



Preparation of Single Layer Nonwoven Fabric Treated With Chitosan Nanoparticles and Its Utilization in Gas Filtration

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Abstract: The rapid industrialization has resulted in increasing pollution levels and leads to serious health problems and environmental hazards. Textile filters are widely used in filtration purposes to eliminate pollution negative impacts on air quality and to improve hygiene at work places. In this context, gas filtration behaviour of four types of spunlaced nonwoven fabrics produced from polyester fibers, viscose fibers and their blends were investigated. The nonwoven samples were treated with Chitosan Nanoparticles (CSNP's) to enhance filtration properties. The characteristics of nonwoven samples such as thickness, mass per unit area, air permeability, and bursting strength have been studied to evaluate their performance. In addition to, FTIR analysis and surface morphology using TEM and SEM. The filtration efficiency of the nonwovens towards harmful gases like (CO, CO₂, and SO₂) was determined. The results demonstrated that, treating nonwoven samples with Chitosan NP's had increased their filtration efficiency through adsorbing the harmful gases. Also, the 100% polyester filter sample is more appropriate for gases filtration applications and achieved its best functional performance gathering the physical and mechanical properties when it is treated with 1.5% CSNP's.

Key words: Air pollution, Gas filtration efficiency, Spunlaced nonwoven, Chitosan, Air permeability, Bursting strength.

1. Introduction:

Air pollution is a considerable huge environmental issue that has a direct harmful impact on human beings and nature. According to the WHO, about two million people die prematurely from polluted air effects annually. Air pollution is found due to dispersing of solid particulates in air such as dust, smoke and fumes, which differ in quality and particle size that are mostly below one micron. Human inhales dust particles varying in size (0.25-1) microns and nearly 55% are retained creating health hazards. Generally, air pollution caused due to emissions of motor vehicle, power stations, town waste incinerators, besides dusts from agricultural and horticultural activities. Increasing air pollution levels causes global warming and damage to the ozone layer. Stationary sources of pollution such as steel mills, smelters, cement plants, refineries...etc, which release contaminants like particulates, aerosols, vapors, or gases can be controlled using a diverse air pollution control devices ^{1,2,3,4}. Air filtration contributes in improving air quality and hygiene at work, which increases over time due to new regulations, increasing in scientific knowledge and health awareness. Filtration is a method of separating dispersed particles by means of passing through a porous, fibrous filter media to improve the purity of filtered material ,and it is divided into; Dry filtration for air, gas, particles and Wet filtration for liquids ^{1,5,7}.

In a mass of polluted air, the concentration of gaseous and solid contaminants, their physical and chemical characteristics, and risk of contamination are important parameters to evaluate air quality at work places^(1,5). Any gas could cause pollution if it reaches an adequate concentration to do harm. Generally about ten different gases caused most concern such as; Carbon monoxide (CO) which is a highly dangerous toxic gas, produced from partial oxidation of carbon-containing compounds and from natural sources like volcanoes, forest fires, and other forms of combustion. It is a colorless, odorless, and tasteless gas, spatially variable and short lived, shares in the formation of ozone^{2,8,9}. Nitrogen oxides (NO₂) and (NO) are produced due to indirect result of combustion, when nitrogen and oxygen react together. Nitrogen oxides pollution comes from vehicle engines and power plants, and plays an essential role in the formation of acid rain, ozone, smog and global warming. Carbon dioxide (CO₂) gas is essential in our daily life, it is exhaled by humans and plants need it during photosynthesis for growth. It is a greenhouse gas released by vehicle engines, shares in global warming and climate change. Sulphur dioxide (SO₂) gas produced when sulphur burns with oxygen in air. Coal, petroleum, and other fuels are often impure and contain sulphur as well as organic (carbon-based) compounds. Sulphur dioxide causes smog, acid rain, and health problems like lung diseases^{1,2,10}.

Various kinds of filter media were developed to reduce the concentrations of noxious dust or gases in the environment such as fabric filters^{1,3,6}. Their basic advantages are; high collection efficiency of particles, various pore sizes and fiber configuration, simple in construction and operation, reasonable filter life, consumes low power and allows easy disposal of collected material and cost competitive. Fabric filters may be from woven, nonwoven or knitted structures, but woven and nonwovens are more appropriate for filtration because of their entanglement structures and thickness^{1,3,5,11}. Nonwoven fabrics are usually constructed using discrete fibers from (1/4 -3) inches long, then the fibers can be wet laid, air-laid, entangled or bonded by mechanical, chemical or heat fusing into a web^{1,3,7}. In nonwoven filters, the fibers are loosely packed into a substantial volume, presenting a fairly long path for air to pass through the filter to remove particulates streams flowing through it. About 70% of total filter media used in air filtration are from nonwovens. It is commonly used in air conditioning applications and other applications where dust loading or particles concentration is small. Nonwoven filters have advantages over woven filters such as high permeability, high filtration efficiency, no yarn slippage, low costs of production, versatility, and diverse functionality^{1,5,7,12}.

The principle of web formation and mode of bonding have an influence on the consistency, thickness, permeability and strength of the nonwovens. Choosing the proper fiber material is essential for tailoring the filter since it deals with the thermal, physical, chemical and biological conditions. Textile filters were based on natural fibers like wool, cotton, cellulose and they were almost substituted by manmade fibers such as polyester, polyamide and polypropylene fibers that are used for general filtration applications, but for high temperature or corrosive environments high performance organic and inorganic fibers like glass fibers, polyimide, etc are used^{5,7,11,13}. Nonwoven fabrics used in filtration applications include spunlacing also known as hydroentanglement. Spunlaced nonwovens have specific properties such as drapability, conformability, softness and relatively high strength which make it unique among all nonwovens. In the production process of spunlaced nonwoven, high-speed water jets are used to rearrange fibers within the web, rebounding against the substrates and dissipating energy to the fibers, cause entanglement and thereby provide web and eventually fabric integrity^{6,7,14}.

To evaluate the filtration performance of air filter, fabrics characteristics and their influence on filtration efficiency should be examined^{1,7}. Porosity and air permeability are vital properties for filtration, where as the porosity increases, air permeability increases too. The relationship between air permeability and nonwovens structural characteristics such as weight, thickness, density and fiber diameter had been investigated in pervious studies. Fabric weight is significant for air permeability, more than the thickness followed by fabric density. Hence, these properties are relevant to filtration of gases and liquids^{7,14}. Bursting strength is also important for filters in industrial applications, as it indicates the resistance behaviour of the fabric during exposure to pressure load, and it is affected by the nature of the fibers, their arrangement and entanglement in the web¹⁵. Air contains micro-organisms in the form of bacteria, viruses and fungi that comprise additional hazards to human health. Air filters can protect against these hazards by imparting antibacterial properties to fabrics¹³.

Chitosan, is a (1, 4) linked glucosamine and N-acetyl glucosamine copolymer, derived from chitin, second abundance natural polysaccharide, figure 1. It is biocompatible, biodegradable, nontoxic and has antimicrobial properties. It can inhibits the growth of a wide variety of fungi, yeasts, and bacteria, due to the

presence of the cationized amino group ($-\text{NH}_3^+$) which binds with negatively charged bacterial surface and causes disrupting in the cell surface and altering its permeability leading to the leakage of intracellular substances and consequently inhibiting further proliferation. Thus, it can be beneficial for the use in air filtration applications. Chitosan nanoparticles show higher antibacterial activity than chitosan itself based on the special character of the nanoparticles^{14,16,17}.

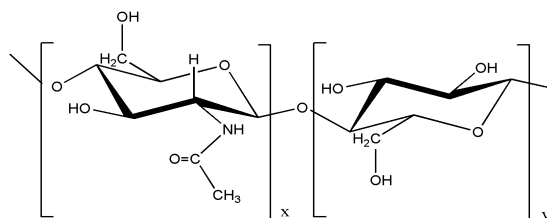


Figure 1. Chitosan molecular structure.

The aim of this work is preparation and characterization of chitosan nanoparticles for modification of spunlaced nonwovens produced using viscose and polyester fibers with different blending ratio to be utilized in gas filtration applications. The nonwovens used were treated with chitosan nanoparticles at different concentration levels to enhance their filtration properties. The physical and mechanical properties of the nonwoven samples have been examined. FTIR analysis and surface morphology using SEM and TEM were studied. Filtration efficiency of the nonwovens towards harmful gases like (CO , CO_2 and SO_2) was determined before and after chemical treatment to evaluate the nonwoven filters functional performance.

2. Experimental:

2.1. Materials:

2.1.1. Nonwovens:

In this work, four types of spunlaced nonwoven fabrics produced from Viscose fibers (VIS) and Polyester fibers (PET) with different blending ratios, and with average fiber diameter $13\ \mu\text{m}$ were used. The specifications of the nonwoven samples are presented in Table 1.

Table 1. Nonwoven samples specifications.

Sample no	Materials	Thickness (mm)	Weight (g/m^2)	Density (g/cm^3)
1	100% Viscose	0.249	33.12	0.133
2	(70% Polyester, 30% Viscose)	0.252	38	0.151
3	(70% Viscose, 30% Polyester)	0.348	48.5	0.139
4	100% Polyester	0.254	52.2	0.206

2.1.2. Chemicals:

Chitosan (Alfa Aesar Company, Medium molecular weight, viscosity 1860 cps, degree of deacetylation 79.0%), Penta sodium tri poly phosphate (TPP), Sodium hydroxide (Modern Lab chemicals, Egypt), Methyl alcohol, Ethyl alcohol and Acetic acid (Sisco Research Laboratories, India) and all other chemicals used are analytical grade and were used without further purification.

2.2. Methods:

2.2.1. Preparation of Chitosan Nanoparticles:

Chitosan nanoparticles (CSNP's) were prepared according to ionotropic gelation with slightly modification as mentioned elsewhere¹⁷.

2.2.2. Finishing of Nonwoven Fabrics with Chitosan Nanoparticles:

Chitosan nanoparticles were applied on nonwoven fabrics using pad-dry-cure method. The fabric was cut to the size of 30×30 cm and immersed in the solution containing CSNP's (1, 1.5 and 2%) and acrylic binder (1%) for 30 min., and then it was passed through a padding mangle. A 100% wet pick-up was maintained for all of the treatments. After padding, the fabric was dried at 80°C for 5 min., followed by fixation for 3 min. at 140°C. Then it was washed and dried to be ready in further characterization.

2.2.3. Characterization of Chitosan Nanoparticles:

The prepared samples were performed by a JASCO FT-IR-6100 Fourier transform infrared spectrophotometer using the KBr pellet disk method for transmittance measurements. Shape and size of Chitosan Nanoparticles was investigated using JEOL. TEM-Specimens for TEM measurements were prepared by placing a drop of colloidal solution on 400 mesh copper grid coated by an amorphous carbon film and evaporating the solvent in air at room temperature. The average diameter of Chitosan Nanoparticles was determined from diameter of 100 nanoparticle found in several arbitrarily chosen are in enlarged microphotographs.

2.3. Characterization of Nonwoven Fabrics:

The nonwoven samples were tested according to the international standards test methods as follows: Thickness of fabrics test (ASTM-D1777), Mass per unit area (weight) of fabrics test (ASTM-D3776), Air permeability test (ASTM-D737), Fabric bursting strength test (ASTM-D3786). The tests were carried out on the fabric samples before and after applying the chemical treatments to evaluate their performance. The tests were performed in the Textile research division at National Research Center. SEM of the treated fabrics was studied using a scanning electron probe micro analyzer (type JXA 840A)–Japan. Surface morphologies were imaged at different magnifications, using 30kV accelerating voltage. The test was carried out at the Central unit for analysis and scientific services at National Research Center.

2.4. Determination of Nonwoven Fabrics Gas Filtration Efficiency:

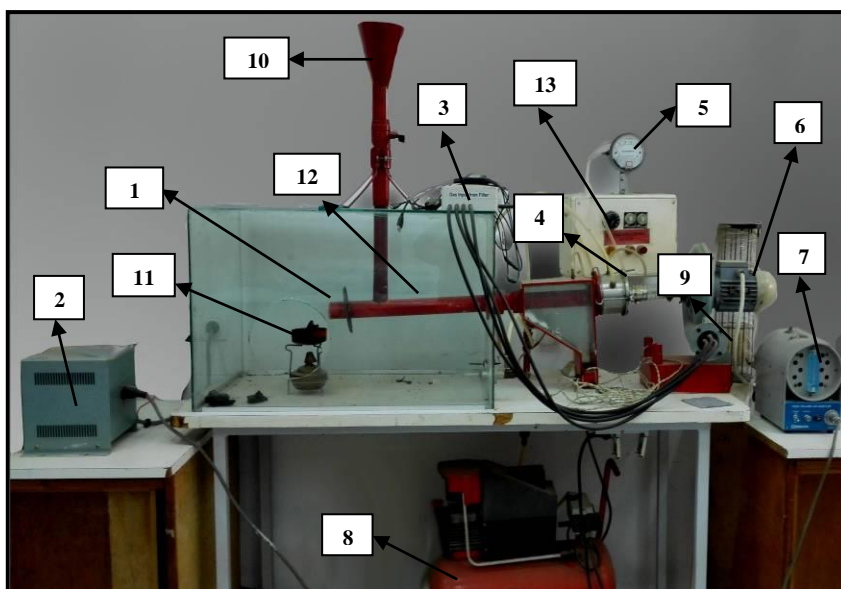


Figure 2. Filtration efficiency testing device.

1- Gas inlet.	2- Converter
3- Gas ducting sensors.	4- Filter sample holder.
5- Differential pressure gauge.	6- Vacuum pump (low speed).
7- Vacuum pump (high speed).	8- Air compressor.
9- Gas outlet.	10- Dust feed inlet
11- Gases source.	12- Flexible joint.
13- Δp controller (differential pressure gauge).	

Gas filtration efficiency of the nonwoven samples was examined using an air filtration apparatus, so as to ensure the durability and effectiveness of the proposed filters to avoid failure during work. The device is supplemented with gas detecting sensors used to detect harmful gases such as carbon monoxide (CO), carbon dioxide (CO₂) and sulphur dioxide (SO₂) in the part per million (PPM) range. The sensors adsorb the gases and convert the concentrations of gases into an electrical signal by changing resistivity. Two types of sensors used which are: Alphasense Digital Transmitter Toxic Gas Sensor to measure concentration of (CO and SO₂) gases and NDIR Transmitter Gas Sensor to measure concentration of (CO₂) gas. The air sampler unit is provided with a pressure gauge to adjust the flow rate of air through the tested fabric. In this study, air flow rate value 15 l/min was used. Figure 1 show the device and its components.

2.4.1. Test Method:

The sample is placed in contact with a vacuum chamber fed with different concentrations of gases emitted from coal combustion source to produce polluted air and were fed to the apparatus by the tube line at a controlled flow rate. Air is sucked by a vacuum pump by the principle of convening; a suspension of each contaminated gas was allowed to pass through the nonwoven filter fabric. To detect the presence of gases in the air, each type of sensors was used separately for measuring the concentration of each gas. The number of gas particles (PPM) passed through the filter is monitored and presented, which assist in examining the filtration efficiency of the filter fabrics and can be determined by using the following formula:

$$\text{Filtration efficiency (E\%)} = \frac{N_1 - N_2}{N_1} \times 100$$

Where, N₁ is the number of inlet gas particles before filtration and N₂ is the number of outlet gas particles after filtration.

3. Results and Discussion:

The work aimed at investigating gas filtration behaviour of four types of spunlaced nonwoven samples treated with Chitosan NP's at different concentrations. The influence of materials characteristics and chemical treatment of nonwovens on their physical and mechanical properties, in addition to their filtration efficiency was studied and evaluated as follows:

3.1. Preparation and Characterization of Chitosan Nanoparticles:

Chitosan Nanoparticles (CSPNs) prepared according to ionic gelation method from electrostatic force between penta sodium tri polyphosphate (TPP) negative charges and Chitosan positive charges at room temperature^{17,18,19}. The chitosan nanoparticles size is affected by concentration of chitosan, TPP, medium pH and time of ultra-sonication. Our previous study optimized the reaction at 0.2 g/ml chitosan solution concentration, 0.1 g/ml TPP concentration, pH 5.5 for 45 min ultra-sonication time¹⁷.

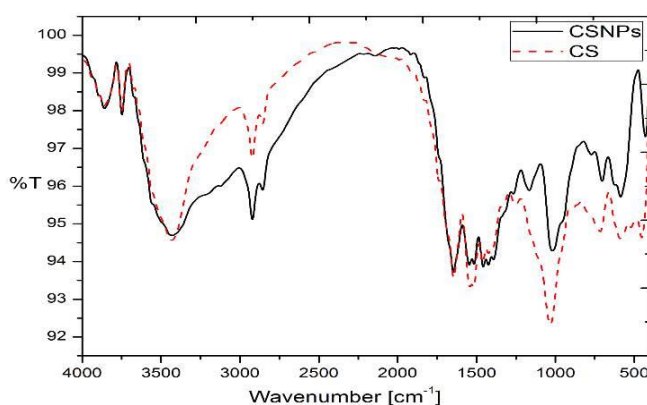


Figure 3. FTIR of Chitosan Nanoparticles (CSNP's) and Chitosan (CS).

FTIR spectroscopy is an important tool used to determine the functional groups in a molecule. As expected, Chitosan and Chitosan nanoparticles shows identical peak absorption as shown in figure 3. The NH₂ and OH group stretching vibration band appears at 3434 cm⁻¹ in CS and shifted to 3399 cm⁻¹ in CSNP's and become wider due to enhancement of hydrogen bonding. Also shoulder peak at 1644 cm⁻¹ in CS disappears

with appearing new one at 1630 cm^{-1} in CSNP's and NH_2 bending vibration peak shifted from 1602 cm^{-1} in CS to 1534 cm^{-1} (20). So that, FTIR assume that TPP tri poly phosphoric groups bind with CS ammonium group to form CSNP's.

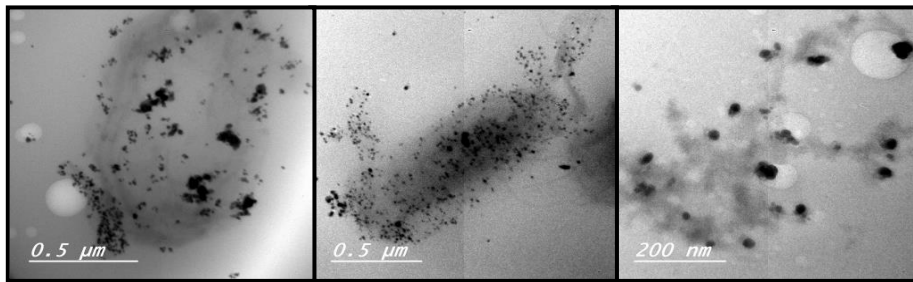


Figure 4 . TEM micrographs of CSNP's at optimum conditions.

Figure 4 shows the images of CSNP's by TEM, which proved that, these nanoparticles have spherical shapes, uniform scattered and their diameter ranged from 15-25 nm. In addition, aggregation of the particles associated with an increasing of TPP and CS concentrations.

3.2. Characterization of Nonwoven Fabrics Treated with Chitosan Nanoparticles:

3.2.1. FTIR Spectroscopy:

The chemical modification of viscose, polyester fabrics and their blend were illustrated by using FTIR spectroscopy as shown in figure 5. The treated samples compared with untreated samples showed the characteristic absorption bands of NH_2 for chitosan nanoparticles similar to that for figure 3, which indicated that the reaction between fabrics and chitosan nanoparticles occurred.

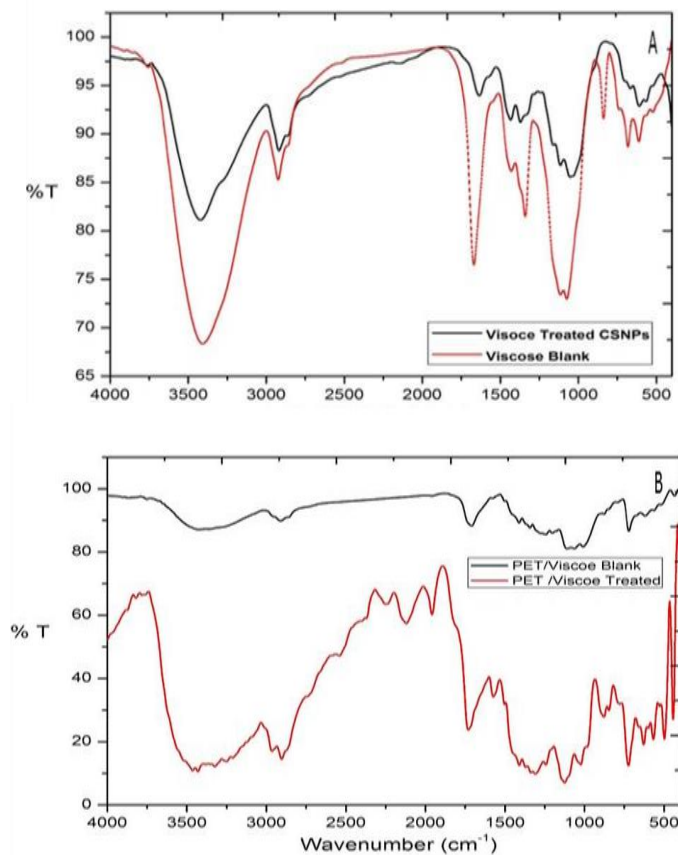


Figure 5 . FTIR spectra of; a) untreated viscose and (70% PET/30% VIS) samples and b) their treated samples with CSNP's.

3.2.2. Morphology Study:

The morphology structure of untreated sample shows smooth surface with normal structure, figure 6a. Although there was deposition of CSNP's on the treated samples surface and some NP's uniform distributed within the fibers, see figure 6(b-e). Figure 6c and 6e shows few irregular CSNP's shapes and it was agglomerated and attached to the fibers during padding process.

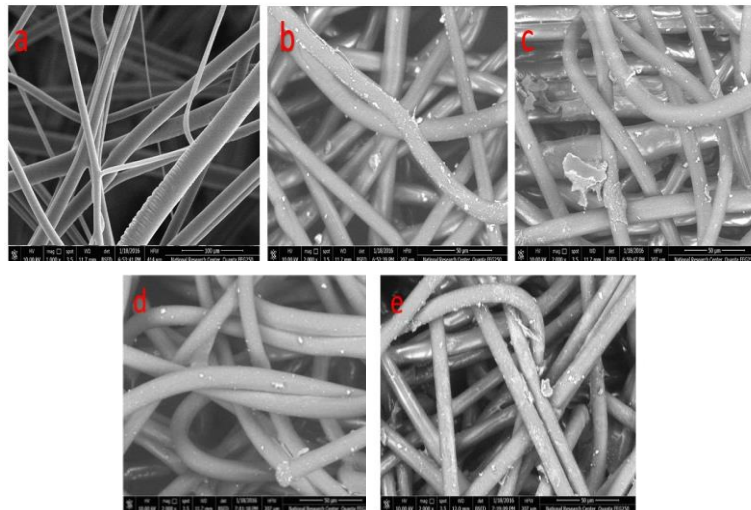


Figure 6. SEM of untreated sample (a) and treated samples (b-e).

3.3. Fabric Thickness:

Figure 7 shows the results of the thickness test performed on the nonwoven samples before and after treatment with Chitosan NP's. It was found that, the blended sample (70% VIS, 30% PET) had the highest thickness before treatment followed by the 100% polyester sample, while the 100% viscose sample recorded the lowest thickness. This can be related to the cross mesh structure of the sample which gives it bulky shape compared with the other samples. Also it was found that, after treatment, the nonwovens thickness increased with increasing chitosan concentrations from (1-2 %) due to forming of a thin film of chitosan coating the fabric surface. The highest thickness was reported for the blended sample (70% VIS, 30% PET) treated with 2% CSNP's, and the lowest thickness was reported for (70% polyester, 30% viscose) sample treated with 1%.

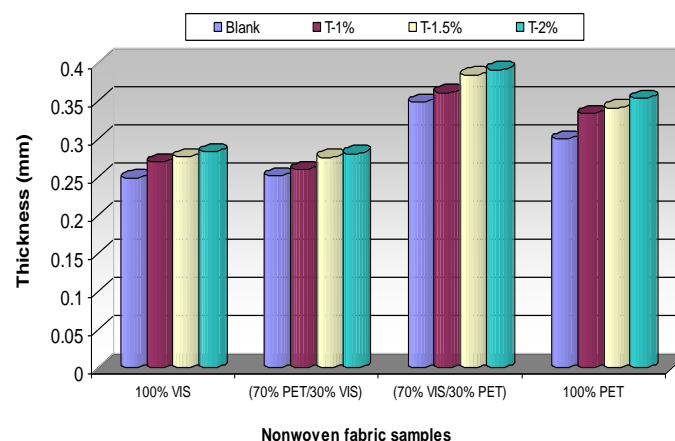


Figure 7. Thickness values of untreated and treated nonwoven samples.

3.4. Fabric Mass per Unit Area:

Figure 8 shows the results of the mass per unit area (weight) test performed on the nonwoven samples before and after treatment with chitosan. It was found that before treatment, the 100% polyester sample had the

highest weight followed by the blended sample (70% VIS, 30% PET), while the 100% viscose sample recorded the lowest weight. This can be explained due to the arrangement of the fibers in the structure which allows more fiber entrapment and the compact structure of the polyester fibers in the fabric structure. Also after treatment, the weight of nonwoven samples increased with increasing chitosan concentration due to coating of chitosan NP's the fibers and forming a thin film on the fabric surface. It was found that, the highest weight was reported for the 100% polyester sample treated with 2% CSNP's and the lowest weight was reported for 100% viscose sample treated with 1%.

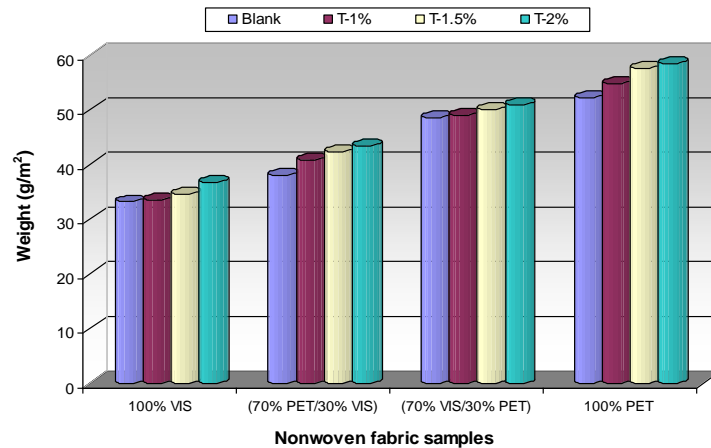


Figure 8. Weight values of untreated and treated nonwoven samples.

3.5. Fabric Air Permeability:

Figure 9 shows the results of the air permeability test performed on the nonwoven samples before and after treatment with chitosan. It was found that, the 100% viscose sample had the highest air permeability values before treatment. This can be demonstrated due to the arrangement of the fibers in the fabric structure and its low density which increased the porosity. After treatment, there is a significant improvement in air permeability of the 100% viscose sample and in the blended sample (70% VIS, 30% PET) compared with the other samples, which showed reduction in air permeability values with increasing chitosan concentration. This may be explained due to high porosity of the 100% viscose sample that allows air to pass through them and increasing the percentage of viscose fibers in the composition of the fabrics. On the other hand, the lowest air permeability value was reported for the 100% polyester sample treated with 2% CSNP's. This may be related to the high density of polyester sample, its compact structure with the high number of fibers bonded and entanglement in the fabric cross-section, which leads to limiting the air flow through the fabric. Moreover the treatment with chitosan NP's that coated the fabric surface leads to decreasing its porosity.

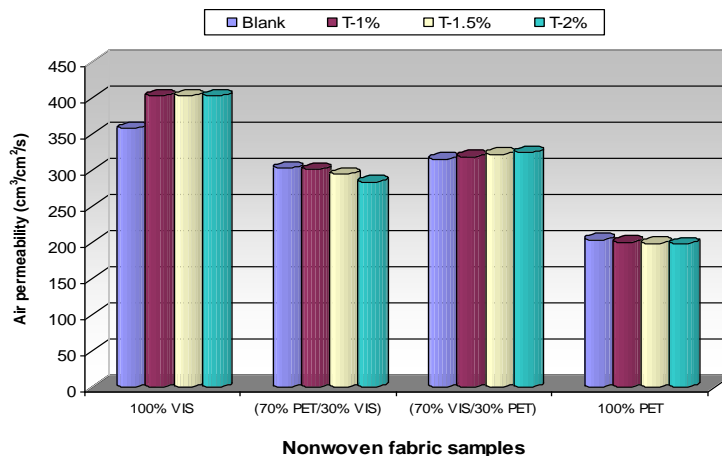


Figure 9. Air permeability values of untreated and treated nonwoven samples.

3.6. Fabric Bursting Strength:

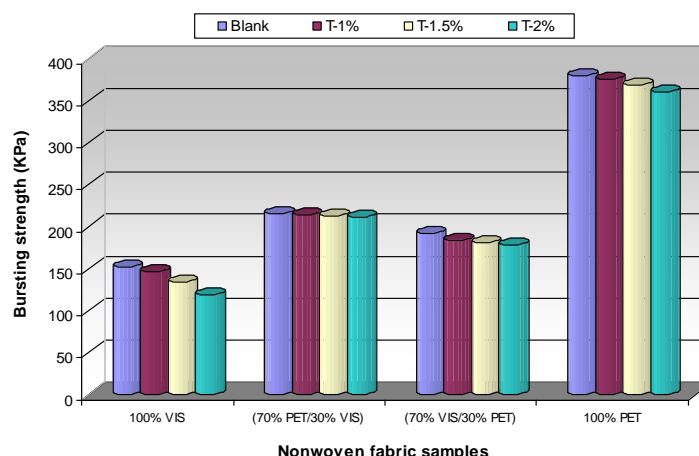


Figure 10. Bursting strength values of untreated and treated nonwoven samples.

Figure 10 shows the results of the bursting strength test performed on the nonwoven samples before and after treatment with chitosan. Bursting strength of filter fabrics indicates their strength and durability. It was found that before treatment, the 100% polyester sample had the highest bursting strength values and the 100% viscose sample had the lowest bursting strength. This can be demonstrated, due to the high density and compact structure of the polyester fabric, in which the presence of high numbers of fibers in the fabric structure increases the frictional resistance and leads to its high strength. After treatment, it was found that the nonwoven samples bursting strength decreased with increasing chitosan concentration. This reduction may be attributed to the formation of intermolecular cross-links formed by chitosan, which affect on the distribution of bursting load among all fibers and decreases their resistance to applied load. The highest bursting strength was found for 100% polyester sample treated with 1% CSNP's and the lowest bursting strength value was reported for the 100% viscose sample treated with 2% .

3.7. Filtration Efficiency Test:

Experiments were performed to measure the concentration of gases (PPM) passing in the airflow without and with using nonwoven samples to determine the filtration efficiency. The influence of physical properties of the nonwovens on their filtration performance was studied. Figures from (11-14) shows the concentrations of carbon monoxide gas, figures (15-18) shows the concentrations of carbon dioxide gas and figures (19-22) shows the concentrations of sulphur dioxide gas passed through the untreated (blank) and treated nonwoven filters, respectively. It was indicated that, the concentration of the three gases was decreased after using nonwoven filters. For CO and SO₂ gases, the highest filtration efficiency was found with the blended sample (70% VIS,30% PET) with efficiency (33%) and (44%), respectively. Also for CO₂ gas, the highest filtration efficiency (19%) was found with the blended sample (70% PET, 30% VIS). After treatment, it was found that, the filtration efficiency exhibited improvement for all samples and varied with varying the concentration of chitosan for all gases. This can be explained due to treatment of the nonwoven samples with chitosan NP's that coated the fabric surface leading to decreasing its porosity. Further, chitosan NP's increases the surface area of fabric that helps in adsorbing the gases from the airflow passing through the filters, owing to the cationic properties of chitosan which offers creation of electrostatic interactions with other compounds and also it is a good barrier to gases.

It was illustrated from figures (11-14) that, treating the nonwoven samples with 1% chitosan leads to increasing CO filtration efficiency for all samples and the highest efficiency was reported for 100% polyester and it recorded (93%). This may be related to increasing weight of fabric after treatment and the compactness of the fabric which decreased its permeability. While increasing the chitosan concentration up to 2% leads to improvement in filtration efficiency of the 100% viscose sample that reached (74.2%).Also, it caused reduction in the filtration efficiency of the blended samples (70% PET, 30% VIS), (70% VIS,30% PET) and 100% polyester sample from (83-81.7%), (76.7-69.3%) and (72.7-70%), respectively. From figures (15-18) it was found that, treating the nonwoven samples up to 1.5% chitosan leads to increasing CO₂ filtration efficiency for all samples and the highest filtration efficiency was found with the blended sample (70% VIS, 30% PET) and it

reported efficiency (38%). Although increasing the chitosan concentration to 2% leads to reduction in the filtration efficiency of all samples. Also, it was indicated from figures (19-22) that, increasing chitosan concentration from (1-2%) leads to increasing SO₂ filtration efficiency for all samples. The highest filtration efficiency was found with the 100% polyester sample and it reported (93%). While it caused reduction in the filtration efficiency of the 100% viscose sample and the blended samples (70% PET, 30% VIS) and (70% VIS,30% PET) from (71.7-66%), (73.3-65.3%) and (58-54.7%), respectively.

- Carbon monoxide (CO) gas:

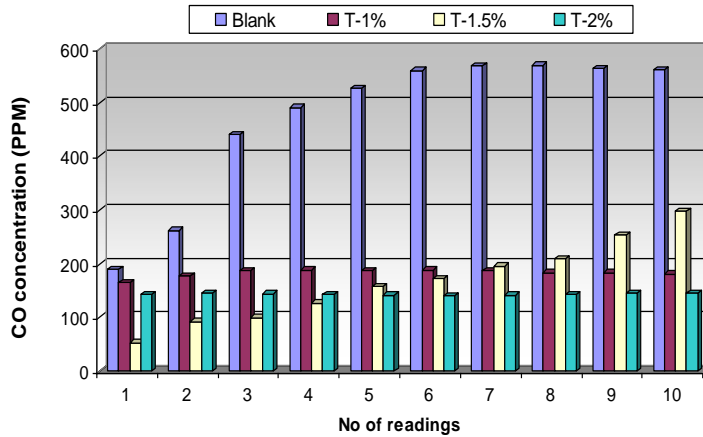


Figure 11. CO concentrations at using untreated and treated 100% viscose filter samples.

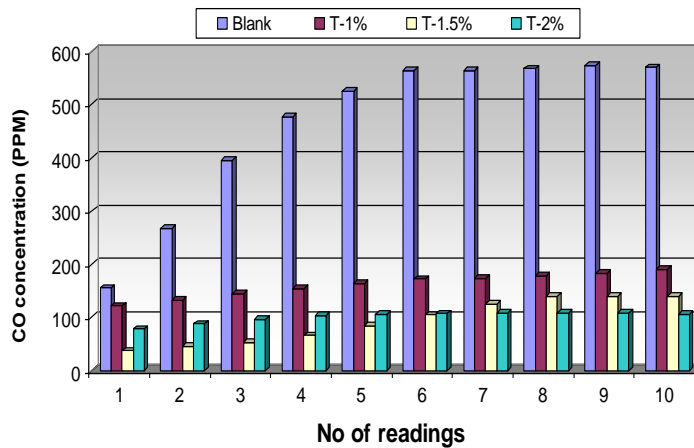


Figure 12. CO concentrations at using untreated and treated (70% PET,30% VIS) filter samples.

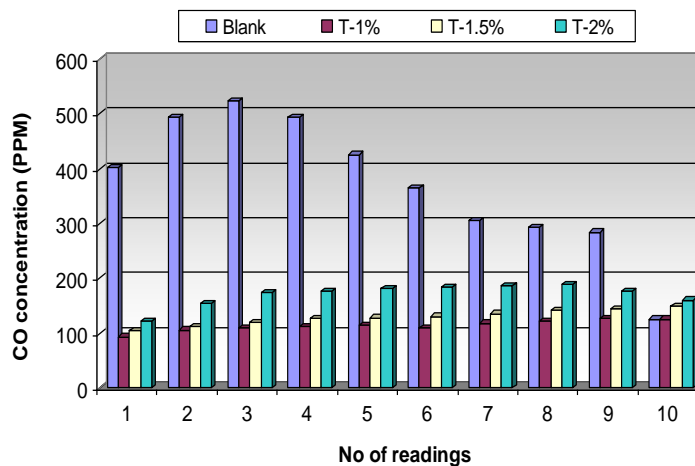


Figure 13. CO concentrations at using untreated and treated (70% VIS,30% PET) filter samples.

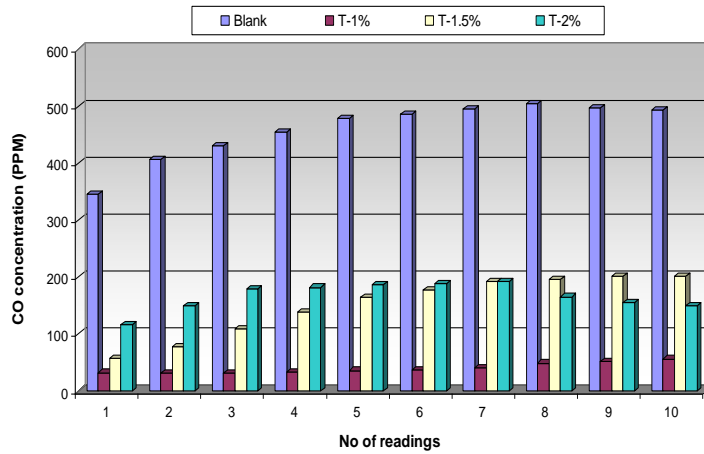


Figure 14. CO concentrations at using untreated and treated 100% polyester filter samples.

- Carbon dioxide (CO₂) gas:

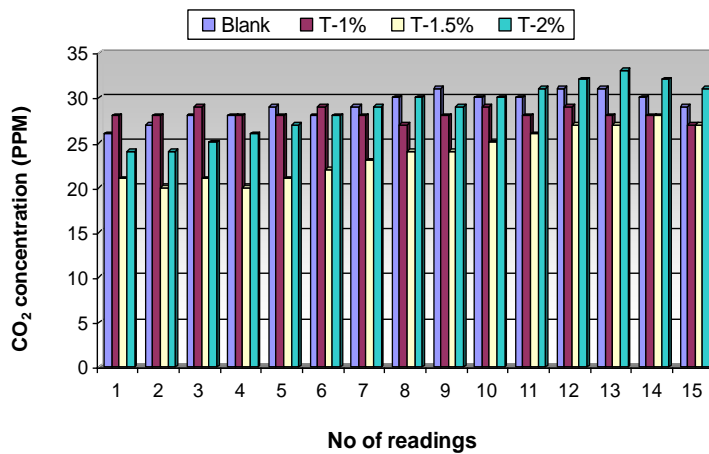


Figure 15. CO₂ concentrations at using untreated and treated 100% viscose filter samples.

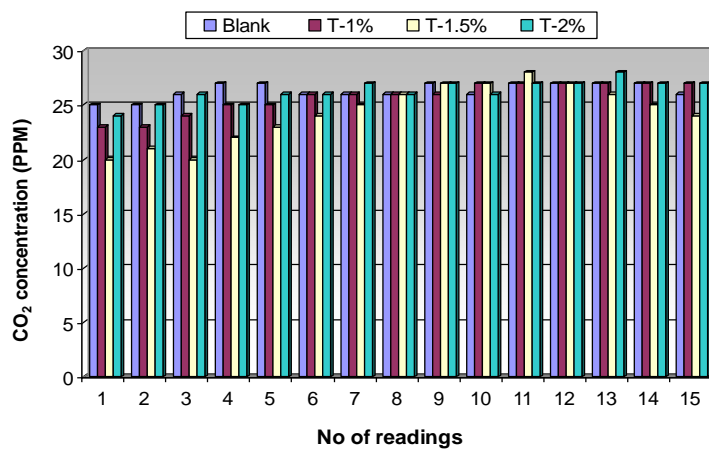


Figure 16. CO₂ concentrations at using untreated and treated (70% PET,30% VIS) filter samples.

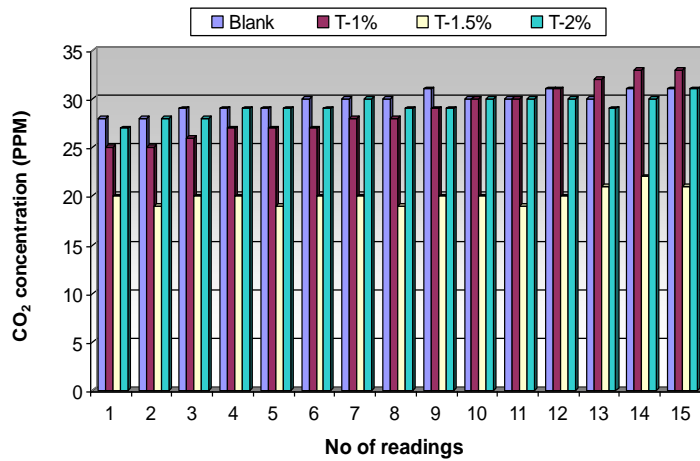


Figure 17. CO₂ concentrations at using untreated and treated (70% VIS,30% PET) filter samples.

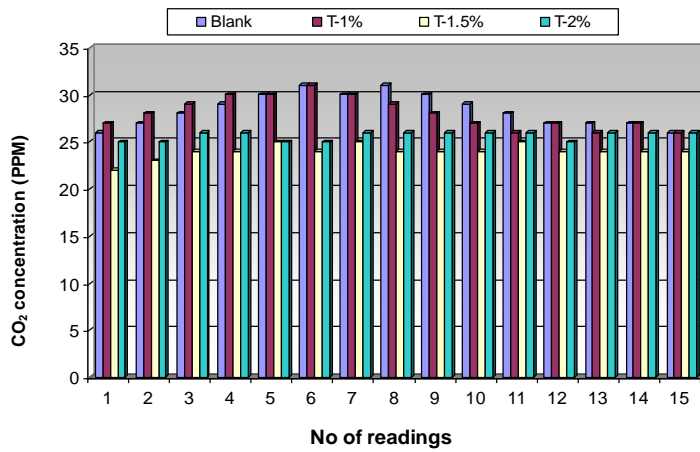


Figure 18. CO₂ concentrations at using untreated and treated 100% polyester filter samples.

- Sulphur dioxide (SO₂) gas:

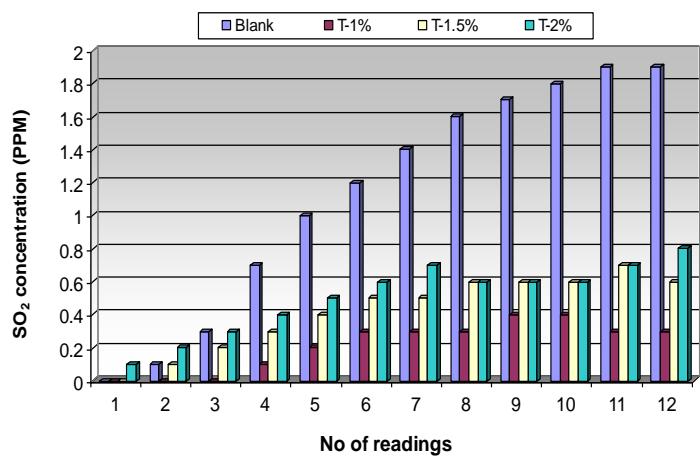


Figure 19. SO₂ concentrations at using untreated and treated 100% viscose filter samples.

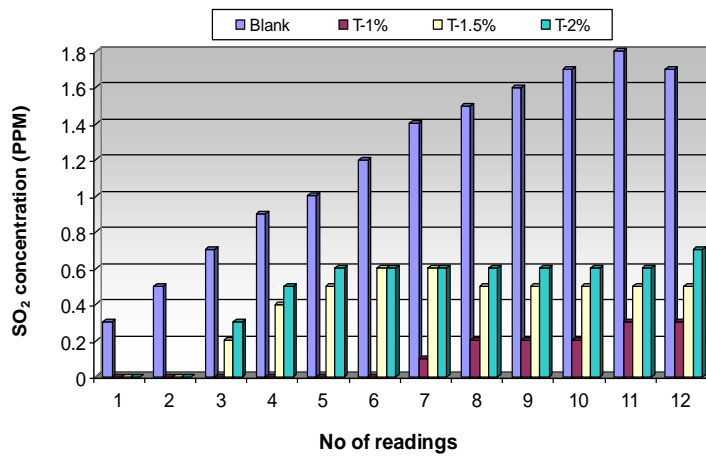


Figure 20. SO₂ concentrations at using untreated and treated (70% PET,30%VIS) filter samples.

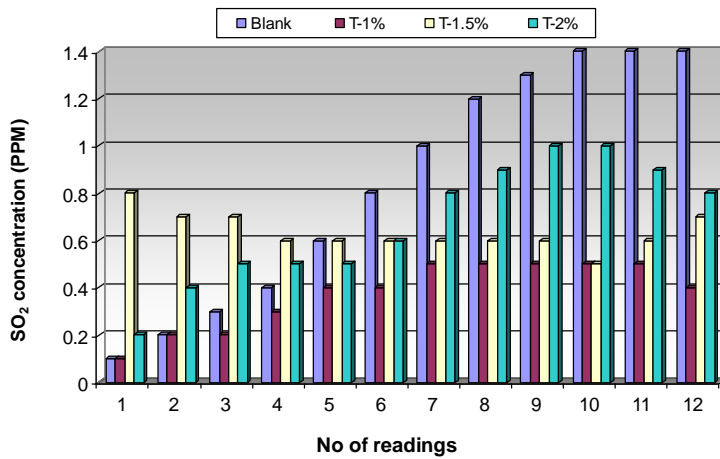


Figure 21. SO₂ concentrations at using untreated and treated (70% VIS,30% PET) filter samples.

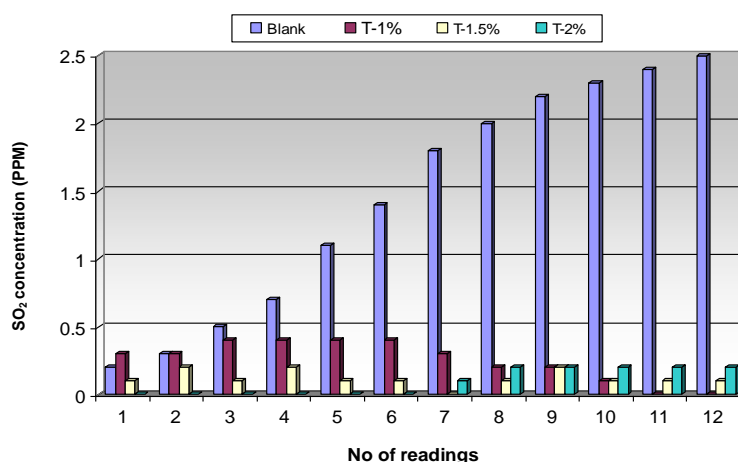


Figure 22. SO₂ concentrations at using untreated and treated 100% polyester filter samples.

Statistical analysis was performed using radar chart to evaluate the functional performance of the nonwoven filter samples with respect to their physical and mechanical properties and gas filtration effectiveness after treatment with chitosan NP's. In comparing the properties of the nonwoven filters, it was found that the blended samples and the 100% polyester sample had better enhanced properties than the 100% viscose sample.

This may be related to its high permeability, low density and low bursting strength that might well negatively affect on the filtration process. Figure 23 shows the radar chart representing the properties of the treated nonwoven samples. It was illustrated that, the most suitable sample for gas filtration applications is the 100% polyester sample treated with 1.5% CSNP's .

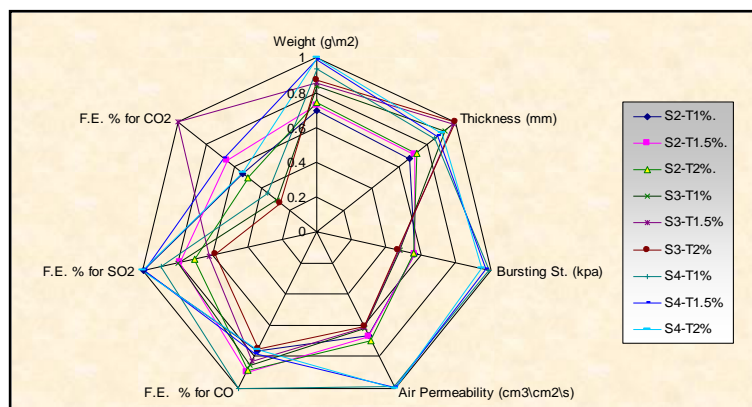


Figure 23. Evaluation of the properties of the nonwoven treated filters; S2-(70% PET,30% VIS),S3-(70% VIS,30% PET) and S4-100% polyester.

Conclusion:

Air filtration becomes essential in our life to reduce the increased levels of air pollutants that affect on human health and environment. Nonwoven filters are used widely in air filtration applications due to their distinctive characteristics. The present work aimed to investigate gas filtration behaviour of spunlaced nonwoven fabrics produced using polyester and viscose fibers with different blending ratio, treated with chitosan NP's at different concentration levels to enhance their filtration properties. The influence of the nonwovens properties and chemical treatment on their filtration efficiency towards harmful gases (CO, CO₂ and SO₂) was studied. The results revealed that, fabrics thickness and weight increased after treatment, while air permeability reduced which enhanced filtration efficiency. Although, the 100% viscose sample and the blended sample (70% VIS, 30% PET) showed improvement in air permeability after treatment. The bursting strength of samples decreased after treatment with increasing concentration. In comparing all properties of the nonwoven filter samples, it was found that the 100% polyester sample is the most suitable sample for gas filtration applications. Since it had better enhanced gas filtration properties specially when treated with 1.5% CSNP's, in addition to high bursting strength compared with the other samples due to its high density and low permeability. Further studies will be accomplished to investigate the antimicrobial properties of the said nonwovens after treatment with chitosan, in order to avoid health problems and improve hygiene for indoor applications.

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