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ADSORBENT FILTERS FOR REMOVING POLYCYCLIC AROMATIC HYDROCARBONS FROM THE ATMOSPHERE

Indoor activities involving cooking and warming, outdoor sources, smoking, and candle and incense burning may introduce a massive portion of polycyclic fragrant hydrocarbons. These are well known for their mutagenicity and carcinogenicity and are omnipresent in urban situations as a result of the combustion of fuel. Due to small particle size, penetration has been suspected to be one major source of indoor polycyclic aromatic hydrocarbons. In the current study, the manufacturing of three types of filters (electrostatic charge-based, pomegranate peel biochar-based, and birds' feathers-based) was carried out. Their efficiency was tested to remove molecules bounded PAHs and also other genotoxic compounds associated with these particles. The electrostatic filter was more efficient (27.42%) than pomegranate peel-based and birds' feathers-based filters (13.86% and 8.32%, respectively). The carcinogenetic effects of PAHs emitted from outdoor and indoor pollutants can be reduced using these kinds of filters.

1. INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are released into the atmosphere due to the incomplete combustion of fuels like petrochemicals and wood mostly carbon-based [1–3]. It has been shown by that a large number of people are exposed to them, and suffer from various health hazards like high oncogenic and mutagenic risk by a well-known class of ubiquitous toxicants PAHs [4, 5]. Smoke discharge from automobiles enhances PAHs impact and toxicity mainly by two factors – particle size and different modes of distribution [6, 7].

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Urban residents spend most of their lives in indoor conditions, where the air quality is usually low due to smoking and using unventilated or malfunctioning stoves, which results in the emission of PAHs into the environment. A direct stimulation was found between their emission and burning sources. Further investigations showed that the nature of the burning material plays a key role in the deposition of PAHs. Due to intense transportation activities in urban areas, the combustion rate increases which leads to an increase in carcinogenic and mutagenic threats. In the current situation, also other related hydrocarbon fragments are emitted both by indoor (cooking, frying, and warming) and outdoor activities (open air sources smoking (BBQ) and continuous burning). Both of these have been assumed one of the major sources of PAHs fragments.

Outcomes of various studies in developing countries showed that PAHs level in urban areas is quite high compared to rural areas [8]. Pakistan is a developing country; therefore, monitoring PAHs emissions should be a priority. Lahore is a very old and one of the mega cities of Pakistan with high-traffic pollution and industrial activities. Economical as well as domestic activities are mainly run by petroleum products (gas and oil). Therefore, their extensive consumption leads to a high prevalence of PAHs in the environment. In cost comparison, liquefied petroleum gas (LPG) is preferred to other petroleum products in automobiles. PAHs level was monitored [9] at different sites in Lahore city, having a higher concentration as compared to some cities of a neighboring country (India).

A comparative study was conducted between three filters having different adsorption materials. Their efficiency correlates with their capability to adsorb polycyclic aromatic hydrocarbons from an inner-city aerosol. Samplings of both processed and unprocessed air were done simultaneously. All samples were analyzed for polycyclic aromatic hydrocarbons after processing by extraction medium. The results showed that all air filter materials had the capability of removing polycyclic aromatic hydrocarbons and their retaining efficiency was correlated with the adsorption capacity of the tested air filter materials.

The main objective of this work was to assess a valuable testing and measuring method to assess how fuel and working combustion factors influence the outflow and the distribution of PAHs within testing materials amid inadequate combustion.

2. MATERIALS AND METHODS

Chemicals. Methanol, acetonitrile (HPLC grade), acetone, and *n*-hexane (analytical grade) from Merck were used. HPLC-grade water was obtained in a Milli-Q system (Quality Operations Laboratory, University of Veterinary and Animal Sciences, Lahore). PAHs analytical standards (phenanthrene, biphenyl, biphenanthrene, naphthalene, anthracene and *p*-anisidine) were supplied by Sigma Aldrich.

Preparation of air filters. Adsorption materials used in this experiment are commercially available. Three different types of filters were prepared. One of them was an electrostatic charge-based filter. Materials used in the preparation of this filter are as follows: Aralik sheet, FBT transformers for high voltage, power mosfet C 5200, wire gauze, aluminum heat sink, resistor 1K, resistor 10K, power supply 5A/12V. All the components of the electrostatic charge-based filter were assembled in the workshop of QOL, UVAS, Lahore. The model is shown in Fig. 1. It can be applicable to generators, chimneys, and also to some extent to house exhaust machines.

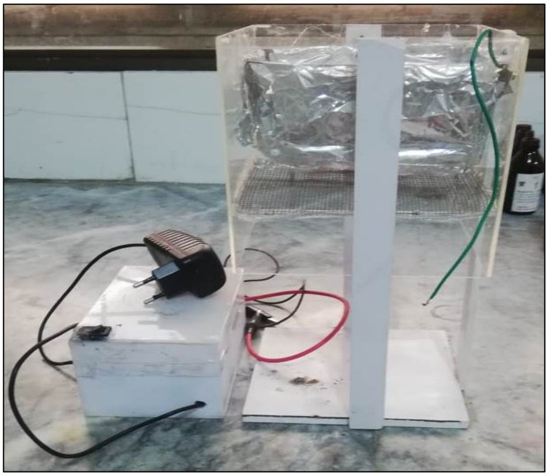

Fig. 1. Model of electrostatic charge-based filter

Birds' feathers-based and pomegranate peel biochar-based filters used for the adsorption of smoke were prepared with the use of sawdust, as the primary adsorbent. It may reduce the heat intensity of upward-moving smoke when it comes in contact with the second adsorbent material (birds' feathers or pomegranate peel biochar).

Fig. 2. Adsorbent filters

Fig. 3. Materials used for the preparation of birds' feathers-based filters: a) steel sieve with fine mesh, b) sawdust used as an initial adsorbent, c) a fine nylon net to hold the second adsorbent, d) birds' feathers, and e) pomegranate peel used as a second adsorbent

The sawdust was placed on a very fine poured steel sieve used as supportive material. Finally, the components were enclosed in cotton cloth to pack them properly. Materials used for the preparation of these filters are shown in Figs. 2 and 3.

Collecting samples by using adsorbent filters. The working efficiency of the filters was checked by collecting smoke residues on cotton plugs placed directly or indirectly in the path of smoke generated from different sources (industrial exhaust, vehicle exhaust, bricks kiln, incinerator) at different intervals of time (15, 30, and 60 mins). After that, the cotton plugs were soaked with an extraction medium.

Extraction of PAHs. The cotton plugs were placed in 250 cm^3 measuring beakers and 50 cm^3 of *n*-hexane–acetone (1:1) mixture was added as an extraction solvent. The mixture was shaken for 1 h on a shaking water bath and allowed to settle for 2 min. This process was repeated twice and the collected solvent in a beaker was dried by the cooling effect of the nitrogen stream. Residues were dissolved in a 1 cm^3 mobile phase after filtration through a 0.22 µm polyamide filter and 0.075 cm^3 was injected into the HPLC system.

Chromatographic conditions. The instrumental analysis was done on the Shimdazu 20A (HPLC) system using the C18 column (250 × 4.6 mm) with a pore size of 5 µm. Stock and working solutions of phenanthrene, biphenyl, biphenanthrene, naphthalene, and anthracene were prepared by dissolving them in acetonitrile and stored in a refrigerator at 4 °C until analysis. Quantification of PAHs was carried out by running two solvents (50% acetonitrile in water and 100 % acetonitrile) at a flow rate of 1.0 cm^3/min at 247 nm in the following ratio 75:25.

Statistical analysis. The percentage removal of individual PAHs was checked with the Tukey pairwise test using Minitab 17.0 software.

3. RESULTS AND DISCUSSION

The removal efficiencies of individual PAHs from different filters are shown in Fig. 4. A significant difference having $p = 0.000$ between these testing objects was found. A significant difference was found between the mean removal efficiency for the test object (electrostatic charge-based filter) at a 95% confidence level as compared to the other two materials.No significant difference was observed for the other two testing objects.

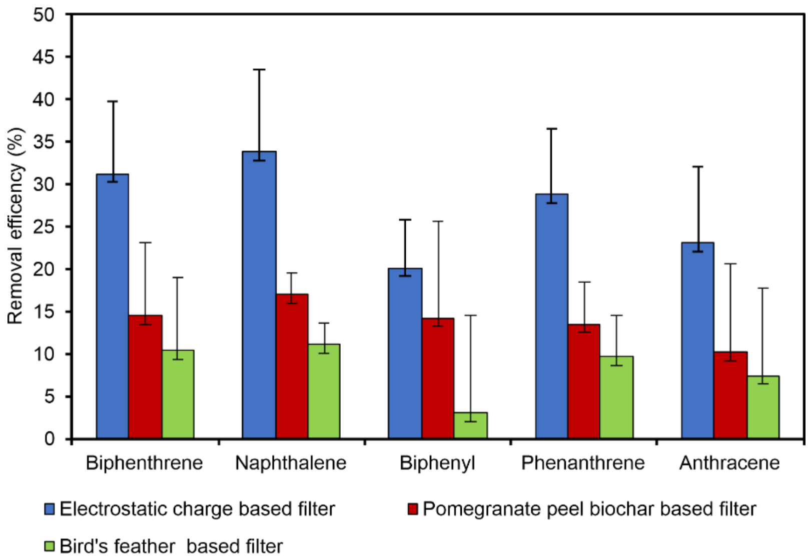

Fig. 4. Removal efficiency of various PAHs for various adsorbent filters:
electrostatic charge-based filter, pomegranate peel biochar-based filter, bird's feathers-based filter

Table 1 shows the removal efficiencies of PAHs examined using different adsorbent filters and the average of all the PAHs for various filters is shown in Fig. 5.

Table 1

PAHs removal efficiency using different filters [%]

PAH	Filter		
	Electrostatic charge-based	Pomegranate peel biochar-based	Birds' feathers-based
Biphenanthrene	31.2	14.44	10.34
Naphthalene	33.78	16.97	11.12
Biphenyl	20.15	14.2	3.03
Phenanthrene	28.85	13.49	9.66
Anthracene	23.11	10.22	7.44
Average PAHs	27.42	13.86	8.32

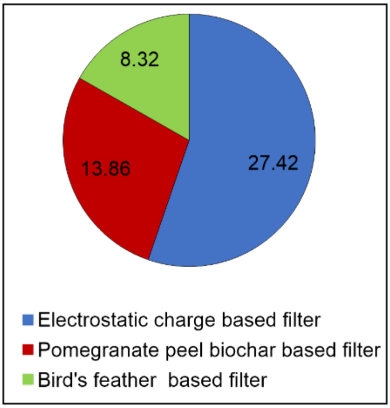

Fig. 5. Overall PAHs removal efficiency for various filters

Adsorption technology is extensively applied to remove organic compounds from industrial waste byproducts. Common adsorbents include aluminum oxides, silica gel, activated carbon, and zeolites. Granular activated carbon (GAC) is the most effective adsorbent however it has a number of disadvantages, including sluggish adsorption kinetics, poor selectivity, the necessity for cost containment systems, and a working capacity of less than 100% [10].

Activated carbon fibers (ACFs), which have a variety of benefits over GACs, including quicker adsorption and desorption kinetics, substantially greater surface areas, a homogeneous micropore structure, and a smaller pressure drop have been created to solve some of these shortcomings [11–17]. Other researchers have looked into a number of aspects that impact the efficacy of GACs in removing organic molecules. Pore size distribution, specific surface area, and surface functional groups of GACs, as well as molecular size, molecular weight, and vapor pressure of organic molecules, are among these variables. The results of discussed filtration on PAH composition and mutagenicity of the indoor particles in a real-life setting is troublesome to anticipate from the information given in this study [18–26].

By applying the designated form of mechanical ventilation framework along with the collection of possible dangerous particles, simultaneously removing PAHs and other mutagenic compounds related to these particles was accomplished to some extent. The indoor environment can be controlled in terms of PAHs concentration and their related genotoxic particles present in the air by application of a filtration process, as compared to open air. Bringing down the indoor molecule concentration would result in a brought down indoor PAH concertation and also for a few molecules bound PAH isomers.

In the present study, the emission was controlled by instantly made filters, which were economically cheap and easily made. After the application and analysis, the PAHs removal efficiency amounted to 27.42% as compared to the other two filter types which enabled the PAHs removal as 13.86% (pomegranate peel biochar-based filter) and 8.32% (birds' feathers-based filter). Moreover, the performance of filters can be made better by improving their pore size.

Noh et al. [27] concluded from their study that PAHs control correlates with particle size, like comparing to MERV11 filter which was required for a lodging unit with a measure of 150–300 m^3 to adequately decrease indoor molecule concentrations. By applying an electrostatic charge-based filter, the emission of PAHs was controlled to a better extent than that of the other two studied filters, as it masks the smoke by trapping the charge particles due to the electric field produced. Moreover, this technique is rather expensive as it involves the usage of electricity.

The masking ability of the other two filters was useful but not as much as in the case of electrostatic charge-based filters. The prolonged exposure of the pomegranate peel biochar-based filter to smoke makes the filter choke. The pomegranate peel biochar-based filter is cheaper than the electrostatic charge-based filter but the efficiency of the latter was better. This source of information makes the possibility of precisely foreseeing the conceivable and well-being advantage from filter application on regular base testing to minimize evacuation of PAHs and related genotoxic particles.

4. CONCLUSION

A significant difference in the PAH removal efficiency was observed between the electrostatic charge-based filter and the other tested filter materials. By applying such filters, there is a low possibility of carcinogenetic effects from outdoor and indoor pollutants. The efficiency of the air filter is an important factor; therefore the material with less capability did not significantly reduce direct-acting mutagens downstream of the air filter, which is indicative that the filter lacks the capability of removing certain mutagenic chemical compounds in this present study.

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