NANOFIBRE INCOPRATED FACE MASK FOR HAZE PROTECTION APPLICATIONS

MUHAMMAD SYAMIL BIN SHAHARANI
B041310317
BMCS
mhmdsyamil@yahoo.com

Report
Projek Sarjana Muda

Supervisor: DR. NUR FAIZEY BIN ABDUL HAMID

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

2017

SUPERVISOR’S DECLARATION

I have checked this report and the report can not be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

Signature :...................................

Name of Supervisor :...................................

Date :...................................

ABSTRACT

Face masks will be used when the haze season arrived but the wearer still faced cough and dizzy after inhale the dirty air. This is due to a larger pore in the filter that allows fine particles past the conventional filter. So the purposed of this study is to develop an efficient face mask that can filter a fine particle using a nanofiber filter. Firstly, the test rig for filtration test using a PVC pipe and aluminum clamp to fit the filter were fabricated. Then, polyvinyl alcohol (PVA) mixed with distilled water was prepared for used in electrospinning process. For electrospinning process, the distance from spinneret and collector was constant which is 10 meter but the time collection of nanofibers was different which is from 2 minutes to 10 minutes. This is because to study the electrospinning collection time and effectiveness of the filtration. Next, the measurement of mass particle concentration was taken by using DustTrakII Aerosol Monitor Model 8530 EP. The average of the inlet measurement is 56 ppm while the lowest at outlet is 35 ppm. For the filtration effectiveness it can be seen an increased trend from t=0 minute to t=10 minutes. The longer electrospinning collection time the more effectiveness filtration of filter. Finally, Scanning Electron Morphology (SEM) was used to determine the morphology of PVA fiber and trapped particles. The average nanofiber diameter were from 209 nm to 305 nm (t=2 till t=10 minutes). Increasing the electrospinning collection time, produced thicker layer of nanofibers web, decrease the filter media porosity, increase the rate of fine particle stranded on the fiber and offer better capture effectiveness of particle on face mask.

ABSTRAK

Topeng muka akan digunakan apabila musim jerebu tiba tetapi pemakainya masih menghadapi batuk dan pening selepas menyedut udara kotor. Ini disebabkan liang yang lebih besar dalam penapis yang membolehkan zarah halus lalu penapis konvensional. Jadi tujuan kajian ini adalah untuk membangunkan sebuah topeng muka yang berkesan yang boleh menapis zarah halus menggunakan penapis nanofiber. Pertama, pelantar ujian telah direka untuk ujian penapisan menggunakan paip PVC dan pengapit aluminium untuk dimasukkan penapis. Kemudian, polyvinyl alcohol (PVA) dicampur dengan air suling telah disediakan untuk digunakan dalam proses electrospinning. Untuk proses electrospinning, jarak dari spinneret dan pemungut adalah tetap iaitu 10 meter tetapi koleksi masa bagi nanofibers berbeza iaitu dari 2 minit hingga 10 minit. Ini adalah kerana untuk mengkaji masa koleksi electrospinning dan keberkesanan penapisan. Seterusnya, pengukuran kepekatan jisim zarah telah diambil dengan menggunakan DustTrakII Aerosol Monitor Digital 8530 EP. Purata ukuran salur masuk adalah 56 ppm manakala yang terendah pada salur keluar adalah 35 ppm. Untuk keberkesanan penapisan ia boleh dilihat arah aliran yang meningkat daripada t = 0 minit hingga t = 10 minit. Semakin lama koleksi masa electrospinning semakin berkesan penapisan penapis. Akhir sekali, Scanning Electron Morfologi (SEM) telah digunakan untuk menentukan morfologi gentian PVA dan zarah terperangkap. Purata diameter nanofiber adalah dari 209 nm hingga 305 nm (t = 2 hingga t = 10 minit). Meningkatkan koleksi masa electrospinning, menghasilkan lapisan tebal nanofibers, mengurangkan keliangan media penapis, meningkatkan kadar zarah halus terdampar di gentian dan menawarkan keberkesanan dengan lebih baik bagi zarah topeng muka.

ACKNOWLEDGEMENT

Firstly, I would like to express my gratitude, honor, respect, and appreciation to all those who gave me chance to complete this final year project. A special thanks to my supervisor, Dr. Nur Faizey Bin Abdul Hamid for his invaluable guidance, a lot of suggestion and encouragement to complete this project. During under his supervision, lot of valuable information is obtained in order to coordinate my projects until complete this report.

A special thanks to goes staff of Faculty of Mechanical Engineering who gave permission to use equipment in Air-Conditioner laboratory and Chemical laboratory to complete this project. Special thanks and higher appreciation to my parents, family and special mate of mine for their cooperation, constructive suggestion and also supports from the beginning until the ends during the period of the project. Also thanks to all my friends and others, that has been contributed by supporting and helps myself during the final year project progress till it is fully completed.

Last but not least, greater appreciation to BMCS classmates and Mechanical Engineering Faculty UTeM for great commitment and cooperation during my final year project. Besides, I would like to appreciate the guidance given by the panels especially in my project presentation that has improved my presentation skills by their comment and tips.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBEREVATIONS

API - Air Pollutant Index

PSI - Pollutant Standard Index

USEPA - United States Environmental Protection Agency

HEPA - High Efficiency Particulate Air

SEM - Scanning Electron Microscope

PM - Particulate Matter

HVAC - Heating Ventilation Air Conditioning

ULPA - Ultra-Low Penetration Air

SULPA - Super Ultra-Low Penetration Air

PP - Polypropylene

PVC - Polyvinyl Chloride

PE - Polyethylene

PVA - Polyvinyl Alcohol

MPP - Most Penetrating Particle

NIH - National Institute of Health

BFE - Bacteria Filtration Efficiency

PFE - Particle Filtration Efficiency

CHAPTER 1

INTRODUCTION

1.1 Background

Haze phenomenon due to accumulated dust and smoke particles in air often occurs in Malaysia (Rahman, 2013). In recent years, many countries in the Southeast Asia including Malaysia, Brunei, Indonesia, Singapore and Thailand have been significantly affected by this problem. One of the worst haze episodes happened in 2013. The Air Pollution Index (API) hit 172 on 19^{th} June 2013. On 20^{th}June, the haze in Malaysia worsened where Johor and Malacca remained the worst-affected states. In Johor for example, Muar recorded hazardous API reading of (383), which was one of the worst recorded API values in Malaysia (Rahman, 2013).

Open burning forest and agricultural wastes from the neighbouring countries caused a haze in our country (Fires, Pollution, & Asia, 2000). Other than open burning, there are problems that could cause haze such as industrial and vehicle emissions. The accumulated dusk and smoke particles in air produces poor air quality which could lead to serious health problems. The riskiest persons are those who have respiratory issues such as asthma and, pneumonia, older people, young children, pregnant women and cancer patients.

Dirtied air can specifically experience the lung alveolar to bring about numerous sicknesses including asthma. As of late, numerous Malaysian urban areas are secured by murkiness air. Figure 1.1 demonstrated the contaminated air at

Malaysia during 2014. The overwhelming metals followed on particles may even prompt serious constant wellbeing issues, for example, growth after long haul introduction under the particles contained environment. The majority of those covers are made of non-woven fabric, actuated carbon, or cotton which has fibre breadth of a few micro meters. They have noteworthy weakness of poor air dismissal and low air porousness.

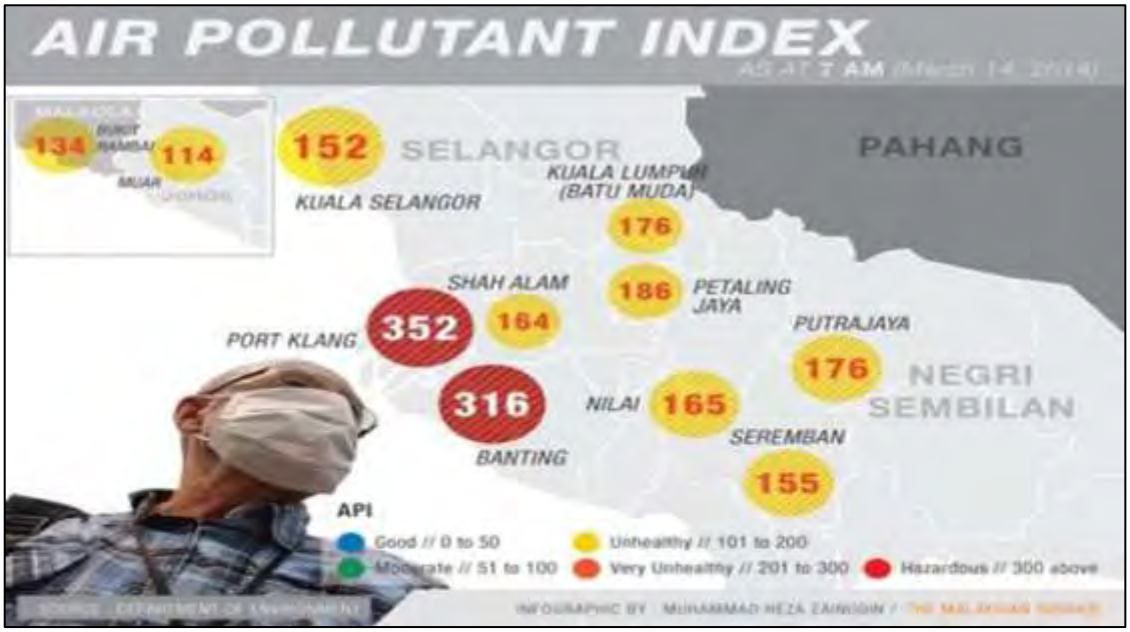

Figure 1.1: The sub-micron surgical face mask used in medical industry(Abdullah, Samah, & Tham, 2012)

Air pollutant index (API) is to show the condition of the air per daily in Malaysia. Air pollutant index (API) is a pointer for the air quality status at a specific area. This API system closely follows the Pollutant Standard Index (PSI) of the United States Environmental Protection Agency (USEPA) and is mainly based on five major pollutants (PM10, SO2, NO2, CO, and O3) in the ambient air (Abdullah et al., 2012). Table 1.1 shows the air pollution index that usually make as a reference.

Table 1.1: Air Pollution Index References (Control, Poor, Sharma, Aditya, & Engineer, 2014).

Percentage	Condition	Description
Below 50	Good	Low contamination with no awful impact on wellbeing
51-100	Moderate	Moderate contamination that does not represent any awful impact on wellbeing
101-200	Unhealthy	Exacerbate the wellbeing state of high hazard individuals who is the general population with heart and lung confusions
201-300	Very Unhealthy	Exacerbate the wellbeing condition and low resilience of physical activities to individuals with heart and lung intricacies. Influence general wellbeing
More than 300	Hazardous	Unsafe to high hazard individuals and general wellbeing.

Given the issues of air contamination and defilement is one thing that often happens, attention must be focused and must address this issue with a fast time period. In this age of advanced technology, various ways to produce equipment for the production of clean environment. Filtration innovation is one of such progressed approaches for making a more advantageous and cleaner environment. The standard bandage used to forestall breathing in the fine particles. Those filters are not ready to sift through the expansive porosity of the veil materials. Some cover is avoided because it has severe breathing capacity, which increased the danger of another well fare.

During the haze, the citizen will provided a surgical face mask by ministry of health. There are three types of fabrics forming technology which is woven, non-woven and knitted. Nowadays, non-woven is used to make up the surgical face masks. The typical material using spun bond technology with 20 gsm of polypropylene and 25 gsm polypropylene non-woven sheet by using melt blown technology to manufacture surgical face masks (Chellamani, Veerasubramanian, & Vignesh Balaji, 2013). Face mask, 1 μ in size, filter the material with two filters and made up of three or four layers. Moreover, the more effective surgical face masks to prevent the spread of fine particle entering the mouth required 85% or even 99% protection.

Polymeric nanofiber have been used in air filtration applications over the last 20 years, and hold promise in an expanding field of filtration applications as it have a technical benefits (Graham et al., 2002). Nanofibers are one of the novel materials which have one request of size littler than traditional filaments. The high surface-to-volume proportion, low resistance and upgraded filtration execution make nanofiber an alluring material for some applications, for example, medicinal services, vitality and air filtration. Activated carbon is used to remove toxic chemicals through adsorption process, whereas High Efficiency Particulate Air (HEPA) filters are used to filter particles such as lint and other debris from the air (Sundarrajan, Tan, Lim, & Ramakrishna, 2014).

Figure 1.2 is a Scanning Electron Microscope (SEM) of electrospun nanofiber. The fibres are approximately 250 nano meters in diameter. As the fibres themselves have a small diameter, the thickness of the nano web can likewise be quite small, with a thickness of four nanofiber diameters approaching only one micron (Graham et al., 2002).

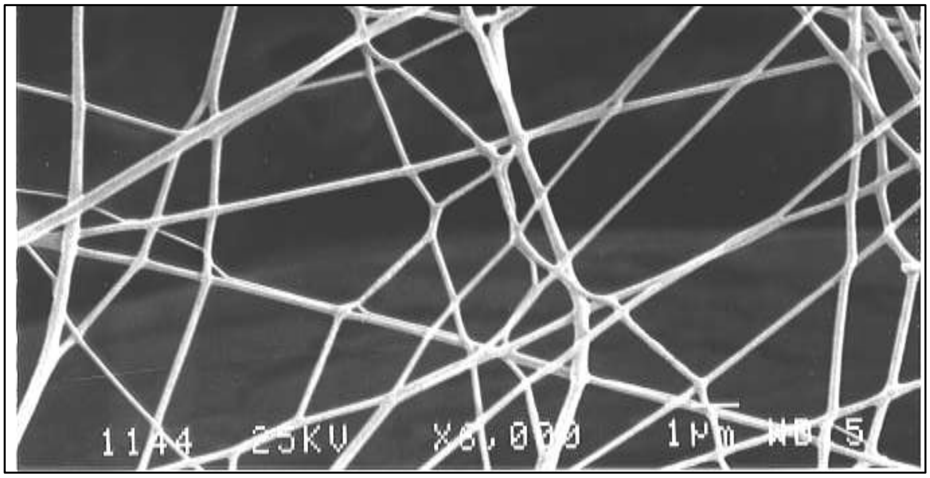

Figure 1.1: A typical Scanning Electron Micrograph of electrospun nanofiber (Graham et al., 2002).

1.2 Problem Statement

Particulate Matter (PM) is a complex mixture of extremely small particles and liquid droplets. On the basis of the particle size, PM is categorized by $PM_{2.5}$ which have a particle sizes below 2.5 μm and PM_{10} have a particle sizes below 10 μm respectively (Liu et al., 2015). There are two types of air filters. There is a porous membrane filter is made by creating pores on solid substrate and it is usually has very small pore size to filter out the larger sizes. The efficiency is high and the pressure drop is large. Next, there is fibrous air filter which filter the particles by the combination of thick physical boundaries and adhesion. This is made of numerous layers of thick fibers of various diameters across from a few microns to many microns. Normally, thick filter is to have a high efficiency. The inadequacy of the second kind of filter is the massiveness, not transparency and the tolerance between air flow and efficiency. So, the two types of filters which are not have a high filtering efficiency, high resistance and not light. Besides that, when the fibre diameter is larger, the particle-capture possibility is decreased a lot which are not effective to capture the small particle.

1.3 Objectives

The objectives of this project are as follows:

1) To developed a high efficient face mask.
2) To understand the relationship between the amounts of nanofibers and filter efficiency.

1.4 Scope of Project

The scopes of this project are:

1) Production of electrospun nanofibers by using an electrospinning process.
2) To evaluate the performance of the filtration membrane by using DuskTrakII Aerosol Monitor 8530.
3) Analysing the nanofibers morphology using scanning electron microscopy (SEM).

CHAPTER 2

LITERATURE REVIEW

2.1 The Air Pollution

These days, the worldwide mindfulness in diminishing contamination has risen fundamentally. Individuals over the world requests better arrangement in controlling the Particulate Matter (PM) contamination created in the environment. The visibility diminished incredibly and the air quality was poor due to a great degree elevated amounts of PM amid hazy days. The combustion from a carbon compound or water will deform on filter surfaces and require more grounded binding amid the way toward attaching to the filter. The soft PM tends to be more difficult to capture rigid inorganic PM with larger amounts of carbon and water content, since the same material are made to capture efficiencies of fibrous filters are lower in soft PM (Liu et al., 2015). Considering the fact by Hinds that to get a better filtration efficiency the fibre diameter must be less, the utilization of electrospun fibres for air filtration applications is a practical range (Matulevicius, Kliucininkas, Prasauskas, Buivydiene, & Martuzevicius, 2016). Air filtration studies indicated that electrospinning of nanofibers by air blowing method was carried out and air flow tests been conducted can be conceivably applied for air filtration applications (Sundarrajan et al., 2014). The need of high performance of filtration on face mask to filter the exterior air pollution from entering the mask which certainly provide better air quality, a good breathability by controlling the efficiency of filtration. The discomforts condition by human are due to have a cough, harmful particles and hazardous air pollution are main problem due to fine particle sizes. The electrospinning of nanofiber is to traps bacteria or fine particle which is widely used in medical masks applications (Chellamani et al., 2013).

2.1.1 Particle Classification

Particulate Matter (PM) is a mixture of microscopic solid and liquid droplets suspended in the air, consisting of various segments, as example acids, organic chemicals, metals, solids or tidy particles, and allergens (Bai & Sun, 2016). The airborne particulates contains of mass concentration and size distribution. Surrounding levels of mass fixation are measured in micrograms per cubic (µg/m^3). The size properties are normally measured as aerodynamic diameter across of the tidy of the particulates as far as microns.

The aerodynamic diameter often recognized into three categorizations as thoracic, fine and ultrafine particles. The size of thoracic particle PM_{10} is the biggest which is below than 10 µm diameter while fine particle $PM_{2.5}$ is below than 2.5 µm diameter. Next, the ultrafine $PM_{0.1}$ is the smallest which is below than 0.1 µm in diameter particles (Bai & Sun, 2016). Particles fine $PM_{2.5}$ and PM_{10} are most expected to cause bad health effects. Particulate matter is the most harmful air pollutants to human health especially in excessive PM circumstances. This specific size molecule raised real worries because of its ethicalness of their size, they can be effortlessly breathed in and travel deep into human lung indirectly causing breathing problem. People who have been presented to PM will increment of cardio-respiratory sickness and dreariness, and a reduction life expectancy that been accounted for by public health (Kwon, Jeong, Park, Kim, & Cho, 2015). For further understanding of the particle sizes, Figure 2.1 represents the comparison of PM_{10} and $PM_{2.5}$ particles between human air and beach sand.

Furthermore, ($PM_{2.5}$) is an essential particles which is created amid burning process that specifically discharged into the air. Conversely, coarse particle (PM_{10}) is the secondary particles is made by mechanical or compound responses in the atmosphere (Liu et al., 2015).

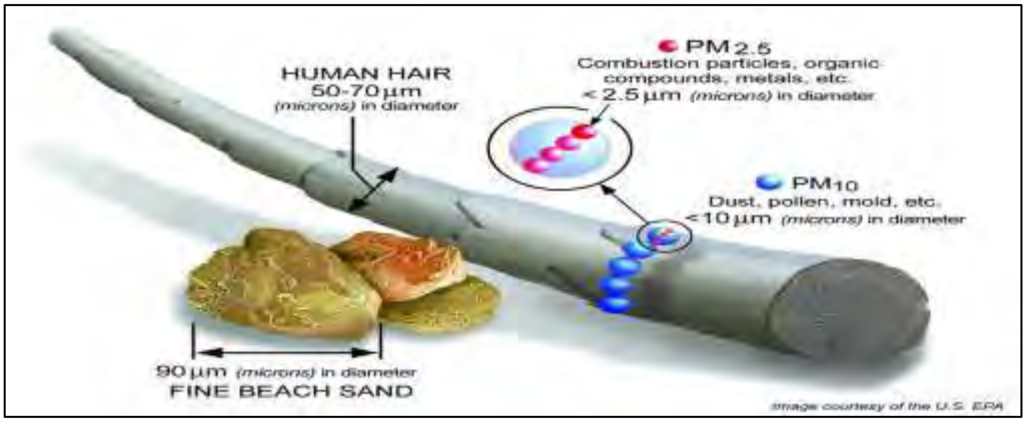

Figure 2.1: A comparison of PM with human air and beach sand (Kim, Kabir, & Kabir, 2015).

The size fine beach sand is the biggest among others which have 90 µm followed by human hair which have 50-70 µm in diameter respectively. Physically, human hairs have a small diameter compared to sand, but for $\boldsymbol{PM_{10}}$ and $\boldsymbol{PM_{2.5}}$ are smallest between human hairs. $\boldsymbol{PM_{10}}$ is a coarse particle which the size are less than 10 µm of diameter which normally for dust, pollen and mold. Then, $\boldsymbol{PM_{2.5}}$ is the smallest particles which have less than 2.5 µm in size and it exist in $\boldsymbol{PM_{10}}$ particle. For example of the particle are from combustion, organic compounds and metals.

2.1.2 Basic Filtration Mechanism

Basically, filtration is the premise by which components for filtration and detachment of particulate matter are created. Filtration and detachment theory is more worried with the components, recorded beneath, for molecule detachment after the molecule enters the surface of the medium. There are four basic mechanisms which are inertial impaction filtration mechanisms, interception, diffusion and electrostatic attraction. When the molecule inertia is so high the inertial impaction is happens that it has adequate force to split far from air streamlines and impact the fibre (Hutten & Hutten, 2016). This component is in charge of collecting bigger particles. Next, the interception is happens when a molecule does not have adequate inertia to break far from the streamline. It may approaches enough to the fibre so that common strengths forces will attach the molecule to the fibre. Again, this component is also in charge of collecting bigger particles.

The diffusion is a very small particle which is below than 0.5 μm based on the Brownian (zigzag) motion. This unpredictable and probabilistic development from the streamline and possibly interface with a fibre surface will bring about a molecule to differ (Hutten & Hutten, 2016). Lastly, the electrostatic is used as an electric charge to shift the particle from the streamline and attracted to fibre. Particles can be captured through the mechanisms depicted in Figure 2.2 as inertial impaction, interception, diffusion, electrostatic, gravity.

Figure 2.2: Aerosol filtration mechanism illustration (Chuanfang, 2012).

2.2 Face Mask Filtration

Face mask filter widely used in the event of air pollution because it is used to filter the mouth and nose from entering the small particles, protect from virus, bacteria, biological substances and particles in the air. Typically, the face mask filter that used is given from a medical industry as shown in Figure 2.3. It is represents the cross sectional filter area in the mask if it cut the surface. The masks have a three layer which is to embodiment the invention and to filter the small particles.

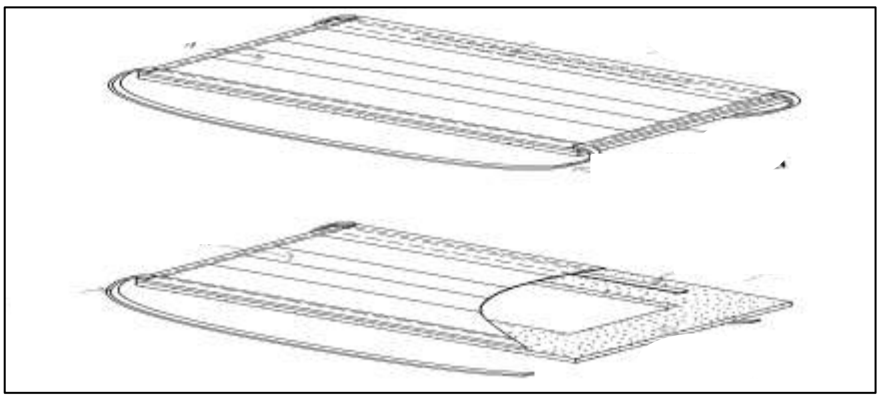

Figure 2.3: An illustration of face mask filtration(Tutor, 2002)

Protect the user from liquids and particles are also other function of face mask. Mostly viruses are small particles which is smaller than 1 micron. So, for the filtration of infection classic masks are not satisfy the criteria (Akalin, Usta, Kocak, & Ozen, 2010). The properties of the filter medium determine how the filter performs to evacuate the particles in the slurry and figure out if the particles shape a cake, are caught in the profundity of the filter, or go through the filter. The structure of materials framing the media is the most direct approach to describe the different sorts of media. The main categories include woven media, non-woven media and membranes. In comparison with woven texture filter, nonwovens offer numerous technical specialized qualities, including more prominent porousness, more specific particular surface range, and controllable pore measure dissemination, and little pore size.

2.2.1 Non- Woven Media

Non-woven fibre media are widely used type of media in industry. Non-woven fibres are widely utilized as a part of the medical field and in protection (Ajmeri & Joshi Ajmeri, 2011). Non- woven fibre are easy to fabricate and inexpensive. In addition, the surface has great filtration properties. It can filter up to very small particle particularly below than 1 micron. Membranes that are produced by directly coating onto the carrier material's surface are based on non-woven fabrics which are additionally backup support and mechanical strength to the nearly thin and fragile polymer (Hutten, 2016). The fabric can be particularly built to give the exact porosity and stream rate required for the specific filtering application. Non-woven is to enhance the effectiveness of filter media while upgrading the removal capacity of both particulate and chemical contaminant.

Non-woven filter have different applications in numerous segments in air, gas, and fluid filtrations. Higher efficiency is the fundamental point for the filter media and enhancing the effectiveness is a consistent improvement in future. Approximately 65-70% of the non-woven filtration media usually for air and gas while for the liquid filtration remaining 30-35%. Heating Ventilation Air Conditioning (HVAC) applications in residential, air and water filtrations in power stations, intake and exhaust air are the examples of their bulk applications which is from air and water filtration. The viruses are the smallest of the contaminants and only can just effectively be evacuated with High Efficiency Particulate Air (HEPA) filtration. Minimum efficiency of a filter that can be called HEPA is 99.97% retention of 0.3-μm particles. ULPA (Ultralow Particulate Air) is a filter that can have an efficiencies of 99.999% , while filters with 99.9999% are called SULPA (Super Ultra-Low Penetration Air) (Hutten, 2016).

Furthermore, fibre size and fibre geometries impact filter pore sizes, as well as straightforwardly decide filtration effectiveness and pressure drops. Fibres of more prominent straight thickness and circular cross areas could lead to more large porosity and porousness, in this way having a decreased pressure drop. Thus, filtration efficiency and pressure drop could influence by combination of fibre sizes and fibre geometries. Efficiency ratio and contains particle size, filtrated air quantity and using time are used to determine the filter efficiency.

Polypropylene (PP) fibre is used because of its non-absorber properties for the basic face masks (Akalin et al., 2010; Mao, 2016). PP has a high electrical resistance to retain the stability of E-charges, to achieve lower pressure drops. The electret filters are widely used in (HVAC) filters, respiratory masks, cabin air filters, vacuum filters, (HEPA)/ (ULPA) filters, dust removals, and engine intake air filters (Mao, 2016). Particulate filters from nanofiber coating by electrospinning process has the ability to filter out the fine particles, dust, pollutants and other air bones contaminants effectively compared than the others. Figure 2.4 show the face mask that usually used in medical industry.

Figure 2.4: The sub-micron surgical face mask used in medical industry

Face mask that usually used in medical industry was manufactured to meet and exceed International Standard of ASTM F2100. The capabilities of mask filtration can be determined by a size of the pores and the filtration efficiency (Molinari, Ph, Nelson, & Barrier, 2014). There are 4 criteria that should be aware on ASTM of medical face mask which is fluid resistance, bacteria filtration efficiency (BFE), particulate filtration efficiency (PFE) and flame spread. Firstly, for the fluid resistance, face mask resistance to penetration by synthetic blood. It also measures capacity of masks development to minimize fluids from going through the material and conceivably corning into contact with the wearer. The protection will get a better if the filtration of the fluid is higher.