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Microplastic Removal in Krueng Aceh River Water Using Ultrafiltration Membrane from Polyethersulfone Polymer (PES)

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ABSTRACT

The Company's input pipes contained microplastics, per the preliminary test findings. While the water yield produced by PDAM Tirta Daroy contains 150 particles/L, the Tirta Daroy Drinking Water Area has 275 particles/L. Microplastics found in the water pose a major risk to living beings if they are consumed. This work aims to characterize the properties, flux, and polyethersulfone (PES) membrane rejection coefficient, which were made utilizing the phase inversion technique with a solvent and additives called N,N-dimethylformamide (DMF). In Sungai Krueng Aceh, titanium dioxide (TiO_2) is utilized to filter out microplastics from the water. Results of Scanning Electron Microscopy (SEM) examination of Membrane Morphology demonstrate that the resulting membrane is an asymmetrical membrane of two layers, the upper layer relatively thin and the lower layer porous. When compared to the PES membrane when it was 15% DMF/TiO_2, the 20% DMF/TiO_2 membrane exhibits a finger-like cross-sectional structure called a macrovoid) with more and larger numbers. Analysis of the microplastic rejection coefficients proved the effectiveness of PES, DMF, and TiO_2 membranes in removing microplastics. Results of tests on the effectiveness of rejecting microplastics after undergoing process filtration with a microplastic rejection coefficient of 94% and 14.2 particles/L utilizing a 20% PES/DMF/TiO_2 membrane Performance of PES membranes: The PES membrane with 20% DMF/TiO_2 has a water flux of 0.467 L/m2.hour compared to 15% DMF/TiO_2 0.733 L/m2.hour. This study's findings on membrane Ultrafiltration have the potential to be used as a water filter standard in PDAM.

1. INTRODUCTION

According to the National garbage Management Information System (SIPSN), Indonesia will produce 28.4 thousand tons of plastic garbage daily, or 15.6% of all waste produced in Indonesia, in 2021. According to KLH's assumptions, Indonesians produce 0.8 kg of garbage per person per day, or up to 189 thousand tons of waste every day [1], [2]. Plastic garbage typically originates from everyday objects including cutlery, packaging bags, pipes, toothbrushes, oil bottles, and bottles for drinks, lotions, soaps, and shampoos [3]. With 28.4 thousand tons of plastic trash produced per day, it poses a threat to human survival and pollutes the environment, particularly the sea, marine biota, and river lakes [4]. When plastic waste is exposed to ultraviolet (UV) rays for an

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extended period of time and is subjected to physical shock as a result of environmental factors, it fragments and shrinks in size, becoming what is known as microplastics (Mp) [5]. Microplastics are defined as plastics with a size between 0,1 and 5 mm. Aquatic ecosystems and even living organisms are negatively impacted by microplastics [6]. Microplastics can also be discovered in bigger macroplastic fragments or in common household items like soap and scrubs [7]. [8] asserts that Mp can have an adverse effect on microorganisms at higher trophic levels through bioaccumulation and can have a stronger negative influence on marine species that inhabit lower trophic levels, such as plankton, which are filter feeders that ingest Mp. All marine species can consume microplastics if one of the microplastic particles resembles food. If microplastics get into the human body, they might be harmful. According to [9], microplastics can have harmful effects, lead to oxidative stress, damage human tissue, and lead to chronic inflammation.

According to [10], there are as many fibers, fragments, and films as 5.45 particles/L in 81% of the tap water in 14 countries (Cuba, Ecuador, England, France, Germany, India, Indonesia, Ireland, Italy, Lebanon, Slovakia, Switzerland, Uganda, and the United States). There are 930 71 particles/L in processed water compared to 6614 1132 particles/L in raw water at the Advanced Drinking Water Treatment Plant (ADWTP) in China. Additionally, drinking water treatment facilities in Germany have high levels of microplastics, up to 0.7 microplastics/m^3 with a size range of 50-150 m. Several Drinking Water Management Installations, including IPAM Ngagel I, II, and III and IPAM Karangpilan I, II, and III, are also owned by the Regional Drinking Water Company in Surabaya City. In the East Surabaya distribution water, there were 56.61 particles per liter in the reservoir water and 30.77 particles per liter in the tap water.

According to data from [11] and [12], the Krueng Aceh River had microplastics at concentrations of up to 150 and 180 particles per liter, respectively. One of the major rivers in Aceh, the Krueng Aceh River flows directly into the Indian Ocean and the Malacca Strait, providing raw water for PDAMs in Aceh Besar and Banda Aceh City [13], [14]. According to the preliminary test results, there were up to 275 particles/L of microplastics in the PDAM Tirta Daroy input pipe and up to 150 particles/L in the water the facility produced. One method for treating water and trash is membrane technology. Membranes may divide larger particle components into smaller ones and can separate chemical components individually. According to [15], the benefits of membrane technology include its ability to function at low temperatures, ability to conserve energy, ability to run constantly, and environmental friendliness.

Microfiltration, ultrafiltration, nanofiltration, reverse osmosis, electrolysis, dialysis, electrodialysis, gas separation, vapor permeation, pervaporation, membrane distillation, and membrane reactors are just a few of the different separation techniques that use membrane filtration [16]. The pore size of ultrafiltration membranes is 0.1-0.001 m, and their permeability is limited to 10–50 L/m^2.hour.bar at low pressures of 1–5 bar [17]. Ultrafiltration membranes can filter out microorganisms including viruses, germs, and pathogens because of the extremely small hole size, resulting in water that is safe to drink straight away. The performance of the membrane in the intended filtration process is significantly impacted by the choice of the proper polymer. According to [18], a variety of popular polymers, such as polysulfone, polyethersulfone, polyvinylidene fluoride, polyacrylonitrile, cellulose acetate, polyamide, polyether ketone, and others, are utilized in the ultrafiltration membrane process.

Due to its excellent performance, good mechanical properties, high thermal stability, outstanding resistance to chlorine and hazardous chemicals, and flexibility into various module configurations, polyethersulfone (PES) is a material that is frequently used in the production of asymmetric membranes [19], [20]. Dimethylformamide (DMF) is a commonly utilized proton-polar solvent that is popular, affordable, and employed as a solvent in many different chemical processes [21]. Because titanium dioxide (TiO_2) can produce membranes with higher hydrophilicity, better thermal and mechanical stability, better permeate performance, and the ability to degrade organic contaminants, TiO_2 is used as an additive in the production of PES membranes [22], [23]. PES/DMF/TIO2 membranes with varying polymer compositions of 15% PES and 20% PES were used in this work. This was done under the same 2.5 bar pressure in order to remove microplastics. The phase inversion technique is the process utilized to create membranes. Because it doesn't utilize organic solvents, which can eventually end up in the environment as waste, this technology is simple to use, the development of pores can be controlled, and it can be used to a

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variety of ecologically benign polymers [24]. PES membranes have undergone substantial development and modification to raise their caliber. Based on these findings, PES-type ultrafiltration membranes will be utilized to remove microplastics in order to lower the amounts of microplastics in the raw water filtration process in PDAM. These membranes have developed pore sizes that range from 0.1-0.001 m.

2. EXPERIMENTAL METHOD

The creation of flat PES membranes was the first step in the research, which also included PES membrane characterization and performance experiments on removing microplastic from water in the Krueng Aceh river. Identification of microplastics based on size, quantity, and polymer type.

2.1 Tools and supplies needed to create membranes

The primary component of the membrane was made of polyethersulfone polymer (PES), which was acquired from BASF Company (USA), while the solvent was dimethylformamide (DMF), which was acquired from Tokopedia, the additive was titanium dioxide (TiO_2), and the on-solvent was distilled water. Glass plates are used as the printing media for the membrane, magnetic stirrers are used to homogenize the membrane solution, and duct tape is used as the membrane thickness limiter. Analytical balances (Daihan Scientific MSH-20A) are also used in the preparation of the dope solution.

2.2 The PES/DMF/TiO_2 Flat Membrane Synthesis Process

Ultrafiltration Phase inversion was used to create PES flat membranes. To create the membrane printing solution, PES polymer with weight variations between 15% and 20% (wt%) was combined with DMS/TiO_2 solvent in a 100 ml beaker glass and stirred with a magnetic stirrer until completely dissolved. A 3 mm thick applicator was used to level the printing solution after it had been placed onto a glass plate. Next, a coagulation bath using distilled water as a coagulant is used to dip the glass plate into. The membrane film was then removed from the glass plate and placed in a container with distilled water for storage. Characterization tests were then performed on PES membranes. With the various printing solutions listed in the table, PES flat membranes with PES codes of 15% and 20% were created. Table 1.

TABLE I. Dope formulations for membrane manufacture

Membrane Name	Dope formulation (% by weight)		
	PES	TiO_2	DMF
PES 15%	15	1,5	83,25
PES 20%	20	1,5	78,5

2.3 Analysis of the PES/DMF/TiO_2 membranes characteristics

One of the crucial factors that must be considered is the features of a membrane. This is since each membrane's structure and properties vary based on the technique, components, and ratios employed during production. While influencing the membrane's capabilities and physical characteristics. The features of the membrane can be determined using a variety of techniques, such as:

2.3.1 Membrane Morphology Analysis

The examination of Hitachi SU3500 SEM is a technique used to ascertain the morphological structure of a membrane. By firing an electron beam in a vacuum, measurements using SEM try to see the form of the pore structure on the surface, the cross-section of the membrane, and the walls of the macrovoid. 1,500–2,000 times magnification was used during the tests.

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2.3.2 Functional Group Analysis

Using Fourier Transform Infrared Spectroscopy (FTIR) Perkin Elmer type spectrum two, a sample's functional groups can be identified, sample quality can be assessed, and unknown components can be located.

2.4 Microplastics Analysis

2.4.1 Microplastic Analysis Equipment and Supplies

30% H_2O_2 was bought from CV.NaCl was acquired from CV and is used to dissolve or eliminate organic materials from microplastic samples. Rudang Jaya is employed as a density separator for the sample and floats the microplastics that are present in the sample. In the lab, distilled water is purchased. Ar-Raniry UIN The Krueng Aceh River's water supply and basic chemistry are both used. The beaker glass is used as a sample storage area, the magnetic stirrer is used to homogenize the samples, volume pipettes are used to transfer sample solution from one location to another, Whatman filter paper is used as the microplastic filtration media, and a stereo microscope is used to view the results of the microplastic analysis process. A tool for identifying microplastics is called XTL-3400.

2.4.2 Procedure for Microplastic Analysis

The dissolved substances in the water sample must be removed from the Krueng Aceh River water sample before it can be examined for their kind, form, and quantity. After mixing 300 mL of NaCl with 100 mL of water from the Krueng Aceh River for 30 minutes, the mixture was left to stand for 24 hours. In the following step, 20 mL of 30% H_2O_2 was added, homogenized for 30 minutes, and then left to stand for 48 hours. A vacuum filter is used to filter the sample solution, and the filter paper is then dried in a desiccator for five minutes. Then, using a stereo microscope of type XTL-3400, examine the size and shape of the microplastics. The filter paper's microplastics were examined by first putting them in a petri dish and analyzing the type of polymer using FTIR.

2.5 Performance Test on Microplastic Removal in Krueng Aceh River Water Using PES/DMF/TiO_2 Membrane

A series of filtration machines operating at a pressure of 2.5 bar were used to test the effectiveness of flat PES membranes in removing microplastics from the water of the Krueng Aceh River. Figure 1. depicts the design diagram for the ultrafiltration membrane filtration unit.

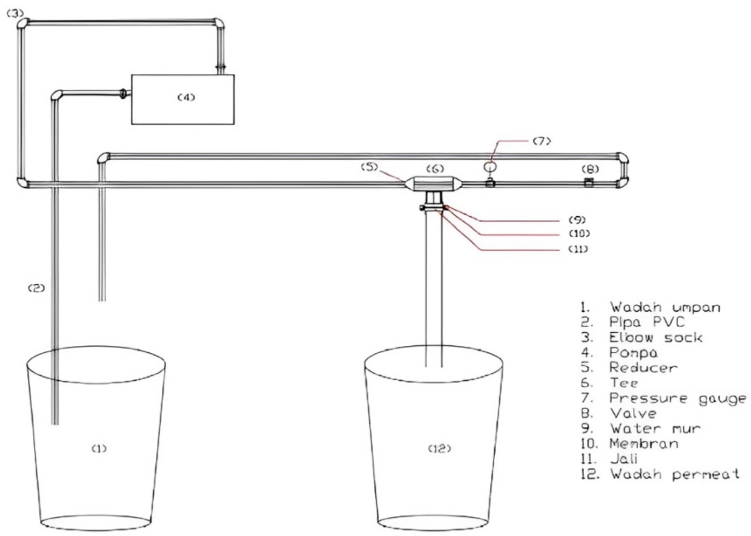

Figure 1. Filtration unit design

To be used in the microplastic cleaning procedure, 10 liters of water from the Krueng Aceh River are prepared. After attaching the membrane to the filtration unit's mesh, the water nut is turned to the right to secure it. To avoid leaks, make sure the water nut is well fastened. Krueng Aceh River water is placed in the feed bucket as a sample to be filtered. The pump is given command via a valve after being turned on until the pressure reaches 2.5 bar. Krueng Aceh River water is flowing.

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Permeate, which is the water from the Krueng Aceh River that flows through the membrane, is gathered in a bucket so that it may be examined for microplastics later. Retentate/flow that cannot cross the membrane is returned to the Krueng Aceh River's collection bucket or the bait bucket.

2.5.1 Analysis of the PES/DMF/TiO_2 Membrane Flux

This step tries to compare the amount of water the membrane produces to the amount of water fed. The membrane's flow value is then calculated. By letting pure water flow across the membrane, flux values (j) are determined. By dividing the gradient of the permeate flow curve (V) against time (t) at constant conditions by the membrane's surface area (A), one may determine the flux value (J) for each operational pressure [25]. Equation 1 was used to compute the flux during microplastic cleanup in the water of the Krueng Aceh River.

$$J = \frac{V}{A \times t} \tag{1}$$

With:
J = flux (L.m^2.hour)
V = permeate volume (L)
A = surface area of the membrane (m^2)
T = time (hours)

2.5.2 Analysis of the Microplastic Rejection Coefficient

To ascertain the membrane's capacity to withstand or pass a species, the rejection coefficient is measured. A spectrophotometer is then used to measure the concentration of the permeate and the concentration of the retentate, which stays on the other side of the membrane. This information will be used to figure out the microplastic rejection coefficient. More than 90% of the projected rejection coefficient (R) is observed. Using the equation, find the average rejection coefficient for two more membrane samples of each material used to make the membrane [26]. Equation 2 is used to determine the amount of microplastic removed from the water in the Krueng Aceh River.

$$R = \left(1 - \frac{Cp}{Cf}\right) \times 100\% \tag{2}$$

With:
R = rejection coefficient (%)
Cp = concentration of microplastic abundance in permeate (mg/L)
Cf = concentration of microplastic abundance in bait (mg/L)

3. RESULTS AND DISCUSSIONS

3.1 Characteristics of PES/DMF/TiO_2 Membranes

3.3.1 TiO_2 PES/DMF/TiO2 Membrane Morphology Analysis

In Figure 2, SEM images of the membrane structure used in this investigation are displayed. A 15% PES membrane is shown in the cross-sectional image (a) at a magnification of 2,000 times. The 15% PES membrane's top layer has a finger-like macrovoid shape with a small size, while the bottom layer has a porous appearance with a macrovoid size and a sponge shape. It can be determined from a straightforward computation of the SEM image scale that the 15% PES membrane features finger-like pores with an average pore size of 2,017 µm. The distribution of particle sizes that enter the membrane pore will be influenced by the pore size distribution. The 15% PES membrane's pore cross section is distributed unevenly, as seen in Figure 2(b). This occurred because, during the production of the dope solution, the TiO_2 component was not entirely dissolved. The fact that the dope solution comprising DMF and TiO_2 was not ultrasonically agitated during the membrane's production led to agglomeration and the total breakdown of TiO_2. Agglomeration is the process by which small or fine particles are combined to form larger or coarser particles [27]. Increasing the TiO_2 content will result in larger membrane pore sizes. The

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addition of TiO_2 nanoparticles to the nanofilm structure can boost the membrane's hydrophilicity because TiO_2 is hydrophilic [28]. The diameters of the macrovoids increased as a result of the TiO_2 addition to the polymer solution. The occurrence of a higher macrovoid with a finger-like structure during the phase inversion process is known as a macrovoid [29].

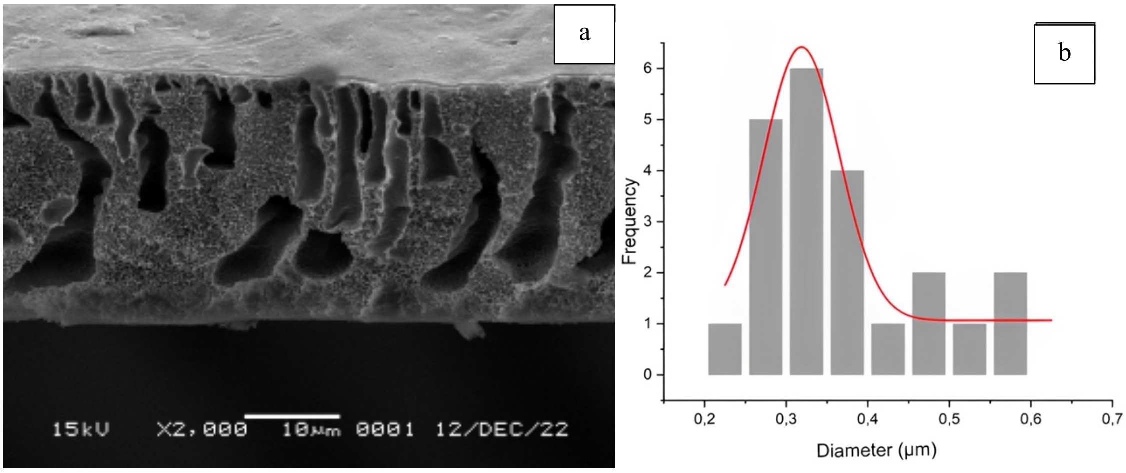

Figure 2. (a) 15% PES cross section, (b) 15% PES membrane pore size distribution

A cross section of a 20% PES membrane at a magnification of 1,500 times is shown in Figure 3(a). The 20% PES membrane is known to have finger-like pore sizes, with an average of 2,817 m and a standard deviation of 19021.61 based on a straightforward calculation of the SEM image scale. In comparison to the 15% PES membrane, the 20% PES membrane has more macrovoids that resemble fingers. Asymmetric membranes frequently contain macrovoids that resemble fingers. This happens as a result of the diffusion of high-viscosity fluids in the membrane by low-viscosity fluids, which results in the formation of finger-shaped cavities known as finger-like macrovoids [24]. The cross section of the 20% PES membrane's pore distribution is depicted in Figure 3(b), and it resembles that of the 15% PES membrane in Figure 3(b) in appearance. According to the data, PES/DMF membranes contain TiO_2 additives, all of which are hydrophilic, which slows the exchange of solvents and non-solvents during the solidification process. Additionally, due to this slowness, the membrane structure develops holes and pores, making the membrane more porous [30].

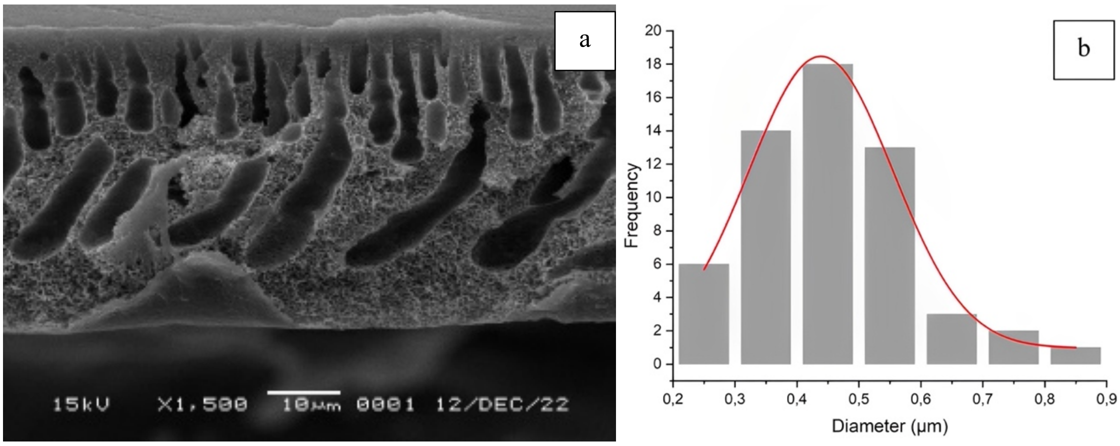

Figure 3. (a) 20% PES cross section, (b) 20% PES membrane pore size distribution

3.1.2 Membrane Functional Group Test Analysis

The goal of FTIR analysis of the membrane is to identify the functional groups it contains. Figure 4 displays the characterization of the IR spectra on PES 15% and 20% membranes. Based on Figure 4, the FTIR test spectrum reveals that all membranes have a spectrum that is nearly identical from one membrane to the next. All wave numbers that manifest are connected to atomic

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vibrations that come from the substance that gives PES its distinctive properties. O-H stretch functional groups were discovered by FTIR analysis for 15% and 20% PES membranes at wavelengths of 3368.35 cm^{-1} and 3367.76 cm^{-1}, respectively [31]. The PES polymer does not include any O-H bonds, and the peaks at 3368.35 and 3367.76 indicate the existence of water molecules as a result of the membrane not being dried for an hour at 105 °C prior to the FTIR test. With reference wavelengths of 1485.27 cm^{-1} and 1485.62 cm^{-1}, the C=C functional group was produced on 15% and 20% PES membranes [32]. At wavelengths of 1240.09 cm^{-1} and 1240.29 cm^{-1}, the C-O stretch functional group was produced on 15% and 20% PES membranes, respectively [32]. According to [33], the SO_2 functional group was produced on 15% and 20% PES membranes at wavelengths of 1105.09 cm^{-1} and 1105.22 cm^{-1}. All wave numbers that manifest are connected to atomic vibrations that come from the substance that gives PES its distinctive properties. According to Fathanah et al. (2019), the C-H functional group was produced on 15% and 20% PES membranes at wavelengths of 834.61 cm^{-1} and 1011.23 cm-^{1}. According to [34], the N-H functional groups were produced at wavelengths of 1577.85 cm^{-1} and 1577.87 cm-^{1}. 486 cm^{-1} was the wavelength used to produce the TiO_2 functional group [35]. Table 2 displays the FTIR spectrum table for membranes with PES variations.

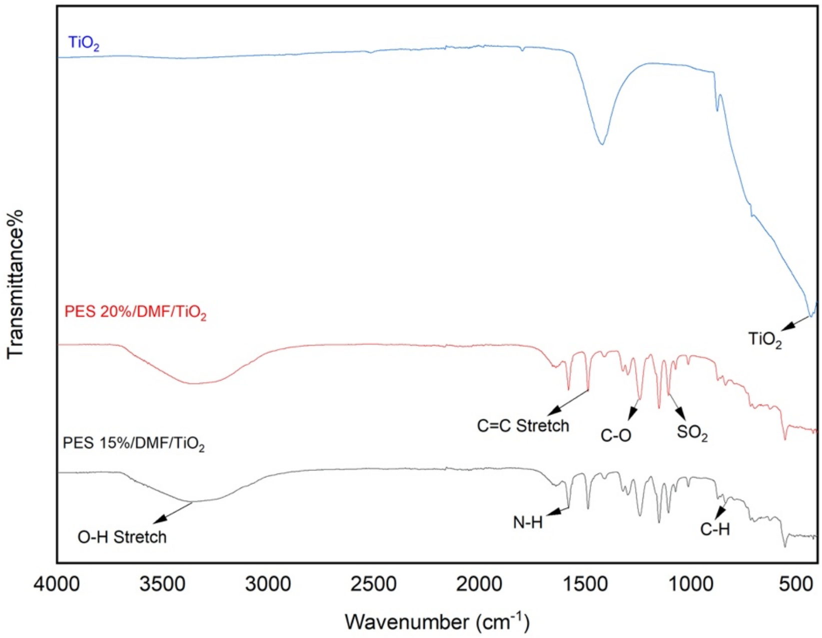

Figure 4. FTIR analysis results of PES 15%/DMF/TiO_2, PES 20%/DMF/TiO_2 and TiO_2 membranes

TABLE II. FTIR spectrum of 15% and 20% PES membrane

Wavenumber Range (cm^{-1})	Wavenumber (cm^{-1})		Group Function
	PES 15%	PES 20%	
3400-3200	3368.35	3367.,76	O-H
1485-1445	1485.27	1485.62	C=C
1240-1190	1240.09	1240.29	C-O
1200-1100	1105,.09	1105.22	SO_2
900-670	834.61	1011.23	C-H
1460-1560	1577.85	1577.87	N-H
0-432	486.00	486.00	TiO_2

3.2 Characterization of Microplastics

3.2.1 Forms and Abundance of Microplastics

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Based on the outcomes of stereo microscope microplastic observations, it was discovered that the water of the Krueng Aceh River contains microplastic particles, as depicted in Figure 5. Films, pieces, and fibers are the types of microplastic that have been discovered in the Krueng Aceh River. The most common types of microplastics found in household garbage include polyamide (PA), polyethylene (PE), polypropylene (PP), and polystyrene (PS). These microplastics are produced by synthetic fibers found in clothing that has been washed, plastic bags, the weathering of plastic objects, and cleaning and cosmetic products. [36].

Microplastics of the kinds PA, PP, and PS were discovered in the Krueng Aceh River during this study. The density of microplastics of the PA type is 1,130–1,350 kg/m^3, that of PE is 910–960 kg/m^3, and that of PS is 1,050 kg/m^3, according to [37]. Since microplastic has density, it will float in water. Microplastics that are lighter than water will float on the surface of the water, whereas those that are heavier than water will sink and become embedded in sediments [38]. River water has a density of 1000 Kg/m^3, so PE microplastic will float in the water since it is less dense than water.

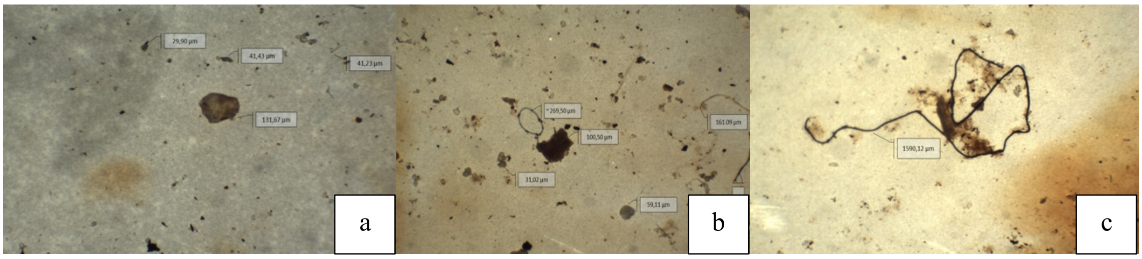

Figure 5. Forms of microplastics in the water of the Krueng Aceh River, Banda Aceh City, with a magnification of 10 times (a) film type, (b) fragment type and (c) fiber type

TABLE III. The average abundance of microplastics in each membrane

Sampling	**Coordinate**	**Volume (L)**	**Average Type Particle Abundance/L**			**Abundance (particle/L)**
			Film	**Fragment**	**Fiber**	
Membrane PES 15%	5°30’51.8”N 95°21’31.3”E	10	1.2	0.8	1	3
Membrane PES 20%			0.9	0.8	1.25	14.2

3.2.2 Functional Group Test Analysis of Microplastic Polymer

The purpose of FTIR analysis of microplastics is to identify the functional groups that are present. Figure 6 depicts the characterization of the microplastics' IR spectra. Based on Figure 6, the FTIR test's spectrum reveals the identification of several functional groups. According to microplastic FTIR analysis, the C=O functional group was found at a wavelength of 1634 cm^{-1}, the CH_2 functional group at 1155 cm^{-1}, and the N-H functional group at 3306 cm-1 [39]. This functional group is a subclass of the microplastic Polyamides (PA) family. According to [39] the C-C functional group was obtained at a wavelength of 997 cm^{-1} and the C-H functional group at a wavelength of 2914 cm^{-1}. This functional group is a subclass of microplastics made of polypropylene (PP). Wave numbers of 694 cm^{-1} and 1452 cm^{-1}, respectively, were used to produce the functional group's CH and CH_2 [39]. This functional group is a member of the Polystyrene (PS) microplastic class.

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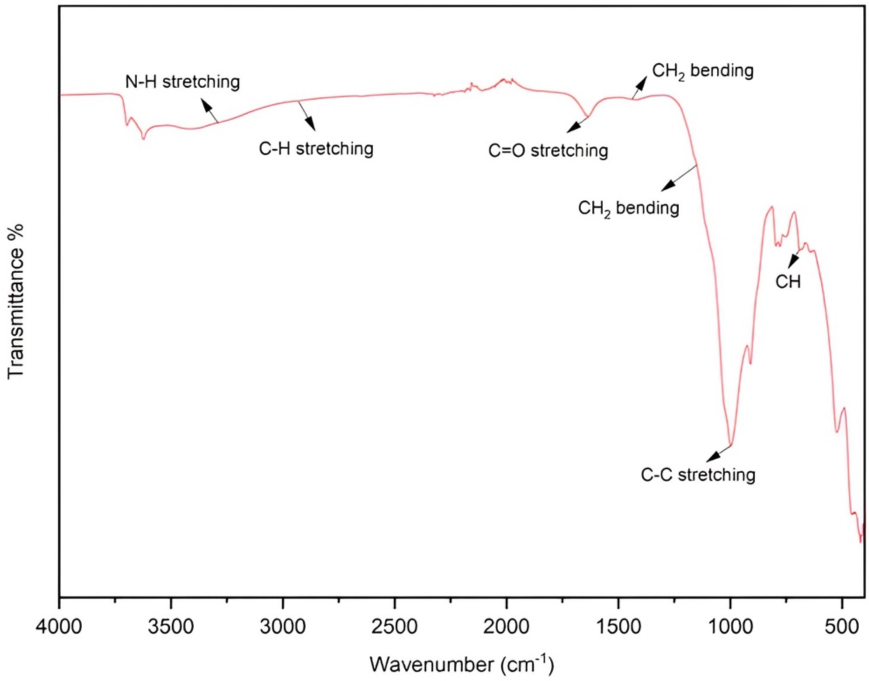

Figure 6. FTIR spectrum of microplastics obtained from the Krueng Aceh River

The microplastics types identified in the samples by the FTIR test were polyamides (PA), polypropylene (PP), and polystyrene (PS). Fishing lines and toothbrush bristles are typically used to make this sort of PA polymer, whereas bottle caps, straws, pipes, and other materials are used to make PP polymer. Plastic cutlery trays, paper cups, CD and cassette cases, and other items are used to make the PS polymer type [37]. For living creatures, this form of microplastic poses unique risks. This class of polyamides can lead to cancer, skin allergies, headaches, and dizziness. Humans who are exposed to this kind of polypropylene may develop asthma and hormonal problems. The type of polystyrene, however, might cause irritation to the eyes, nose, and throat as well as lightheadedness and unconsciousness [37]. Table 4 displays the FTIR spectrum table for various forms of microplastics.

TABLE IV. FTIR Spectra of Microplastics

Wavenumber (cm-^{1})	**Group Function**	**Microplastic Type**
1634	C=O stretching	PA
1155	CH_2 bending	
3306	N-H stretching	
997	C-C stretching	PP
2914	C-H stretching	
694	Aromatic CH out-of-plane bending	PS
1452	CH_2 bending	

3.3 Performance of PES/DMF/TiO_2 Membrane
3.3.1 Membrane Flux Analysis

High water permeability and high solute rejection membranes are those that operate well as filters. The goal of flux analysis is to quantify the volume of solution moving through the membrane at any given moment. Figure 7 shows the PES membrane flow with the addition of TiO_2 additive using DMF solvent. Based on Figure 7, it is typically discovered that the resultant flow decreases with increasing PES polymer concentration. A 20% PES membrane has a water flux of 0.467 L/m^2/hour at a pressure of 2.5 bar compared to a 15% PES membrane's 0.733 L/m^2/hour. The outcome demonstrates that the flux value of the 15% PES membrane is higher than that of the 20%

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PES membrane. Membranes made of PES 15% and PES 20% display distinct flux values. This is because the membrane will be denser and have a greater flux value as the concentration of membrane-forming polymers increases. The flux value is impacted by the addition of TiO_2 as an additive to the PES membrane [29].

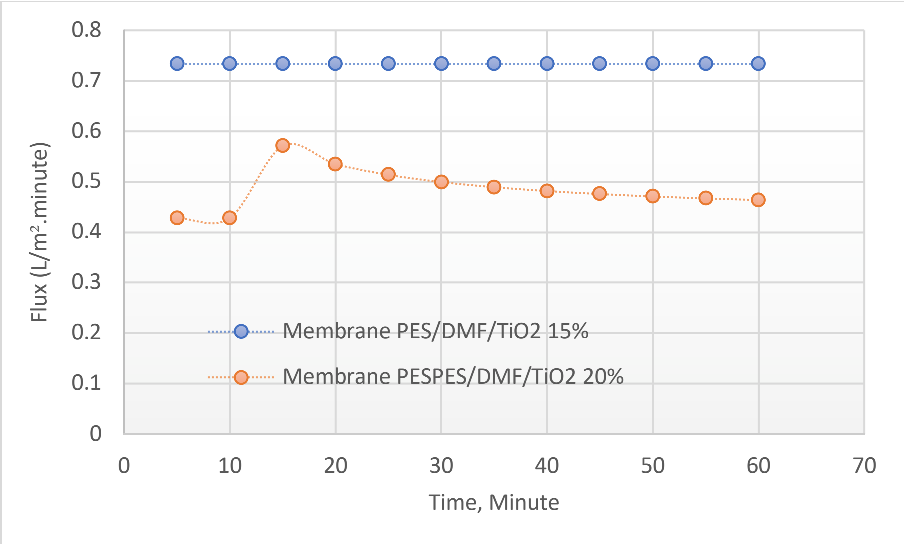

Figure 7. Graph of the relationship between flux values and pressure on various types of membranes

3.3.2 Microplastic Rejection Coefficient Analysis

The size range of the discovered microplastics is 0.80mm to 1.91mm. P of 2.5 bar is used in this analysis. Figure 8 displays the findings of the rejection coefficient analysis. Figure 8 demonstrates that the rejection of microplastics rises with the addition of polymers. It was discovered that a PES 20%/DMF/TiO_2 membrane with an average pore size of 2,817 m had a 94% microplastic rejection rate, while a PES 15%/DMF/TiO_2 membrane with an average pore size of 2,017 μm had an 83% microplastic rejection rate. Results from the PES 20%/DMF/TiO_2 membrane are superior to those from the PES 15%/DMF/TiO_2 membrane.

This is consistent with the findings of morphological structure analysis (SEM), which demonstrate that the addition of TiO_2 causes the size of the pores created to decrease, increasing the rate at which microplastic rejection rises. TiO_2 affects porosity, which results in tighter membrane pores [40]. When compared to a 15% PES membrane with the same number of additives, 0.45%, the 20% PES membrane has more dense (higher density) holes. This is because more membrane-forming polymers are concentrated, resulting in more solid membranes and a lesser flux value. This results in a significant amount of microplastic being retained on the membrane's surface and improves the separation process; the output permeate has a lower concentration than the incoming feed.

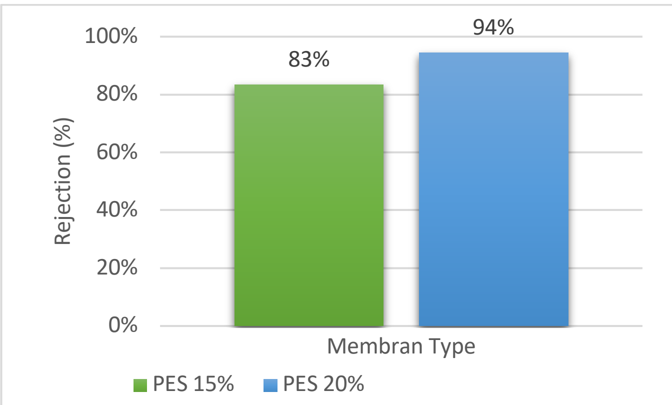

Figure 8. Microplastic rejection results on 15% PES and 20% PES membranes

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4. CONCLUSION

The membrane structure of the PES 15%/DMF/TiO_2 membrane and PES 20%/DMF/TiO_2 membrane exhibits a finger-like macrovoid (morphology). The two types of membranes' structures differ because the 20% PES membrane solidifies more quickly than the 15% PES membrane during the membrane formation process because its printing solution contains more polymer than that of the 15% PES membrane, which results in a denser structure. A PES/DMF/TiO_2 membrane is used in the water collection system for the Krueng Aceh River to collect microplastics of different forms, including films, pieces, and fibers. According to the results of the PES/DMF/TiO_2 membrane performance test for removing microplastics, the water flux for the 15% PES membrane was 0.733 L/m^2.hour and 0.467 L/m^2.hour for the 20% PES membrane. A 20% PES membrane's rejection coefficient is 94%, compared to a 15% PES membrane's value of 83% for the removal of microplastics.

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