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DESIGN AND FABRICATION OF A HIGH-EFFICIENCY PARTICULATE AIR FILTRATION SYSTEM

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ABSTRACT

Air pollution, particularly the increase in dust and allergens during the summer, has significantly driven the demand for effective air purification solutions. Air purifiers are devices designed to remove contaminants from the air in various environments, including homes, offices, and industrial settings. These devices offer substantial benefits, especially for individuals suffering from allergies and asthma, and play a crucial role in reducing exposure to harmful substances like second-hand tobacco smoke. The effectiveness of air purifiers is paramount in highly polluted cities such as New Delhi, Patna, and Gwalior, where air quality poses a significant health risk.

A standard air purifier typically employs a multi-stage filtration system to capture a wide range of airborne contaminants. Among these, High-Efficiency Particulate Air (HEPA) filters are critical for removing microscopic particles, including dust, pollen, pet dander, and certain bacteria and viruses. To be classified as a true HEPA filter, it must adhere to strict standards, capable of removing at least 99.97% of particles as small as 0.03 microns. This level of filtration ensures that the air circulating in a room is significantly cleaner and healthier.

The market offers a diverse range of air purifiers, incorporating various technologies beyond HEPA filtration, such as activated carbon filters for odor and gas removal, ionizing technology, and UV sterilization. Often, high-performing air purifiers combine multiple filtration and purification methods to achieve comprehensive air quality improvement. When purchasing an air purifier, it is essential to select a quality product equipped with true HEPA filters from reliable sources, avoiding less effective "HEPA-type" alternatives. The availability of these devices from numerous sources underscores their growing importance as a necessity for maintaining healthy indoor environments.

Keywords: HEPA(High-Efficiency Particulate Air), UV(Ultraviolet).

I. Introduction

The increasing prevalence of pollution, dust, and allergies, particularly during seasonal shifts, has driven a significant rise in the demand for effective indoor air purification. Air purifiers are devices designed to remove contaminants like dust particles and fibers from the air, offering substantial relief to individuals with allergies and asthma. Their importance is especially pronounced in highly polluted urban centers such as New Delhi, Patna, and Gwalior.

Commercially available air purifiers range from small, standalone units for individual rooms to largescale systems integrated into HVAC systems, commonly used in medical, industrial, and commercial settings. These devices also play a crucial role in industrial processes, removing specific impurities like CO2 from the air.

A standard air purifier utilizes various filters and filtration stages to remove contaminants. These filters can include HEPA filters, which are highly effective at capturing airborne particles, activated carbon filters for odors and gases, and pre-filters to remove larger particles. The selection of the appropriate air purifier and filter types is crucial to ensure effective removal of specific pollutants and maintain a healthy indoor environment. As awareness of air quality's impact on health grows, the demand for efficient air purification solutions continues to rise.

II. Literature

The document highlights the growing importance of air purifiers in addressing the increasing problem of indoor air pollution. It emphasizes the role of these devices in removing contaminants and creating healthier environments, particularly for vulnerable populations like allergy and asthma sufferers.



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1. The Problem of Indoor Air Pollution:

The document establishes that indoor air contains various pollutants, including dust, pollen, pet dander, mold spores, and volatile organic compounds (VOCs). It notes that these contaminants can have adverse health effects, triggering allergies, asthma, and other respiratory problems. The text also acknowledges the severity of air pollution in specific urban areas, citing New Delhi, Patna, and Gwalior as examples of highly polluted cities where air purifiers are especially beneficial. This aligns with broader research that underscores the significance of indoor air quality and its impact on human health.

2. HEPA Filtration Technology:

A central focus of the document is on High-Efficiency Particulate Air (HEPA) filters. It presents HEPA filters as a highly effective technology for removing airborne particles. The document accurately describes the HEPA filter standard, stating that true HEPA filters must remove 99.97% of particles as small as 0.03 microns. It also explains the mechanisms by which HEPA filters trap particles, including direct impaction, sieving, interception, and diffusion. This aligns with established literature on filtration science, which recognizes HEPA filters as a gold standard for particulate removal.

3. Air Purifier Components and Technologies:

The document provides an overview of various components and technologies used in air purifiers. It discusses activated carbon filters for removing odors and gases, pre-filters for extending the life of HEPA filters, and other filtration methods. While the emphasis is on HEPA filtration, the document acknowledges that different technologies can be combined to achieve comprehensive air purification. This reflects the broader industry trend of multi-stage filtration systems that address both particulate and gaseous pollutants.

4. Applications of Air Purifiers:

The text briefly touches on the diverse applications of air purifiers, ranging from residential use to commercial and industrial settings. It highlights their importance in healthcare facilities, where they help maintain sterile environments and prevent the spread of airborne infections. This aligns with the understanding that air purification plays a critical role in various sectors, contributing to health, safety, and productivity.

5. Consumer Considerations:

The document emphasizes the importance of selecting high-quality air purifiers with true HEPA filters. It cautions against "HEPA-type" filters, which may not provide the same level of effectiveness. The text also acknowledges consumer concerns about the cost of air purifiers and the need for greater awareness of their benefits.

Overall Assessment:

The document provides a useful overview of air purification, with a strong emphasis on HEPA filtration. It accurately describes the technology and its applications. However, it could benefit from incorporating more citations to support its claims and provide a broader context within the existing body of research on indoor air quality and air purification technologies.

III. Components Used

1. HEPA Filter

HEPA filter as a crucial component in an air purifier. It emphasizes its effectiveness in eliminating airborne particles, including allergens like dust, pollen, pet dander, mold spores, and dust mite feces. The document specifies that HEPA filters are designed to capture a high percentage of particulates, including bacteria, viruses, and DNA-damaging particles. A key point is the adherence to strict standards: a filter must remove 99.97% of particles as small as 0.03 microns to be classified as a true HEPA filter. This highlights the importance of HEPA filters in providing cleaner air by trapping microscopic contaminants that can trigger allergies and other health issues.

2. Activated Carbon Filters

Although the primary focus is on HEPA filters, the document does make a brief reference to activated carbon filters. It notes that air purifiers may utilize these filters to remove odors, gases, and volatile



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organic compounds (VOCs). This is an important component as HEPA filters primarily target particulate matter, while activated carbon is essential for addressing gaseous pollutants, thus providing a more comprehensive air purification solution.

3. Pre-filters

Pre-filters are generally used to capture larger particles like dust and hair, which extends the life of the more expensive and finer HEPA filter. By removing these larger particles in an initial stage, pre-filters prevent the HEPA filter from clogging prematurely and maintain the overall efficiency of the air purifier

4. Fan/Blower

the fan or blower, its function is implicitly understood. The fan is essential for circulating air through the air purifier, drawing contaminated air in and forcing it through the filters. The effectiveness of the air purifier is directly related to the fan's ability to move a sufficient volume of air, ensuring that the air in the room is processed multiple times per hour. Fan speed settings are also important for user control and noise management.

5. Housing

It's a necessary component. The housing is the structure that holds all the filters and the fan together. It is designed to direct the airflow efficiently through the filters, preventing air from bypassing them. The housing's design also impacts the air purifier's portability, stability, and aesthetic appeal. A well-designed housing minimizes air leakage and maximizes filtration effectiveness.

6. Germicidal Ultraviolet Lamp

The 245 nm ultraviolet light is able to sterilize a variety of bacteria. The germicidal lamp is used to purify the air and it is able to eliminate odour caused by smoke and mold. Ultraviolet light works independently from the other filters to neutralize micro-organisms. This is especially efficient at converting pathogens, mold spores, etc., to harmless by-products.

7. Negative Ionizer

Using electricity, air ionizers create negative ions which are then discharged into the air. These ions continuously clean your room by bonding with dust particles, bacteria, cigarette smoke, etc. This ionizer needs to be cleaned when you hear a creak sound from the filter. Using the brush tool provided, clean the dust around the ionizer.

8. Odour Sensor System

Odour sensor is able to detect concentrated odours in the air and automatically adjust the fan speed according to the air quality display: Red (Poor), Orange (ordinary), Green (Excellent)..

9. Air quality indicator and fan controller

This indicator detects the air quality and shows it to the user using a color coded system, where green is low level of pollution, yellow is medium level of pollution and red means high level of pollution. Based on the level of air quality in the room, the fan speed is automatically changed.





V. Methodology

The methodology employed for developing the air purifier prototype follows a systematic approach, integrating both hardware components and software algorithms. Below is a detailed explanation of the process:

Hardware Components:

• Sun Board (Foam Board)

Sun board or Foam board is a very strong, light, and easily cut sheet material used for the mounting of vinyl prints, as backing in framing, and for painting. It usually has three layers- an inner layer of polystyrene foam and a white clay coated paper on the outside.

• Adhesive Tapes

Adhesive tapes are a combination of a material and an adhesive film and used to bond or join objects together instead of using fasteners, screws, or welding. Applying adhesive tapes in lieu of mechanical fasteners enables you to use lower temperature applications, which can simplify the manufacturing processes.

• Super Glue

Super glue, or cyanoacrylate, is the general name for a family of fast-acting adhesives with industrial, medical and household uses. It usually comes in a small tube, and is often sold as "Super Glue

Operational Process:

1. When the power is turned on, the fan above the filters creates a suction action in the empty space below the filters.

- 2. This suction causes the surrounding air to enter the area below the filters.
- 3. The air is then sucked into the filters.
- 4. Initially, the air passes through the cold catalyst filter.
- 5. In the cold catalyst filter, harmful gases are removed from the air.

6. Examples of gases removed include formaldehyde, ammonia, ozone, benzene, etc.

VI. Future Scope

1. The Growing Problem of Air Pollution in India

* Increased vehicular population, significant construction activities, and industrial expansion are major contributors to the rise in outdoor pollution across Indian cities.

* The drive for economic growth, coupled with a population exceeding 125 billion, leads to continued environmental strain, including deforestation for infrastructure development.

* These actions have far-reaching consequences, resulting in the increasing toxicity of groundwater, crops, and the air we breathe.





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* Future generations will bear a heavy burden due to current environmental irresponsibility.

* While attention is often given to food and water intake, the critical importance of air quality is frequently overlooked.

2. Health Impacts of Air Pollution

* A rise in respiratory symptoms, particularly among children, indicates the severe damage inflicted on the respiratory system by airborne toxins.

* Increased visits to doctors and reliance on medication are further evidence of the adverse health effects of air pollution.

* Air pollution is a causative factor in various health conditions, including wheezing, sneezing, coughs, asthma, and more serious illnesses such as heart attacks and lung cancer.

3. The Necessity of Air Purifiers

* It is crucial to not only purify indoor air but also to actively prevent pollutants from entering indoor spaces and to maintain a clean and pure environment.

 $\overline{*}$ In today's context, air purifiers are becoming as essential as water purifiers for maintaining health.

* Studies, including those conducted by the British Allergy Foundation, have demonstrated that breathing air cleaned and purified by devices like Sharp air purifiers reduces the intake of toxins, leading to a decrease in medication needs and absenteeism.

4. Consumer Awareness and Market Trends

* Many air purifier brands prioritize dust and particle removal, often neglecting the broader spectrum of pollutants and the holistic health benefits consumers expect.

* A common misconception is that indoor air is safe; however, poor ventilation and limited sunlight allow various indoor activities (e.g., cooking, using cleaning products) to contribute to air toxicity.

* While air purifiers offer a solution, their adoption is gradual due to a lack of immediate, tangible results and the perceived high cost (e.g., an investment of ₹20,000 or more).

5. Future of Air Purification Technology

* Growing public awareness of air pollution's health effects is driving increased demand for air purifiers and more advanced technologies.

* Leading brands are investing in research and development to meet this demand.

* Current market offerings include air purifiers with specialized features like mosquito catchers, car purifiers, and air sterilizers, although these segments are still relatively small.

* While HEPA and carbon filters are prevalent, future demand will likely shift towards more sophisticated technologies, such as Plasmacluster Ion Technology, to address air pollution comprehensively.

* Addressing consumer confusion regarding air purifier performance indicators is essential for market growth.

* The Indian air purifier market has significant potential as awareness of the health impacts of air pollution on individuals, families, and children increases.

* Innovations in air purification systems must focus on a holistic approach, encompassing the removal of bacteria, viruses, odors, dust, pollen, and other pollutants.

VII. Conclusion

There are many different kinds of air purifier available in the market with different technologies. Some may have HEPA, carbon, ionizing, UV technology and many more. Some purifiers also contain more than one technology for advanced functioning and better results. Thus, choose the best one matching your requirement and budget. The main function of HEPA Filter is to remove contaminated viruses from the air and provide clean and pure air. Thus, HEPA Filter is a crucial purchase element for the one suffering from dust or pollen allergy. Strict standards have been set for the filters to be classified as HEPA. A HEPA Filter should be able to remove 99.97% particles being small as 0.03 microns.So buy only a quality product from reliable sources and avoid buying "HEPAType" or "HEPA-Like" filters, as these filters will not provide you the best result as compared to the true HEPA Filters. Finally,



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there are many sources from which you can order your HEPA Filter Air Purifier. Why wait for more to avail such luxury home stuff. Click here if you like to buy the best HEPA Air Purifier

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