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Studies on Air Filtration Efficiency of Nanofibers

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ABSTRACT: This study has been undertaken to investigate Air quality index by checking the filtration efficiency of nanofibers compared to traditional nonwoven fiberglass filter. Advantage and disadvantage are also discussed of nano technology with compared to traditional nonwoven fiberglass filter. Different pollutant which exists in air is also discussed with their effect on human body and environment. To measure the air quality with available technology regarding counting particulate matter and Volatile Organic Compounds is also discussed. In this study, the challenge is to produce low cost nanofibres, so that low cost air filter can be made. Requirement of clean air in hospital and in protective clothing is also taken into consideration.

Keywords: Air Quality Index, Nanofibers, Electro Static Spinning, Non Woven Fabric etc.

Abbreviations: PM, Particulate Matter; AQI, Air Quality Index; HEPA, High Efficiency Particulate Air; VOC, Volatile Organic Compounds; ULPA, Ultra Low Particulate Air.

I. INTRODUCTION

In earlier time for making filter, knitted and woven fabric were to be used, but they were having limitation of catching fine particles. After that non woven fabric came into the picture, which was cost-effective, but again they were unable to catch particles, having the size in microns. In today's scenario to fulfill requirement of clean air, nanofibers along with nonwoven fabric is used. Production of nanofibers is quite expensive due to low production rate & high raw material cost. So to fulfill this requirement there is a need to produce low cost nanofibers. Utilization of nanofibers is basically in filters. The performance of the nanofibers is based on the filter flow rate along with catching and holding the smallest particles without blocking it. Nanofibers have better-quality interference and inertial impaction efficiencies and hence help in slip flow Sundarrajan *et al.*, [1]. The movement of the molecules past the nanofibers without colliding with the nanofibers at the fiber surface, subsequently improving performance at a given pressure drop [2]. So there is a big advantage in making filters by using nanofibres along with nonwoven fabric as compared to conventional knitted and woven fabric filters. These nanofibres filter shows excellent filtration property. Currently both, industries and consumer markets use nanofibers which are incorporated in commercial filters in air, automotive and liquid applications.

II. PARTICULATE MATTER – 2.5

It refers to minute dust particles which can enter human body through breathing and can even enter the bloodstreams through lungs. Pollution caused by smoke from cars and trucks are a main cause of increase in these particles. Inhaling these harmful particles can cause various diseases with symptoms like nonfatal heart assaults, troubled asthma, erratic heartbeat, reduced lung work, and other respiratory issues, like, trouble of the aviation routes, trouble relaxing.
Inhaling these particles for a long-term and short-term may lead to premature demise of the person or harmful cardiovascular diseases, including frequent visits to the hospitals and emergency department for heart attacks and strokes. Continuous exposure to these minute particles also lead to respiratory problems .For instance asthma attacks, linked with more respiratory symptoms such as wheezing, coughing and breathlessness as well as less lung development in children. Momentary exposures to thoracic rough particles may lead to early death due to heart and lung disease EPA (2014) [3].

III. VOLATILE ORGANIC COMPOUNDS

Also known as VOC – Any chemical we smell is because of VOC, which in other words means that any chemical whose vaporization point is close to a room temperature can be smelled by humans. Some of these chemicals are highly reactive and when reacted with other chemicals they become even more foul. But some VOC's cannot be smelled or humans cannot smell them at lower levels. They are mostly widespread inside closed doors, where they can build up. Paint, cleaners and Gasoline are a few products that contain VOCs.

IV. AIR QUALITY

Air contamination consists of a mixture of many potions like fluid beads, dust particles and gases. Shares of these particles are passing in the air, while others are seemingly permanent. Toxins which are highly reactive or have a tendency to stay on the surface can stay in the atmosphere for more time; these particles are characterized by the adulteration arrangement and climatic situations including daylight, temperature, wind speed and precipitation.

Toxins are emitted by a wide variety of man-made and naturally happening bases. Examples of toxins caused by human sources can be running old technological plants, cars, and oil and gas generation industries. Natural toxin sources incorporate out of control fires, volcanic emissions and dust storms, among others. Some toxins, also named as "essential contaminations", are transferred reasonably from a source like lead, sulfur dioxide, counting particulate issue, nitrogen dioxide and carbon monoxide. Other particles, also called optional toxins are formed by substances discovered by the wind flowing downwind from the source. This assembly includes ozone particles (O_3) and some other types of particulate issue.

V. IMPACT OF DIFFERENT POLLUTANT EXISTING IN AIR ON ENVIRONMENT AND HUMAN BODY

Lead (Pb):
Human Body: Lead has the most adverse effect on children. It harms their nervous system resulting in loss of IQ. It also impacts their learning abilities, memory and conduct. In adults, lead can cause cardiovascular and renal diseases which may lead to diseases like anemia.
Environment: The presence of lead is there in atmosphere. This lead gets collected in soil and also resides in air sources, because of activities like mining and depositing of this discharge in water bodies thereby polluting them. This also causes soil erosion. Places adjacent to point sources of lead reveal a number of harmful effects comprising of changes in community composition, losses in flora and fauna, hampering the neurons present in vertebrates. In plants and animals, it further leads to a decrease in growth and reproductive.
Sulfur Dioxide (SO_2):
Human Body: Sulfur Dioxide heightens is already existing in respiratory diseases like asthma, wheeze, chest tightness and cough. Asthma patients are the most adversely effected, but if a very high level of SO_2 is present in the atmosphere, it can lead to respiratory symptoms in people without lung disease. Exposure to this air over a period of time can lead to death also. EPA (2014) [3].
Environment: SO_2 adds to the increase of acid in soil and surface water. This leads to decline in vegetation and death of local species in aquatic and earthly environment. It also increases the content of mercury in surface waters which leads to death of fishes and other wildlife and increases particle formation, which in turn leads to a net cooling effect in the atmosphere.
Nitrogen Dioxide (NO_2):
Human Body: Nitrogen Dioxide aggravates respiratory symptoms and then may also damage them; it leads to increased hospital, mainly in people suffering from asthma in children and aged persons. It may also cause respiratory infection.
Environment: It may lead to acidification and nutrient pollution (eutrophication, nitrogen saturation) of soil and surface water. It may also cause oxygen reduction in waters which may lead to losses of plants and animals, and changes in biodiversity losses. It can also increase levels of ozone particles, and methane with related environmental and climatic effects.
Carbon Monoxide (CO):
Human Body: Carbon Monoxide decreases content of oxygen required by the human body organs and tissues; worsens the heart disease and leads to severe health problem.
Environment: CO adds to the formation of CO_2 and ozone, greenhouse gases that increase the temperature of the atmosphere. EPA (2014) [3].
Volatile Organic Compounds (VOCs):
Human Body: VOCs constitutes of some toxic air pollutants that may lead to cancer and/or other grave health issues. They also add to ozone formation with related health hazards.
Environment: They add to ozone formation with related environmental and climate effects. Also, it contributes to the creation of CO_2 and other organic aerosols that may have an adverse effect on the atmospheric temperature, respectively.

VI. AIR QUALITY INDEX

AQI	Air Pollution Levels	Health implications
0-50	Good	Air condition is considered satisfactory, and air pollution poses no risks.
50 - 100	Moderate	Air quality is acceptable ; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution
101- 150	Unhealthy for sensitive groups	Members of sensitive groups may experience health effects. The general public is not likely to be effected.
151- 200	Unhealthy	Everyone may begin to experience health effects; members of sensitive group may experience more health effects
201-300	Very Unhealthy	Health warning of emergency conditions. The entire population is more likely to be effected
300 +	Hazardous	Health alert : Everyone may experience more

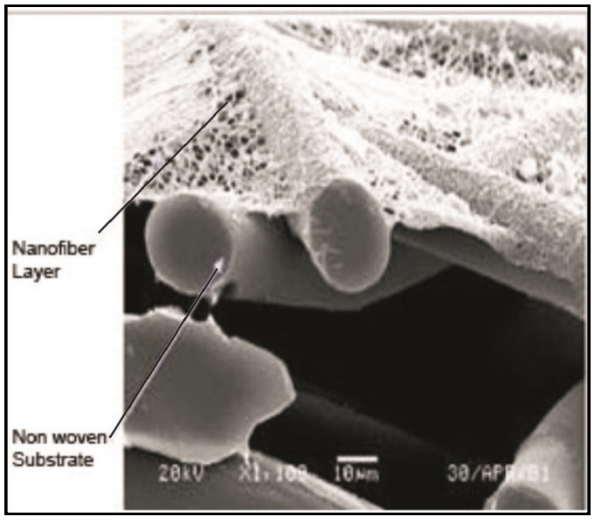

Fig. 1. Electrospun Nanofibers on a nonwoven substrate.

Fig.1 showing the deposition of nanofibers on a nonwoven fabric. The human hair has an average diameter of 100 microns. Fine cotton has an average diameter of 20 microns. Nanofibre is 1000 times finer as compared to human hair .Nanofibers are so tiny that it is impossible to handle them in their singular form.

VII. FILTRATION EFFICIENCY OF NANO FIBER MEMBRANE

Fig. 2. Fine dust loading on cellulose.

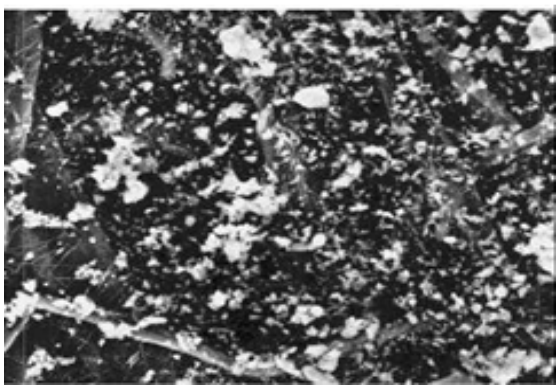

Fig. 3. Cellulose nanofibers composite.

Fig. 2 shows the fine dust deposited on the simple cellulosic fabric during air filtration. Fig. 3 shows the fine dust deposition on a fabric composite made of cellulosic material and nanofibers web during air filtration. It clearly shows the great improvement in filtration efficiency.

In the study of air filtration, fiberglass and activated carbon are usually used because of their many possible benefits Sundarrajan *et al.*, [1]. Toxic is eliminated by using activated carbon along with harmful chemical vapors with the help of adsorption procedure, while high effectiveness particulate air (HEPA) networks are used to catch particles, like micro dust and other particles which are bigger in size than PM 2.5. Nano technology field has developed in a big way and is used in different fields like hospital & environment. The use of nanotechnology is now commercial in the market and many applications are using it like, sportswear, coatings, sunscreens, car air filter, and textile materials. Out of all the nanotechnology application, nanofibers are only unique material which have been inspected in that volume or has been blended with different materials, like, textile materials and fiberglass.

Owing to proficient system of Brownian diffusion along with intervention, the nanofibers can capture any minute nanoparticles obvious all around in air. As per a study on polymers Maze *et al.* [4], it was stated that the improvement in the filtration size of the Effective Neutralizing Materials for nanoparticles can be achieved by increasing the air stream temperature and decreasing the diameter of the fiber. In a different research, Wang *et al.*, [5] studied the use of nanofibers filters for filtration of nanoparticles with old-fashioned fiberglass filters. The study revealed that the filters made up of nanofibers have higher benefit for particles larger than 100 nm with equated to old-fashioned fiberglass filters.

VIII. REQUIREMENT OF CLEAN AIR IN HOSPITAL

Nanofibers for diverse applications have been examined that the probable exploitation of nanofibers is incredible and will be a big leap forward spaces in future. The most stimulating part for nanofibers filters shall be its usage as a medium in pollution free air solicitations in medical health centers. This thought measured the filtration ability of nylon-6 nanofibers layers, outperforming whatever the popularized high-productivity particulate air channel (HEPA). A notable disadvantage of nanofibers is the high weight loss over the nanofibers film. In any case, this investigation indicates about their usage with HEPA channel for high skill in application of pollution free air, for example in ICU in hospitals. Diverse processes wherein the defiled air containing different pathogens and microorganisms confined in a room can be detached before transferring into different confined environment because of centrally cooling arrangement. As of late, nanofibers were examined for application of pollution free air by numerous organizations.

The uses of silver in unification of antimicrobial means with nanofibers have been acknowledged to display antimicrobial characteristics in the filters. Lala *et al.* [6], (2007) stated antimicrobial action for cellulose acetate (CA), poly acrylonitrile (PAN) and poly vinyl chloride (PVC) nanofibers membranes comprising of Ag nanoparticles. Electrospun PAN ENMs on cleaning with hydroxylamine formatted of $–C(NH_2)$ N–OH groups, which were exposed for the amalgamation of Ag^+ ions and after that by Ag nanoparticles formation Zhang *et al.,* [7]. The study further stated that tremendous reaction was found against microbes via ENMs that encompasses Ag and Ag+ particles. They also had adequate conveyance assets for filtration of air processes. Antibacterial nylon nanofibers with Ag and the antibacterial actions of the nanofibers in contradiction of Gram-negative bacteria and gram-positive aerobic organisms were stated to be excellent by Montazer and Malekzadeh [8].

IX. NANOFIBERS IN PROTECTIVE CLOTHING

Nanofibers can also be used in applications such as defensive clothing. Though, for aerosol the augmented filtration effectiveness was detected for ENMs, comparatively raised drop in pressure was stated. Nanoparticles Gibson *et al.* [9] and (3-carboxy-4-iodosobenzyl) oxy-b- cyclodextrin which are reactive organic materials have been unified into nanofibers. This has been achieved by mixing with solutions of polymer and after that a simple electro spinning verified for the

cleansing of chemical warfare agents (CWA) Ramakrishnan *et al.* [10]. The sanitization effectiveness of these ENMs was stated to be greater than orthodox activated charcoal. A mixture of polymer solution along with nanoparticles caused the creation of nanoparticles totals and hence catalytic activity was condensed. In order to solve this issue, electro spraying procedure was used to spray nanoparticles and was jointed with electro spinning method, where nanoparticles were made accessible on the nanofiber surfaces stated by Roso *et al.,* and Jaworek *et al.*, [11-12].

For the filtration of nanoparticles in defensive clothing applications, Facini *et al.* [15], discovered nylon nanofibers as the probable material. A shrill covering of nanofibers above textiles delivered over 50% retention of 200nm size nanoparticles and 80% withholding of 20 nm nanoparticles, which was additionally enhanced by 99% efficiency Desai *et al.,* [13].

Electrospun nylon 6 nanofibers left over nylon/cotton woven fabric were assessed for 300 nm size NaCl particles for filtration competence in PC applications by Vitchuli *et al.*, [14]. They attained an effectiveness of greater than 99.5% without forfeiting pressure drop and air permeability.

X. AIR SENSORS CHECKING AIR QUALITY

The new age of cost effective, highly moveable air quality sensors is giving a thrilling chance for people to use this technology for a lot of applications outside old-style regulatory or regulatory-equivalent monitoring. Air pollution sensors even today are in an early stage of technological development, and a lot of sensors have not yet been assessed to define the correctness of their dimensions. EPA has explicit guidelines that must be used in providing regulatory-grade air monitors. No cheaper sensors presently meet these firm necessities or have been officially submitted to EPA for such a determination.

XI. MATERIAL AND TESTING METHOD USED TO MEASURE POLLUTANT IN AIR BY AIR QUALITY DETECTOR

Material.

– Nonwoven Material – Spun bond and Melt Blown polypropylene fabric

– Nanofibers: Polyester and Nylon

Method.

HCHO & TVOC (Include Benzene) in the Air

– Sample Mode: Diffusion Type

–Detection Technique: Semiconductor Sensing technology

– Density Unit: mg/m^3

PM 1/ PM 2.5/ PM 10

– Detection Technique: Laser Scattering

– Particle Diameter: 1µg/ m^3, 2.5 µg/ m^3,10 µg/ m^3

– Detection mode: Density (Per Liter)

XII. CONCLUSION

The nanofibers along with non woven fabric show excellent filtration efficiency. The filter was able to improve the air quality by almost 99 %.

Hence from the above mentioned analysis, we can determine that there are many studies have gone under different noncommercial fibers. So there is a vast possibility to make nanofibers filters having commercially used and easily available raw material. We can get a very good result by using polyester and nylon nanofibers membrane along with HEPA and ULPA filter. So study should emphasize on making of polyester and nylon nanofibers and then start using it in air filtration. If we can decrease the developing cost of polyester and nylon nanofibers, then there is a huge possibility to decrease the cost of air filter. It not only helps us protecting us from the environment pollution but also it can play pivot role in the national economy.

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