness of these natural powders and the two-stage filtration system across diverse real-world settings with varying air pollutant profiles. Additionally, optimizing the efficiency of both the natural powder filters and the $PM_{2.5}/PM_{10}$ filter, along with investigating strategies for filter regeneration or replacement, are important areas for future research. Despite these challenges, the findings underscore the potential of utilizing eco-friendly materials for sustainable indoor air quality improvement, paving the way for the development of effective and environmentally friendly air purification solutions.

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