DEVELOPMENT OF NON-WOVEN FABRIC SUPPORTED FUNCTIONALIZED MULTI-WALLED CARBON NANOTUBE(MWCNT)/POLYETHERSULFONE (PES) MEMBRANE FOR WATER TREATMENT IN SARAWAK RURAL AREA

Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

by

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DECLARATION

I, hereby, declared this report entitled "Development of Non-woven Fabric supported Functionalized Multi-Walled Carbon Nanotube(MWCNT)/Polyethersulfone (PES) Membrane for Water Treatment in Sarawak Rural Area" is the result of my own research except cited in reference.

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Date	:	23 MAY 2018

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.)

………………………………………

(Principal Supervisor) – Signature & Stamp

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ABSTRAK

Akses kepada air bersih di kawasan luar bandar disumbangkan oleh peningkatan pencemaran air dan kekurangan kemudahan rawatan. Teknologi membran membuka laluan untuk rawatan air yang cekap dan akhirnya akses kepada bekalan air bersih dengan bantuan pengisi nano seperti CNT. Keupayaan membran komposit filem nipis yang terdiri daripada MWCNT, PES dan NWF yang berfungsi, untuk merawat air permukaan luar bandar di Sarawak telah dikaji. Objektif projek ini adalah untuk membenamkan membran komposit filem yang tipis dengan MWCNT yang berfungsi, untuk mencirikan membran dan menganalisis prestasi membran dalam merawat paras BOD / COD permukaan air Sarawak. MWCNT telah difungsikan menggunakan pengadukan panas dengan kekuatan berlainan asid yang kuat dan ringan. Campuran MWCNT / PES dibuat menggunakan NMP sebagai pelarut organik di bawah keadaan pengadukan magnet panas. Membran dihasilkan menggunakan teknik pemendakan. Analisis Raman mendedahkan bahawa MWCNT yang dirawat berasid menunjukkan kecacatan dalam strukturnya, seperti yang ditunjukkan dalam nisbah I_D/I_G. TEM digunakan untuk memerhatikan kesan asid pada morfologi MWCNT dari segi penyingkiran, pemendekan panjang dan kecacatan sampingan. Teknik pencirian FTIR digunakan untuk membezakan membran dengan mengenal pasti kumpulan berfungsi yang ada sekarang. Analisis morfologi membran dilakukan menggunakan SEM untuk memahami penyebaran MWCNT dalam pembentukan membran dan PES pada substrat NWF. Sampel air dikumpulkan dari dua sumber yang terletak di Sarawak, Air Terjun Satow, Kpg. Sungai Bobak dan Rantau Panjang, Bt. Kawa dan diuji BOD dan COD. Tiga jenis membran dipilih untuk menapis sampel menggunakan penapisan vakum. Prestasi membran dinilai dari segi pengurangan BOD dan COD dan pemeriksaan warna dan kekeruhan dalam sampel yang ditapis. Membran menunjukkan keupayaan pengekalan zarah daripada p sampel Sungai Rantau Panjang. Membran MWCNT NWF mentah NWF menunjukkan keputusan yang paling konsisten dengan perubahan 0% dalam tahap BOD dan pengurangan tahap COD sebanyak 76%.

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ABSTRACT

Access to clean water in rural area is contributed by increasing water pollution and lack of treatment facility. Membrane technology paves a path for efficient water treatment and ultimately access to clean water supply with the help of nano-fillers such as CNT. The capability of a thin film composite membrane comprising of functionalized MWCNT, PES and NWF, to treat rural surface water in Sarawak has been studied. The objectives of this project was to fabricate a thin film composite membrane with functionalized MWCNT, to characterize the membrane and analyse the membrane performance in treating BOD/COD level of Sarawak surface water. MWCNT was functionalized using hot stirring with different strengths of acid treatment which are strong and mild. The MWCNT/PES slurry was made using NMP as organic solvent under the condition of hot magnetic stirring. Membrane was fabricated using immersion precipitation technique. Raman analysis revealed that acid-treated MWCNT showed defect in its structure, as reflected in the I_D/I_G ratio. TEM was employed to observe effect of acid on the morphology of the MWCNT in terms of debundling, length shortening and sidewall defect. FTIR characterization technique was used to distinguish the membranes by identifying the functional groups present. Morphological analysis of the membrane was done using SEM to understand the dispersion of MWCNT in the membrane and PES formation on NWF substrate. Water samples were collected from two sources located in Sarawak, Satow Waterfall, Kpg. Bobak and Rantau Panjang River, Bt. Kawa and send for BOD and COD testing. Three types of membranes were chosen to filter the samples using vacuum filtration. Performance of membrane was evaluated in terms of BOD and COD reduction and colour and turbidity inspection in filtered samples. Membrane showed particulates retention capability with the decolouration of Rantau Panjang River samples. NWF Raw MWCNT/PES membrane showed the most consistent result with 0% change in BOD level and up to 76% COD level reduction.

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DEDICATION

To

God, the Almighty Father, for lending me His spirit, courage and strength,

My beloved parents, Bakri Jurong and Pirintine Johor, for their endless prayer, support, encouragement, and financial contribution

My siblings, Jeremy, Valerie and Ivory for their unending support in forms of advice and consult

and my friends for the joy and laughter.

Thank you so much.

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LIST OF ABBREVIATIONS

BOD	-	Biochemical Oxygen Demand
COD	-	Chemical Oxygen Demand
CNT	-	Carbon nanotube
DOE	-	Department of Environment
FTIR	-	Fourier-Transform Infrared
IR	-	Infrared
MF	-	Microfiltration
MWCNT	-	Multi-walled Carbon nanotube
NF	-	Nanofiltration
NWF	-	Non-woven fabric
PE	-	Polyester
PES	-	Polyethersulfone
PET	-	Polyethylene terephthalate
PTFE	-	Polytetrafluroethylene
RO	-	Reverse Osmosis
SEM	-	Scanning electron microscope
SWCNT	-	Single-walled carbon nanotube
TEM	-	Transmission electron microscope
UF	-	Ultrafiltration
UN	-	United Nations
WQI	-	Water Quality Index

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CHAPTER 1
INTRODUCTION

1.1 Background

Water pollution is a prevalent problem affecting many especially the rural people. Water pollution are contributed by factors such as irresponsible waste discharge by industrial factories and use of agricultural chemicals among many other. The pollutants flow downstream, affecting rural people who uses the water source for daily consumption. Rural people are deprived from clean water access due to economic and geographical demanding factors. Water which are polluted contains harmful substances and likely to cause waterborne diseases such as cholera and dysentery or even be the catalyst for other dangerous diseases.

Membrane technology as illustrated in Figure 1.1 has been suggested as an alternative to replace the conventional methods of water treatment due to its cost efficiency (Wiesner *et al.*, 1994) and this is proven by its ability to remove various contaminants, enables use of nonconventional water sources, delivers high level of mechanisation and only needs little land and chemical use (Qu *et al.*, 2012). CNTs are widely used as nano-membrane. CNTs can be categorized into two types which are SWCNTs and MWCNTs. Although there has been a lot of research involving SWCNTs as a main constituent for membrane nanotechnology due its significant advantages against MWCNTs in terms of its properties, MWCNTs do provide a cheaper alternative yet significantly equivalent performance as the SWCNTs in water treatment. MWCNT properties can be enhanced with functional groups through a process called functionalization and mixed with polymer to create polymer matrix membrane. MWCNT/PES is a common membrane studied by many researchers in water treatment application such as desalination and forward osmosis (FO) due to its ability to

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provide high water, antibiofuling property and salt rejection. The incorporation of MWCNT/PES with non-woven fabric (NWF) creates a strong thin film composite (TFC) that can treat surface water.

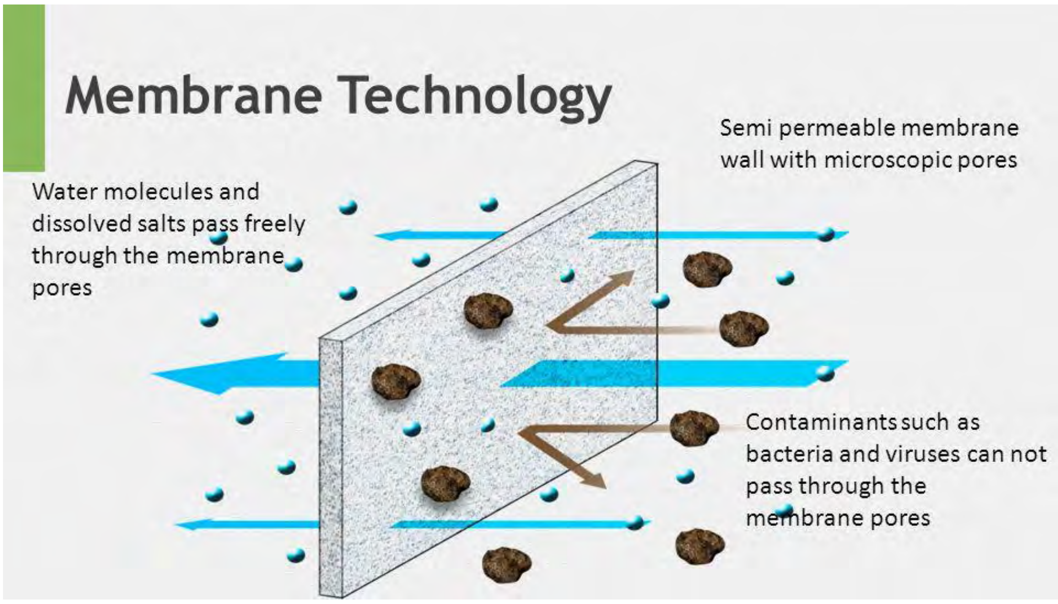

Figure 1.1: Principle of membrane technology in treating polluted water. (Source: Considerations and operational challenges in choosing Membrane Filtration for a Water Treatment Plant Upgrade Ed Cross Division Manager, Water Supply and Co., (Summers, A.,2016))

1.2 Problem statement

Access to clean water is an ongoing problem affecting many of the global population in this era of technology. Majority of those affected are from under-developed and developing countries. According to the 2017 report on drinking water, sanitation and hygiene by (Grojec, A., 2017), 844 million people are deprived from access to basic drinking water service. In rural area, one of three people in the world which accumulates to 1.9 billion people are having access to safely managed water services. In Malaysia, a minimum requirement of basic drinking water services is being provided to 89% of the rural population while the other 11% are reported to have access to unimproved and surface water source as their uptake for daily consumption and uses. In some cases, the Malaysian rural people must store the water they collected in household tanks or centralized reservoir in case of emergency when the water source dries up especially during the dry seasons.

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Due to the geographic nature of Malaysia, the rural people depends on freshwater sources originating from the mountains (groundwater), nearby rivers (surface water) and rainfall as their main source of water supply. Some examples of surface water – such as river, lake and reservoirs, as long as it is exposed to the atmosphere – is significantly been polluted due to the rapid growth of population and urbanisation (Huang, *et al.*, 2015). Factors such as industrial, agriculture and domestic waste which are being brought by the water greatly affects the quality of surface water (WPP, 2012) which makes it risky for rural people to use the water for their consumption. Water stored in storage tanks, which are not filtered, cannot be instantly deemed safe for consumption as water itself may have been exposed to animal faeces or chemical substances from agricultural and industrial activities beforehand. Water originating from freshwater can no longer be consumed untreated due to these pollutants containing bacteria, virus and parasite which causes diseases and in some worst case scenario, deaths (Haseena *et al.*, 2017). This problem poses a great threat to the human health especially those who are living in rural areas whom are unaware of the importance of safe and clean water.

1.3 Objectives

This research project is focusing on objectives as below:

1) To fabricate functionalized MWCNT-PES membrane incorporated with hydrophilic non-woven fabric.

2) To characterize the non-woven supported MWCNT-PES membrane composite.

3) To analyse the performance of the membrane on treating BOD/COD level of surface water in rural area.

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1.4 Scopes

The scopes of this project focused on aspects and factors that were heavily related in achieving the objectives mentioned below.

1.4.1 To fabricate a functionalized MWCNT/PES membrane incorporated with hydrophilic non-woven PE fabric

In order to achieve objective one, the project focused in the making of a polymer composite membrane which consisted of functionalized MWCNT and PES. MWCNT was functionalized using wet oxidation method or also known as acid treatment method. The treatment involves the usage of acid mixture comprising of different intensity which are strong and mild. Functionalized MWCNTs were mixed with PES to create polymer composite slurry. The polymer composite slurry was then incorporated with non-woven PE fabric as the substrate.

1.4.2 To characterize the non-woven PE fabric MWCNT/PES membrane composite

To accomplish objective 2, the characterization for this project covers three phases which are 1) characterization between raw and functionalized MWCNT, 2) the characterization of the composite membranes and 3) the characterization of the composite membranes after treating water. Phase 1 shows the comparison between the structure and composition of the raw as-provided commercial MWCNT and the oxidised functionalized MWCNT. Phase 2 aims to reveal the morphology of the fabricated membranes while phase 3 aims to prove the filtration capability of the membranes by analysing the surface morphology after filtration.

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1.4.3 To analyse the performance of the membrane on treating BOD/COD level of surface water in rural area

In order to achieve objective 3, the type of water chosen as sample is surface water. The surface water samples were taken from two different sources, river and waterfall. The sources were known water supply used by neighbouring and distant rural areas which has yet to have access to the water supplied from water treatment plant. The analysis was based on the biochemical oxygen demand (BOD) and chemical oxygen demand (COD) of water from both sources. The performance of the membrane composites was evaluated by comparing the BOD and COD levels before and after the water was filtered. The Water Quality Index (WQI) set by the Malaysia Department of Environment (DOE) was used as reference to determine the level of BOD and COD and its respective classes.

1.5 Project Significance

This project will benefit the rural community as it will provide a future prospect in providing them with safe and clean drinking water. Besides that, the findings of this project will be helpful for organizations to consider investing in membrane technology that will provide efficient and effective treatment towards polluted water. The purpose of this project can also be used in view of overcoming the rising issue of global water scarcity due to increasing demand for water in whom developing and under-developed countries will be greatly affected in the future.

1.6 Project Organization

The project consists of five chapters which shows about the development of the functionalized MWCNT-PES-NWF membrane composite in treating rural-originated surface water.

Chapter 1 contains six sub-chapters which started with the background which talks about the benefits of membrane technology and its performance enhancement in water filtration

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after being doped with functionalized MWCNT. The problem statement encompasses the problems such as global water scarcity and the costly setup for water treatment facilities in rural areas in which membrane technology hopes to tackle. The objectives of this project revolved around the fabrication of a functional membrane composite made of functionalized MWCNT-PES-NWF. The properties of the membrane were then analysed using several characterization methods and its performance for water filtration was also evaluated. The scopes were carefully evaluated and planned to ensure that objectives determined were achievable and completed.

Chapter 2 covers summarized discussions from past researches regarding global water scarcity and its effect, the benefits of membrane technology and its capability in treating water. Included were also the benefits and advantage of carbon nanotubes (CNTs) in providing means of efficient filtration capabilities and the methods of fabricating membrane composite.

Chapter 3 shows the methods and procedures leading to the fabrication and characterization of the membrane composite. List of materials, apparatus and equipment were also included in this chapter. Methodology for this project was developed based on similar previous researches with consideration of the availability of equipment and materials in the laboratory.

Chapter 4 contains the results of the characterization of the membrane and also the performance of the membrane in treating rural-originated water. The results were then discussed with prior relevant researches in order to accurately deduce the meaning of the results.

Chapter 5 concludes the project with the summary of the discussions obtained from the results in chapter 4. The summary is of accordance to the project objectives that have been determined in chapter 1. Limitations of the project are presented to provide guidelines for improvement in future research. Further improvements, in aspects such as method and analysis, were discussed in the recommendation section for future research.

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CHAPTER 2
LITERATURE REVIEW

This chapter contains the literature review of the project which is related to the objectives and scope presented for this project. All the information was extracted from articles, journals and books related to the topic of the project and focused on the objective and scope that has been determined.

2.1 Water

Water is the main source of life and it plays a vital role on determining the living standards of the society. Composed from hydrogen and oxygen atom bonded via polar covalent, water molecule is also known as a universal solvent which causes various substances to dissolve in it. This is due to the molecule's polarity of negative charge and positive charge carried by the hydrogen and oxygen atom respectively. The polarity of these atoms helps water dissociate ionic compounds into their positive and negative ions (Helmenstine, 2017). The importance of water management can greatly contribute to the Millennium Development Goals which emphasizes on the following areas which are eradicating extreme poverty and hunger, achieving universal education, promoting gender equity and women empowerment, reducing child mortality, improving maternal health, combating diseases, ensuring a sustainable environment and developing a global partnership for development (Soussan *et al.*, 2006).

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2.1.1 Water security

Water security is defined as the availability of satisfactory quantity and quality of water for the use of health, living, ecosystem and production to ensure human and ecosystem health (Grey & Sadoff, 2007; Malek, *et al.*, 2013). Grey & Sadoff (2007) stated that global climate change is to increase the intricacy and costs to maintain water security. Hirji & Davis (2009) claimed that the event of climate change is expected to have noteworthy effects on the availability and use of water. Noteworthy effects of climate change were decreasing availability of freshwater which threatens the water energy and food security and increasing health risks due to heat waves, vector-borne diseases, water shortages and contamination (Bank, 2014). With climate change affecting every country in the world, water security is determined by water infrastructure which helps to access, store, regulate, move and conserve the water resource (Grey & Sadoff, 2007). In Malaysia, water security is still bound by the "Sectorial" approach for water management system which reflects the "Supply" Management Mode rather than the approach called Water Demand Management (WDM) that is being implemented in developed countries in which WDM reduces the use of water and wastage by better management to ensure continuous water supply and distribution (Malek *et al*., 2013).

2.1.2 Water scarcity

Water scarcity as defined by UN Water (2006), is the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully. It is expected that by 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity and two-thirds of the world will be faced with stress conditions due to the water usage rate which doubles the rate of population increase (UN Water, 2006). Although 71% of Earth is covered with water, 97% of it consists of saline water and not suitable for drinking (Israel, 2010) making the need for water desalination treatment a crucial part in providing safe drinking water.

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2.1.3 Water pollution

Water is polluted by the discharge of various pollutants released from everyday activities caused by human and industrial activities which threatens the health of the population and by rendering water bodies unsuitable thus damaging the quality of the environment (Imoukhuede & Afuye, 2016). Water pollution are caused by factors such as substance drawn from the air, silt from soil erosion, chemical fertilizers and pesticides, run-off from septic tanks, outflow from livestock feed lot and waste from both industrial and urban origin (Fewtrell, 2005). The existence of many types of micro-organism in the polluted water will negatively affect the consumer, causing what is called water-borne disease. According to Soussan *et al*. (2006) in their article, they stated that water-borne diseases such as malaria and cholera which happens to be the main killer in many parts of the developing world, affecting those who are vulnerable especially children.

2.1.4 Safe drinking water

According to the organization, UN Water (2005), they stated that access to safe drinking water is a basic human right and essential for achieving gender equality, sustainable development and poverty alleviation. Based on a drinking water review by UNICEF & WHO (2017) , as of 2015, 71% of the global population have access to a safely managed drinking water service, which is defined as a service that is located on premise, available when needed and free from contamination. However, 12% of the global population has access to a water service lower than basic and 11% (refer Figure 2.1) of the overall Malaysian rural population were amongst them (Grojec, 2017). The drinking water service can be categorized into five different levels, which are safely managed, basic, limited, unimproved, surface water whose definition are summarized in Table 2.1.

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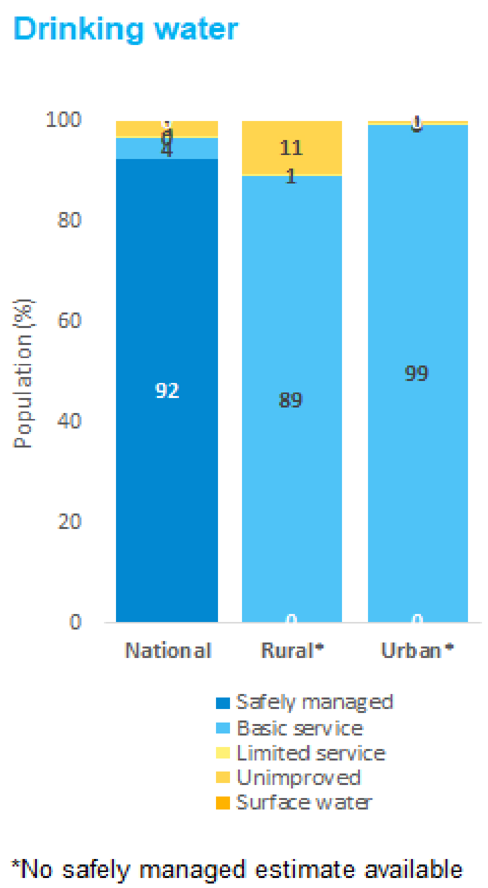

Figure 2.1: Drinking water coverage in Malaysia (Generated from https://washdata.org/)

Table 2.1: JMP ladder for water drinking services (Grojec, 2017)

SERVICE LEVEL	DEFINITION
SAFELY MANAGED	Drinking water from an improved water source that is located on premises, available when needed and free from faecal and priority chemical contamination
BASIC	Drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip, including queuing.
LIMITED	Drinking water from an improve source for which collection time exceeds 30 minutes for a round trip including queuing
UNIMPROVED	Drinking water from an unprotected dug well or unprotected spring
SURFACE WATER	Drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal

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