Development of Indoor Air Filters Using Textile Substrate

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Funding or Supporting Agencies and Grants Details:

No funding was received for this research work.

ABSTRACT

Indoor air pollution poses significant health risks, and effective mitigation strategies are necessary to ensure a safe and healthy indoor environment. This research paper presents the development of an innovative indoor air filter using activated charcoal-coated fabric as a filtration medium. The study aims to explore the effectiveness of the activated charcoal-coated fabric filter in removing airborne pollutants and improving indoor air quality. The filters will be characterized for efficiency test, pressure drop, dust holding capacity, airflow capacity, and microbial efficiency. It is expected that the developed filter would be able to remove the pollutants and increase the pressure drop which may reduce the maintenance and replacement of the filter. Additionally, it will also be able to kill or remove certain microbes such as bacteria, fungi, and viruses and may contribute to the development of cost-effective and efficient indoor air filtration systems. The activated charcoal-coated fabric filter has the potential to be widely adopted in residential, commercial, and industrial settings, effectively reducing indoor air pollution and improving occupants' health and well-being.

Keywords: Activated charcoal; Air filtration; Fabric filter; Filtration efficiency; Indoor air pollution; Indoor air quality.

1. INTRODUCTION

Clean and healthy air is essential for human well-being, and its significance becomes even more pronounced in the context of indoor environments. With the majority of individuals spending a significant portion of their lives indoors, the quality of the air we breathe indoors has a direct impact on our overall health and productivity (1). Indoor air pollutants, including particulate matter, volatile organic compounds (VOCs), and various harmful gases, pose significant risks to human health, potentially leading to respiratory problems, allergies, and even more severe health conditions (2). Following are the airborne particulates that pose a threat to human beings:

- **Course particles:** These are some of the largest particles present in the air such as wind-blow dust ranging from 2.5 to 10 microns (3).
- **Fine particles:** The particles which can adversely affect human health fall under this category such as smoke and haze. They are in diameters ranging from 2.5 microns or smaller (4).

- **Ultrafine particles:** These are the smallest particles of all, having diameters smaller than 100 nm in size. If these particles enter your body then they can pass through any lung tissue right into the bloodstream. Once they reach your lungs, they can circulate throughout your body along with your blood cells and oxygen (4,5).

Air filtration is a process in which dust particles, poisonous gases, microorganisms, etc. are removed from the air by trapping them or killing (microorganisms) by means of fabrics and fibrous filters (6). To combat the adverse effects of indoor air pollution, air filtration systems have been developed and widely used. These systems aim to remove harmful pollutants and maintain a healthier indoor environment. Traditional air filters are typically composed of fibrous materials such as glass fibers or nonwoven fabrics, which rely on their physical structure to trap and capture airborne particles. While effective to some extent, these filters often have limitations in terms of their filtration efficiency, pressure drop, and the range of pollutants they can effectively capture (7,8).

In recent years, considerable research has focused on the development of innovative air filtration materials to overcome these limitations and enhance filtration performance. One such material gaining attention is activated charcoal-coated textile substrates. Activated charcoal, also known as activated carbon, is a highly porous form of carbon with a large surface area and adsorptive properties. When incorporated onto textile substrates, it offers the potential to significantly improve the efficiency of air filtration systems by adsorbing a wide range of pollutants, including volatile organic compounds, odors, and harmful gases (9).

This research paper aims to investigate the effectiveness of activated charcoal-coated textile substrates for air filtration applications. By examining the adsorption capabilities of activated charcoal in combination with textile substrates, we seek to assess their performance in capturing and removing various indoor air pollutants. The outcomes of this study are expected to contribute to the advancement of air filtration technologies, providing insights into the potential of activated charcoal-coated textile substrates as a viable alternative for improving indoor air quality. This research would be helpful for indoor applications, personal protective equipment, automotive and transportation, industrial applications, etc.

2. TYPES OF AIR FILTERS

2.1. High-Efficiency Particulate Air (HEPA)

Theoretically, HEPA filters can remove at least 99.97% of airborne allergens and pollutants with a size of 0.3 microns. HEPA filters are typically composed of polypropylene or glass fibers with diameters ranging from 0.5 to 2.0 micrometers. The interlaced fiber bundles are formed into fiber sheets and pleated together to increase the overall surface area of the filter. HEPA relies on a combination of three mechanisms to trap the particles from the air, which are 1. Direct impaction, 2. Interception, and 3. Diffusion (10). Figure 1 shows the HEPA filters, their components, and their working (11).

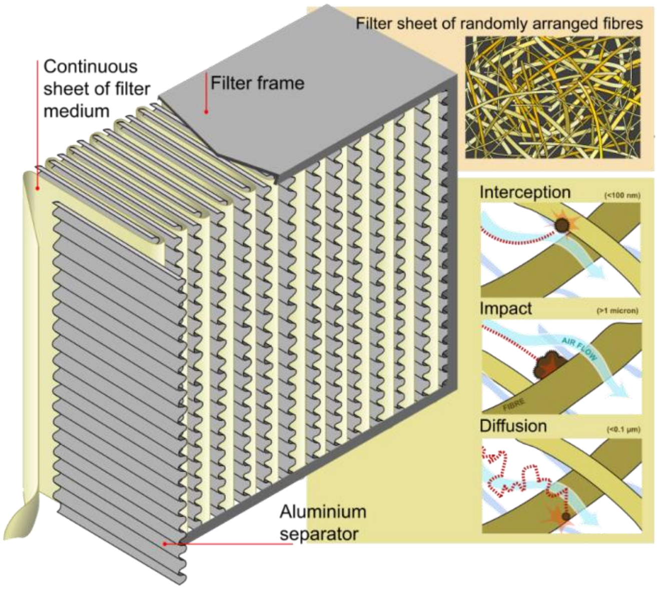

Figure 1. HEPA Air Filter and its Working

2.2. Carbon Filters or Activated Charcoal Filters

This is a method of filtering that uses a bed of activated carbon to remove impurities (Figure 2). These filters work by the adsorption principle, in which pollutants are trapped in the pores of activated charcoal (12).

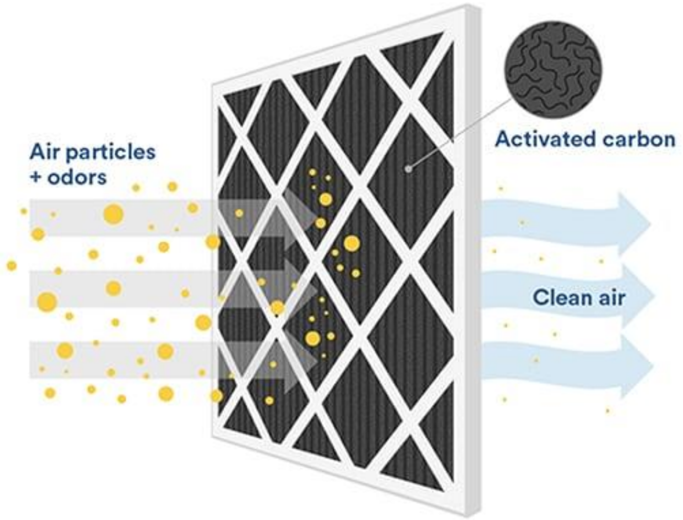

Figure 2. Activated Charcoal Filter and its Working

2.3. Ultraviolet Filters

These filters use short-wave UV light to kill bacteria and viruses. When air passes through these filters then UV lamps disinfect it with germicidal radiation. UV filters are excellent at killing microorganisms that could be hazardous to our health. One potential danger with these filters is that these filters can transform oxygen into ozone, which could be hazardous to our health. These filters are costly to install (13). Figure 3 shows the UV light filters which consist of a number of UV lamps (14).

Figure 3. UV Light Filters

2.4. Electrostatic Filters

These filters clean the air by using static electricity, which is a safe and naturally occurring phenomenon. In these filters, airborne particles are attracted and held by static charge, until they are removed by washing. These filters consist of two sections 1). Ionizing section, and 2) Collector section (7). The filters are cleaned automatically by washing with high-pressure water (15).

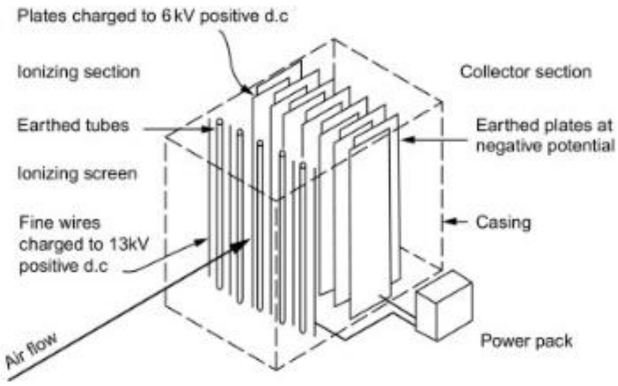

Figure 4. Working of Electrostatic Filter

2.5. Foam Air Filters

These are made of engineered porous form made from polyurethane, polyester, polyether, or a combination of these materials. They have lower efficiency due to their larger open pores and have less filter material that strangles the particles (16)(Figure 5).

Figure 5. Foam Air Filter

3. MATERIALS

Activated charcoal, textile substrate, and polymer binder are the materials that will be required for this project.

4. METHOD

Initially, the textile substrate will be coated with polymer using the knife coating method. Once, the substrate leaves the coating head assembly, an activated charcoal will be sprinkled on the coated textile substrate. Fabric with activated charcoal will be allowed to cure for the required duration. Finally, the activated charcoal-coated textile substrate will be covered with another layer of fabric and both layers will be sewn. A similar process will be followed on the other side of the fabric as well to prepare the final activated charcoal-coated textile substrate filter.

5. PROPERTIES TO BE TESTED

(1) **Efficiency test:** With this test, the filtration efficiency of the air filter can be determined. This indicates how well it eliminates particulate matter from the air. Usually, particulate size is measured in the range of 0.3 to 10 micrometers.

(2) **Pressure drop test:** The pressure drop or resistance across the air filter when air passes through it can be measured using this test. If the pressure drop is found to be higher that means the filter is more restrictive, which can impact the airflow and power consumption of the ventilation system.

(3) **Dust holding test:** This test determines the quantity of dust the filter can hold before its efficiency commences to reduce. It helps calculate the filter`s lifespan and required maintenance.

(4) **Airflow capacity test:** With this test, we can determine the maximum airflow rate that can pass through the filter without significant pressure drop or leakage. It makes sure that the filter can handle the required airflow for the required application.

(5) **Microbial efficiency test:** This test determines the filter`s ability to kill or remove bacteria, fungi, spores, or other microorganisms residing in the air.

6. EXPECTED OUTCOMES

It is expected that activated charcoal-coated textile substrate would be able to remove the pollutant air particles. Its pressure drop will increase slightly due to the use of a binder. It will be able to hold the dust for a long duration before its efficiency will start to reduce so maintenance will get reduced. It will also show good ability in capturing coarser particles. It will also be able to kill or remove certain microbes such as bacteria, fungi, and viruses.

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