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Nonwoven Nylon-6 Functional Filters for Protection from Air Pollutants

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THE present work aims to assess the effectiveness of Nylon-6 nonwoven fabrics containing antimicrobial substance (AS) and grafted with poly methacrylic acid (PMAA), polydimethylaminoethylmerthacrylate (PDMAEMA) and the blended fabric containing the above mentioned two types of nonwoven fabrics for air and gas filtration. The efficiency of the textile filters on the removal of anions and cations pollutants from the atmosphere of the selected indoor sites were studied under the normal conditions in the indoor environment. Air samples were collected before and after fitting the three tested types of textile nonwoven filters. The absorption method was used for collecting the gaseous pollutants, SO_2, NO_2 and NH_3, before and after filtration. The removal efficiency % of each filter was calculated. Nonwoven fabric containing 1:1wt/wt from two types of nonwoven fabrics showed high removal efficiency when applied for the collection of suspended anion and cation particulates.

Keywords: Nylon-6 Nonwoven Fabrics, Antimicrobial, Grafting, PMAA, PDMAEMA, Ion Exchanger, Air Filtration.

Introduction

Clean air is considered a basic requirement for human health. Pure air cannot be seen or smell and consists mainly of nitrogen (N_2), 78.09%; oxygen (O_2), 20.94%; argon (Ar), 0.1% and carbon dioxide (CO_2), 0.0318%.

There are two types of air pollutants in the atmosphere: (a) Primary air pollutants which are emitted directly from the source, such as sulfur and nitrogen oxides, ammonia, volatile organic compounds and polycyclic aromatic hydrocarbons; and (b) secondary air pollutants, which are formed by chemical or physical transformation in the atmosphere such as ozone, oxidants, sulphate, nitrate, chloride and phosphate.

Primary Air Pollutants may be solid or liquids and their particle sizes are varied from greater than 500 μm to less than 0.01 μm [1]. Particulates larger than 50 μm settle out of the air quite easily under the influence of gravity, are reported as dust fall, and cause two major problems, deposition and adhesion. Deposition refers to dirt on clothing and homes. Dust fall (fallout) samples are generally indication of particulate concentration. Sample of very small area is considered to be representative of a large segment of the geographical community [2]. Particles less than 5 μm tend to form stable suspension and particulate matter smaller than 0.1μm will not settle.

Published data on air quality in various public utility premises point to increase pollution level in atmosphere [3]. This has been directed special attention of scientists to the improvement of the quality of air and solve problems if the concentrations of polluting agents exceed the highest admissible values.

People spend more than 90% of their times indoors in tightly sealed, poorly ventilated work places, commercial and public buildings. Diseases can be transmitted via many routes, including inhalation of aerosols and bioaerosols [4]. Inhalation of bio-aerosols (microorganisms suspended in the air) is a primary mechanism of respiratory infections. Allergic rhinitis, asthma,

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irriative symptoms and infectious diseases increased among residents and workers exposed to airborne microorganisms and allergens [5].

In the last decade, nonwoven fabrics have made great developments in air and gas filtration technique, which is the simplest and most common method for particle control and air cleaning [6,7]. Development of nonwoven fabrics specific for chemical, biological, and radiological agents have received particular interest. It is estimated that by the year 2020 air filters market will surpass 19 billion dollars [8].

Different nonwoven filters for removing particulate contamination from air were designed. Mechanical and electrical filters have been used for removing some radioactive agents and most of the biological agents. Nowadays, mechanical filter is used expensively in heating, ventilation and air-conditioning systems to remove contaminant agents from the air [9]. The backing support for such filter media contains blends of synthetic fiber and glass microfiber and composite media using cellulose or synthetic fiber nonwovens [10-12].

Some biological agents of higher level pathogens like viruses and bacteria cannot be removed by air filtration only. But, such pollutants can be inactivated or killed by using biocide chemicals incorporated into the fibrous filter. These bioactive agents may be applied on the filter surface in the form of finish [13], coating [14], incorporated inside the fiber [15], in the form of grafted chains [16] or finally during melt extrusion process [17].

Atmospheric chemical agents are presented mainly in the form of toxic gases. Previous studies, have reported different methods for removing such gases [18-23]. The most important among these methods are:

1- By using fibrous filter alone or incorporated with adsorbent or sorbent materials [18].
2- By catalitic conversion of volatile compound into less hazardous one on the fiber surface [19].
3- By using for filtration modified with structuring agents fibers during wet or dry spinning [7, 20, 21].
4- By using fibers impregnated with smaller, more active sorbent particles [22].
5- Finally, by using coated porous fibers [23].

Recently, simple technology for pilot scale production of Nylon-6 nonwoven fabrics grafted with polymethacrylic acid (PMAA) [24] or polydimethylaminoe thylmethacrylate (PDMAEMA) [24] was suggested. This technology consists of the creation of antimicrobial substance (AS) in Nylon-6 fibers followed by grafting with methacrylic acid (MAA) [25] or with dimethylaminoethylmethacrylate (DMAEMA) [26] using Cu^{2+}-$K_2S_2O_8$ redox system. The assessment of the produced above nonwoven fabrics as ion-exchangers in wastewater treatment was carried out [27].

The present study aimed to assess Nylon-6 nonwoven fabrics grafted with either PMAA or PDMAEMA as fibrous functional materials in air and gas filtration.

Experimental Work

Materials

Nylon-6 used in this study was in the form of nonwoven fabrics containing antimicrobial substance (AS) and grafted either with polylmethacrylic acid (PMAA) or with polydimethylaminoethayl-methacrylate (PDMAEMA)

Methacrylic acid (MAA), Dimethylaminoe thylmethacrylate (DMAEMA), Potassium Persulphate ($K_2S_2O_8$), and Copper Sulphate ($CuSO_4$ .H_2O) were all of pure grade chemicals Antimicrobial substance (As) under the trade name "Katamine" was in the form of 50% aqueous solution (Russia).

Methods

Fixations of (AS) on Nylon-6 Fibers

The treatment of Nylon-6 fibers with (AS) was carried out using the method described by Shalaby [25].

Grafting of Nylon-6 fibers with MAA and DMAEMA

Nylon-6 Fibers containing AS were grafted with either MAA or DMAEMA using the method described by Shalaby [25,26].

Analysis

The efficiency of the textile filters in removal of anions and cations pollutants from the atmosphere of the selected indoor sites were studied under the normal conditions in the indoor environment. During performing the experiments, the temperature and relative humidity were ranged between 25-30°C and 40-30% respectively. Air samples were collected before and after fitting the three tested types of textile non-woven filters. The experimental room was operated at a manufacturer recommended low flow rate of 1 liter/min for 24 hours.

The absorption method was used for collecting the gaseous pollutants namely, SO_2, NO_2 and NH_3, before and after fitted filter holder of the tested nonwoven fabric. The sampling equipment consisted of gas bubblers through which the gas sample was drawn, calibrated vacuum pump with flow rate set at 1 L/min and dry gas-meter are connected. The absorbance was measured by means of a UV/Visible spectrophotometer (Novaspec - LKB model 4049 - Biochrom, Cambridge, England). The concentration of gaseous pollutants (μg/m^3) was calculated from standard curve and the volume of air sampled. Modified West and Gaeke method [28], Jacobs and hochhiest method [29] and colorimetric Nessler's method [30] were used for the determination of SO_2, NO_2 and NH_3 respectively.

The absorption of cations and anions in ait was carried out according to the method described by Stern [31].

The removal efficiency is defined as the ratio of concentrations of air pollutants collected by the nonwoven fabrics to its concentrations before filtration, as follows:

$$\text{Removal Efficiency (\%)} = \frac{\text{Concentration of pollutant collected by nonwoven fabric}}{\text{Concentration of pollutant fed}} \times 100$$

Results and Discussion

The grafted nonwoven Nylon-6 fabrics with different vinyl monomers, mainly (Nylon-6→T(AS)→gr PMAA (I), (Nylon-6→T(AS)→gr PDMAEMA (II), Nonwoven fabric containing 1:1wt/wt from each of I and II, were applied for the collection of suspended anion and cation particulates using the filtration method.

The effect of the chemical composition of the used nonwoven Nylon-6 fabrics on the removing efficiency of anion particulates (Cl^-, NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-}) and cation (Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}) from ambient air was investigated. The obtained results are listed in (Tables 1-6).

Based on these results, one can conclude the following:

1- In general, the used Nylon-6 nonwoven fabrics grafted either with PMAA or PDMAEMA are characterized with high efficiencies in removing both anions and cations particulates from ambient air, irrespective of the nature of ions. The ability of polyamide fabrics to remove the said pollutants depends on the nature of the investigated ions.

2- The maximum removing efficiency of anion particulates was observed when Nylon-6 nonwoven fabric grafted with PDMAEMA (Table 3) was used for air filtration. This may be due to the presence of antimicrobial substrate with N^+ can form ionic bond with anions. The same holds true in case of using Nylon-6 nonwoven fabric grafted with PMAA. But in this case the first player in collecting anions is the antimicrobial substrate only (Table 1).

3- The application of Nylon-6 nonwoven fabric produced from a (50/50 Wt %) mixture of Nylon-6 fibers grafted with PMAA and Nylon-6 fibers grafted with PDMAEMA leads to outstanding removal (92% - 96%) of anion particulates from ambient air, irrespective of the collected anion (Table 5).

4- Nylon-6 nonwoven fabrics grafted either with PMAA or with PDMAEMA can remove cations from ambient air (Tables 2 and 4). But, it is worth mentioning that, the removing efficiency is higher in case of applying nonwoven fabric grafted with PMAA (Table 2) than that grafted with PDMAEMA (Table 4). This may be due to the electrostatic attraction between the carboxylate anion (COO^-) and the cations under investigation.

The collecting of cations by tertiary amine group in case of applying nonwoven fabric containing antimicrobial substrate and PDMAEMA is mainly due to the formation of complexes on the surface of the filter.

Gaseous Pollutants

Sulphur dioxde, nitrogen dioxide and ammonia are the major gaseous pollutants in industrial and urban areas.

SO_2 is a highly soluble irritating gas that is absorbed quickly and almost entirely in the nose and upper airway of healthy subjects during quiet breathing [32] existing respiratory and cardiovascular disease [33]. It is oxidized photochemically or catalytically to H_2SO_4. Sulphates have adverse health [34]. Epidemiological studies have indicated that sulphates may be more toxic than SO_2. Sulphates are also known to be the major contributors to reduction in visible range. Also they are chiefly responsible for the acidic forms that are deposited on soil by wet and dry processes [35].

The oxides of nitrogen include seven known gaseous compounds, however only nitric oxide (NO) and nitrogen dioxide (NO_2) are emitted in significant quantities to the atmosphere. The major source of (NO) and (NO_2) is combustion of fuels in industry and transportation. Nitrogen oxides, when released into the atmosphere , nitric oxide is oxidized to form the more toxic pollutant nitrogen dioxide. Nitrogen dioxide acts as a precursor to the formation of photochemical smog and as a trigger for a number of secondary pollutants [36]. Nitrogen oxides in the atmosphere leads ultimately to formation of nitrate. NO_3 also assists the corrosion of metals and the deterioration of textiles, and can damage vegetation.

Ammonia presents in the environment as a result of natural processes and industrial activity. Auto exhausts are also a source of ammonia in the urban atmosphere. As one of the few alkaline atmospheric trace gases, ammonia reacts with acidic pollutants, such as sulphur and nitrogen oxides, to from particulate ammonium salts. Ammonia is base and thus increase the pH of rainwater [37].

In the present study, the gas (SO_2,NO_2,NH_3) adsorption efficiency of fabricated nonwoven Nylon-6 fabrics grafted either with PMAA or PDMAEMA was investigated. The obtained results (Tables 7-9) showed the following:

1- In general, the adsorption efficiency of the modified nonwoven fabrics is higher than that of unmodified fabric for filtration. At the same time, the adsorption efficiency of the modified fabrics various among the different types of filters.

2- The obtained data revealed that, the values of adsorption efficiency in all cases, are the same when using the same modified filter, irrespective of the types of adsorbed gas.

3- The adsorption efficiency attained 50%when nonwoven Nylon-6 fabric grafted with PMAA was used. The application of such filter for removal of acid gases (SO_2 and NO_2) is based on the reaction between the salts of weak acids and strong acids which formed when gases dissolve in the water contained in the filter used [38] (Table 7).

4- In case of using nonwoven Nylon – 6 fibers grafted with PDMAEMA the adsorption efficiency increased and attained 60% (Table 8). Such filter containing tertiary amino groups in the grafted macromolecule have high dynamic activity with respect to acid gases.

5- The maximum value of the adsorption efficiency (75%) was obtained when a blended Nylon -6

TABLE 1. Efficient (%) of Nylon-6 Nonwoven Fabric Grafted With PMAA (Nylon -6 →T (AS) → gr PMAA) in Removing Anionic Particulates

No.	Type of Nonwoven Filter Used	Concentration of Anionic Particulate in Ambient Air (µg/m³)				
		Chloride	Nitrite	Nitrate	Phosphate	Sulfate
1	<u>Nylon-6 Nonwoven Fabric (Blank)</u> (a) Before Filtration	26.8	39.9	81.3	3.15	23.4
	(b) After Filtration	25.0	37.0	79.0	3.0	22.0
	Reduction in Anion Particulate Concentration (%)	6.7	7.3	2.8	4.8	6.0
2	<u>Nylon - 6 →T(AS) → gr PMAA</u> (a) Before Filtration	26.8	39.9	81.3	3.15	23.4
	(b) After Filtration	4.2	7.7	9.5	0.21	7.9
	Reduction in Anion Particulate Concentration (%)	84.3	80.7	88.3	93.3	66.2

TABLE 2. Efficient (%) of Nylon-6 Nonwoven Fabric Grafted With PMAA (Nylon -6→T (AS) → gr PMAA) in Removing Cationic Particulates from Ambient Air.

No.	Type of Nonwoven Filter Used	Concentration of Cationic Particulate in Ambient Air (μ g/m³)				
		Na^{+}	NH_4^{+}	K^{+}	Mg^{2+}	Ca^{2+}
1	Nylon-6 Nonwoven Fabric (Blank) (a) Before Filtration	37.6	169.6	30.5	36.5	131
	(b) After Filtration	36.0	155.0	29.0	35.0	125
	Reduction (%) in Cation Particulate Concentration (%)	4.3	8.6	4.9	4.1	4.6
2	Nylon-6→T(AS) → gr PMAA (a) Before Filtration	37.4	169.6	30.5	36.5	131
	(b) After Filtration	6.8	27.7	12.1	15.8	48.7
	Reduction in Cation Particulate Concentration (%)	81.8	83.7	60.3	56.7	62.8

TABLE 3. Efficient (%) of Nylon-6 Nonwoven Fabric Grafted With PDMAEMA (Nylon -6 → T (AS) →gr PDMAEMA) in Removing Anionic Particulates from Ambient Air.

No.	Type of Nonwoven Filter Used	Concentration of Anionic Particulate in Ambient Air (μ g/m³)				
		Chloride	Nitrite	Nitrate	Phosphate	Sulfate
1	Nylon-6 Nonwoven Fabric (Blank) (a) Before Filtration	26.8	39.9	81.3	3.15	23.4
	(b) After Filtration	25.0	37.0	79.0	3.0	22.0
	Reduction in Anion Particulate Concentration (%)	6.7	7.3	2.8	4.8	6.0
2	Nylon-6 →T(AS) → gr PDMAEMA (a) Before Filtration	29.9	2.60	91.1	3.2	68.4
	(b) After Filtration	3.6	0.40	27.5	0.7	7.6
	Reduction in Anion Particulate Concentration (%)	88.0	84.6	69.8	78.1	88.9

TABLE 4. Efficient (%) of Nylon-6 Nonwoven Fabric Grafted with PDMAEMA (Nylon -6 →T (AS) → gr PDMAEMA) in Removing cationic Particulates from Ambient Air .

No.	Type of Nonwoven Filter used	Concentration of Cationic Particulate in Ambient Air (μ g/ m3)				
		Na^{+}	NH_4^{+}	K^{+}	Mg^{2+}	Ca^{2+}
1	Nylon-6 Nonwoven Fabric (Blank) (a) Before Filtration	37.6	169.6	30.50	36.5	131
	(b) After Filtration	36.0	155.0	29.0	35.0	125
	Reduction in Cation Particulate Concentration (%)	4.3	86	4.9	4.1	4.6
2	Nylon - 6 → T(AS) → gr PDMAEMA (a) Before Filtration	32.0	170.0	30.5	20.1	128.0
	(b) After Filtration	7.6	35.5	11.1	5.9	33.5
	Reduction in Cation Particulate Concentration (%)	76.3	75.1	63.5	70.6	73.8

TABLE 5. Efficient (%) of Blended Nylon-6 Nonwoven Fabric Produced from Nylon-6→T(AS) →gr PMAA and Nylon-6→T(AS) → gr PDMAEMA Fibers (1:1 w/w) In Removing Anionic Particulates from Ambient Air.

Type of Nonwoven Filter Used	Type of Removing	Concentration of Anionic Particulate in Ambient Air (µ g/m^3)				
		Chloride	Nitrite	Nitrate	Phosphate	Sulfate
Blended Nylon – 6 Nonwoven Fabric Produced from Nylon-6→ T(AS)→ gr-PMAA (40%) + Nylon-6 →T(AS)→gr PDMAEMA (18%) (1:1 Wt/Wt)	Before Filtration	12.4	10.3	7.8	1.4	17.3
	After Filtration	0.5	0.8	0.6	0.06	0.06
	Reduction in Particulate Concentration (%)	95.7	92.2	92.3	95.7	96.5

TABLE 6. Efficient (%) of Blended Nylon-6 Nonwoven Fabric Produced from Nylon-6→T(AS) →gr PMAA and Nylon-6 → (AS) → gr PDMAEMA Fibers (1:1 wt/wt) In Removing Cationic Particulates from Ambient Air.

Type of Nonwoven Filter Used	Type of Removing	Concentration of Cationic Particulate in Ambient Air (µ g/m^3)				
		Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}
Blended Nylon – 6 Nonwoven Fabric Produced from Nylon-6→T(AS)→ gr-PMAA (40%)+Nylon-6 →T(AS)→gr PDMAEMA (18%) (1:1 wt/wt)	Before Filtration	6.1	16.5	8.4	2.3	20.6
	After Filtration	1.2	1.8	1.9	0.4	3.9
	Reduction in Particulate Concentration (%)	80.3	89.1	77.4	82.6	81.1

TABLE 7. Efficient (%) of Nylon-6 Nonwoven Fabric Grafted with PMAA (Nylon-6→T(AS) →gr PMAA) In absorbing SO_2, NO_2 and NH_3.

No.	Type of Nonwoven Filter Used	Concentration of Gases in Ambient Air (µ g/ m^3)		
		SO_2	NO_2	NH_3
1	Nylon-6 Nonwoven Fabric (Blank): (a) Before Filtration	30.0	60.0	45.0
	(b) After Filtration	28.0	55.0	43.0
	Reduction in Gas Concentration (%)	6.7	8.3	4.4
2	Nylon-6→T(AS)→gr PMAA (40%) (a) Before Filtration	30.0	60	45.0
	(b) After Filtration	15.0	30.0	23.0
	Reduction in Gas Concentration (%)	50.0	50.0	48.9

TABLE 8. Efficient (%) of Nylon-6 Nonwoven Fabric Grafted with PDMAEMA (Nylon-6→T(AS) →gr PDMAEMA) in absorbing SO_2, NO_2 and NH_3 From Ambient Air.

No.	Type of Nonwoven Filter used	Concentration of Gases in Ambient Air (μ g/ m^3)		
		SO_2	NO_2	NH_3
1	Nylon-6 Nonwoven Fabric (Blank): (a) Before Filtration	30.0	60.0	45.0
	(b) After Filtration	28.0	55.0	43.0
	Reduction in Gas Concentration	6.7	8.3	4.4
2	Nylon-6 →T(AS)→gr DMAEMA (18%) (a) Before Filtration	30.0	60.0	50.0
	(b) After Filtration	12.0	26.0	24.0
	Reduction in Gas Concentration (%)	60.0	56.7	52.0

TABLE 9. Efficient (%) of Blended Nylon-6 Nonwoven Fabric Produced from (Nylon-6→T(AS) →gr PMAA) And (Nylon-6→T(AS) →gr PDMAEMA) (1:1 wt/wt) in absorbing SO_2, NO_2 and NH_3 From Ambient Air.

No.	Type of Nonwoven Filter used	Concentration of Gases in Ambient Air (μ g/ m^3)		
		SO_2	NO_2	NH_3
1	Nylon-6 Nonwoven Fabric (Blank): (a) Before Filtration	30.0	60.0	45.0
	(b) After Filtration	28.0	55.0	43.0
	Reduction in Gas Concentration (%)	6.7	8.3	4.4
2	Blended Nylon – 6 Nonwoven Fabric Produced from Nylon-6→T(AS)→ gr-PMAA (40%) +Nylon-6 →T(AS)→gr PDMAEMA (18%) (a) Before Filtration	32.0	65.0	48.0
	(b) After Filtration	8.0	16.0	12.0
	Reduction in Gas Concentration (%)	75.0	75.4	75.0

nonwoven fabric produced from (50% Wt %) of Nylon-6→T(AS) → gr-PMAA (50 Wt %) and Nylon-6→T(AS)→gr- PDMAEMA (50 Wt %) was used as adsorption filter (Table 9).

Conclusion

The effect of the chemical composition of the used nonwoven Nylon -6 fabrics on the removing efficiency of anion (Cl^-, NO_2^-, NO_3^-, PO_4^{3-} and SO_4^{2-}) and cation (Na^+, NH_4^+, K^+, Mg^{2+} and Ca^{2+}) particulates from ambient air was investigated. In general, the used Nylon-6 nonwoven fabrics grafted either with PMAA or PDMAEMA are characterized with high efficiencies in removing both anions and cations particulates from ambient air, irrespective of the nature of ions. The values of removing depend on the type of collected ions.

The maximum removing efficiency of anion particulates was observed when Nylon-6 nonwoven fabric grafted with PDMAEMA was used for air filtration. The application of Nylon-6 nonwoven fabric produced from a (50/50 wt%) mixture of Nylon-6 fibers grafted with PMAA and Nylon-6 fibers grafted with PDMAEMA leads to outstanding removal (92 % -96%) of anion

Particulates from ambient air, irrespective of the collected anion.

Nylon-6 nonwoven fabrics grafted either with PMAA or with PDMAEMA can remove cations from ambient air. But, it is worth mentioning that, the removing efficiency is higher in case of applying nonwoven fabric grafted with PMAA than that grafted with PDMAEMA. The collections of investigated cations from ambient air with higher percentages (77.4%-89.1%) were obtained when blended Nylon-6 nonwoven filter containing both grafted PMAA and PDMAEMA was used for cleaning air.

The gas (SO_2, NO_2, NH_3) adsorption efficiency of fabricated nonwoven Nylon-6 fabrics grafted either with PMAA or PDMAEMA was investigated.

It was found that this property is higher in case of modified nonwoven fabrics than that obtained after using unmodified one fabric for filtration. At the same time, it was found that this increase is different for different types of the used filter. The values of adsorption efficiency are the same when using the same modified filter, irrespective of the types of adsorbed gas.

The maximum value of the adsorption efficiency (75%) was obtained when a blended Nylon -6 nonwoven fabric produced from (50 % Wt %) of Nylon- 6→T(AS) →gr PMAA and (50 Wt %) of Nylon-6→ T(AS) gr-PDMAEMA was used as adsorption filter.

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فلاتر وظيفية من أقمشة نايلون-6 غير منسوجة لحماية الهواء من الملوثات

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يهدف هذا البحث الى تقييم فاعلية أقمشة النايلون-٦ غير المنسوجة المحتوية على مادة مقاومة لتأثير الميكروبات والمطعمة بكل من بولى حمض الميثاكريليك وبولى ثنائى ميثيل أمينو ايثيل ميثاكريلات وكذلك الاقمشة المخلوطة المحتوية على النوعين سالفى الذكر من الاقمشة غير المنسوجة فى الاستخدام كفلاتر لكل من الهواء والغازات. هذا وقد تم دراسة قدرة هذه الفلاتر النسجية على ازالة الملوثات الكاتيونية والانيونية من المساحات الداخلية المختارة وذلك عند الظروف العادية. ولتحقيق ذلك تم اخذ عينات الهواء قبل وبعد امرارها خلال عينات الاقمشة غير المنسوجة سالفة الذكر. وقد استخدمت طريقة الامتصاص فى تجميع الملوثات الغازية وبالتحديد ثانى اكسيد الكبريت، ثانى اكسيد النيتروجين والنشادر وذلك قبل وبعد عملية الفلترة. وأعقب ذلك حساب النسبة المئوية لفاعلية الازالة لكل من الفلاتر الثلاث. هذا وقد اظهرت النتائج التى تم الحصول عليها ان الفلتر المكون من مخلوطى الاقمشة غير المنسوجة المطعمة بكل من بولى حمض الميثاكريليك وبولى ثنائى ميثيل امينو ايثيل ميثاكريلات بنسبة ١:١ بالوزن تتسم بقدرة عالية عند استخدامها فى تجميع الجسيمات الكاتيونية والانيونية.