Journal of Airport Engineering Technology (JAET)
https://e-journal.poltekbangplg.ac.id/index.php/jaet

Volume: 3, No. 2. June, 2023: pp. 68-74
E-ISSN; P-ISSN: 2774-9622; 2775-4871
DOI: 10.52989/jaet.v3i2.100
Submitted: 2023-04-03; Revised: 2023-04-19; Accepted: 2023-05-01

POLYVINYLIDENE FLUORIDE MEMBRANES WITH TIN (IV) DIOXIDE (SNO_2) ADDITIVES: ENHANCING WATER TREATMENT FOR AIRPORT ECO GREEN

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Abstract

Water treatment is a significant process of realizing Eco Airport in airport development that does not cause environmental damage, protects the environment, and seeks to minimize the impact of environmental pollution due to airport operations. The growth and development of the global economy make a significant contribution resulting in increasingly uncontrolled disposal of wastewater, resulting in a series of environmental problems related to providing clean water at airports. This study discusses water filtration using membrane technology with Polyvinylidene Fluoride (PVDF) polymer mixed with Tin (IV) Dioxide (SnO_2). This study aims to analyze the microstructure formed through Scanning Electron Microscopy (SEM) testing and determine the mechanical properties and performance in water treatment of mixed PVDF and Tin (IV) Dioxide (SnO_2) membranes. This research is a new method in water treatment. The research method used was quantitative with initial membrane specimen formation, membrane preparation, flat sheet method, and testing methods (tensile testing, Scanning Electron Microscopy (SEM) observations, and Clean Water Permeability (CWP) testing. The results of this study, namely the formation of mixed membranes, showed the corresponding results as an alternative to water filter membranes. PVDF and SnO_2 mixed membranes subjected to tensile tests using ASTM D638 standards, the surface structure of mixed membranes using SEM showed significant differences at each concentration, and the performance of water treatment performed with CWP showed an increase with increasing PVDF concentration and SnO_2 for the airport. The conclusion is that water treatment performance using Clean Water Permeability (CWP) increases with increasing concentrations of PVDF and SnO2, which are suitable for airports.

Keywords: *eco airport, tensile strength, membrane, permeability, SnO_2*

Introduction

Wastewater treatment is the most important step in reducing water pollutants and improving the quality of the water environment because it offers clean water with guaranteed quantity and quality in many arid areas, coastal areas, or remote locations. Wastewater treatment results from public interest in the environmental impact caused by the discharge of untreated or partially treated wastewater and the issuance of state laws on water pollution control (Khaliq, 2019).

An environmentally friendly airport (Eco-Airport) is sustainable and takes a comprehensive management approach to ensure economic continuity, operational efficiency, and natural resource conservation (Baxter et al., 2018). The complexity of the activities at the airport is one of the sources that will potentially harm the environment. One of the forms of waste generated due to airport operations is domestic waste in the form of wastewater. The wastewater comes from the high use of clean water for airport management, including canteens, restaurants, offices, shops, use of toilets, aircraft operations, and others (Parasara et al., 2015).

Domestic wastewater produced by Husein Sastranegara Airport is in the form of gray water and black water and is treated in one STP using a biofil system. Wastewater treatment at Husein Sastranegara Airport has not maximized because the results of laboratory tests during the 2017-2019 period show that almost all parameters still exceed the predetermined threshold values and still smell a strong odor around the wastewater treatment plant. The 3R principle that is Reduce, Reuse, and Recycle has not been fully implemented, such as no use of treated waste water or rainwater (Raffah, 2021).

Global economic growth and development significantly contribute to human welfare, one of the influencing factors is industrialization and urbanization (Fard et al., 2018). Industrial developments, both oil and gas and non-oil and gas, which cause water, air and soil pollution caused by industrial waste products. Disposal of wastewater is getting out of control, resulting in a series of environmental problems related to providing clean water. Water plays a major role in most household and industrial processes (Kumar, 2013). Economic and industrial growth is superior, wastewater discharges from industrial and municipal sources are also growing at the same pace. The composition of industrial wastewater is very complex, ranging from water, pathogenic and non-pathogenic bacteria to gases such as hydrogen sulfide, carbon dioxide and methane (Li et al., 2019).

Heavy metal ions in generated wastewater cannot be degraded microbially and therefore migrate through soil, water and air, contaminating drinking water and the food chain and can damage human health and the environment (Fan et al., 2016). Membrane definitively means a thin layer between two phases and serves as a selective separator. Membrane separation works based on differences in diffusion coefficients, pressure, or concentration differences (Mirwan et al., 2020). Membranes have been considered as a technology that can overcome global water shortages (Talaeipour et al., 2017). Membranes have many advantages such as low energy consumption, low use of chemicals, stable operation, easy scaling to low maintenance costs (Arahman, 2014).

Therefore modifications are made to the polymer membrane to increase the hydrophilicity of the membrane, such as mixing polymer with third compounds, chemical grafting and surface modification of the membrane (Penboon et al., 2019). PVDF is widely used in industry in various applications due to its excellent chemical stability, good thermal stability, high mechanical strength and flexibility, radiation resistance and low cost (Qurrota & Kusumawati, 2021).

Tin (IV) Dioxide (SnO_2) is a type of metal oxide that has potential as a photocatalyst (Vince, 2018). SnO_2 has widely used in various applications because of its high chemical stability and low toxicity, SnO_2 can be used to decompose compounds and toxins that are harmful to the environment in wastewater. In addition, SnO_2 has no adverse health effects and is difficult for the human body to absorb when inhaled or injected. Membrane modification by mixing Tin (IV) Dioxide (SnO_2) in PVDF polymer is expected to improve the mixed membrane's performance, starting from characteristics, and mechanical properties to performance against water treatment.

Methods

Research on the manufacture of PVDF membranes uses quantitative research methods (Almeida et al., 2017) by preparing membrane specimens by preparing the necessary materials and equipment. Like PVDF, Tin Dioxide (SnO_2) and N, N-Dimethylformamide (DMF) obtained from PT. Dira Sonita, Palembang. The membrane manufacturing equipment includes: the mixing process assisted by a magnetic stirrer at the Faculty of Engineering, Sriwijaya University. Identification of natural properties assisted by Scanning Electron

Microscopy (SEM) and identification of strength assisted by a tensile test conducted at the Bangka Belitung Manufacturing Polytechnic, as well as identification of permeate values assisted by a Clean Water Permeability (CWP) tool. Then the membrane preparation was carried out, namely making membranes on 3 specimens with a ratio of the weight fraction (wt%) of the mixture and the addictive substance in each sample, namely 15wt%, 17.5wt% and 20wt%.

Table 1. Membrane Composition

Membrane	PVDF (gram)	DMF (gram)	SnO_2 (gram)
PVDF SnO_2 15wt%	7.5	42.425	0.075
PVDF SnO2 17.5wt%	8.75	41.1625	0.0875
PVDF SnO2 20wt%	10	39.9	0.1

After preparing the membrane, printing the membrane is done. This study used a glass plate and duct tape as a membrane template. PVDF membranes were made by phase inversion using the immersion method in a coagulation bath filled with water, the results of the membrane printing using this method were in the form of flat sheets. The membrane is cut using a crankcase knife to specified dimensions according to ASTM D638 Type IV (Jhansi, 2016).

The membrane was printed and cut, then tested the PVDF membrane. The test determines the characteristics, mechanical properties, and water treatment performance of polymer materials used as water filter membranes. This research involved tensile testing, Scanning Electron Microscopy (SEM) testing, and Clean Water Permeability (CWP) testing. Tensile testing is a basic test used to determine the mechanical strength of a material, in this case, a membrane. The test specimens carried out in this test were in the form of a flat sheet that was stretched until it broke, using a Tensile test tool (ZWICK ROEL Material Testing Machine) and using the ASTM D 638.05/2008 Tensile Test On Plastics standard.

Figure 1. ZWICK ROEL Material Testing Machine

SEM observation is a type of testing using an electron microscope by scanning the specimen using a high-energy electron beam ona scan with a raster pattern.

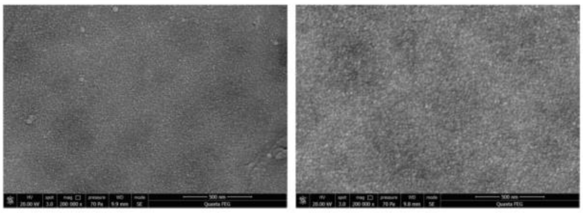

Figure 2. SEM observation results on PVDF membranes

Clean Water Permeability Test (CWP) aims to determine which membrane is porous or stable over the entire surface. In this test the membrane was tested for 1 hour using a dead-end system as (Kesari et al., 2021). The dead-end system is a membrane filtering process by flowing water directly into the membrane (Toledo & Mas, 2018). In this case an angle will be formed between the direction of water flow and the membrane pores.

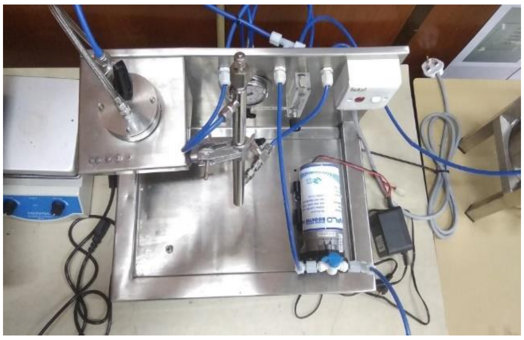

Figure 3. Clean Water Permeability (CWP)

Results and Discussions

In this research, polymer membrane mixing of Polyvinylidene fluoride (PVDF), N,N-DimethylFormamide (DMF) was carried out with 1% Tin Dioxide as an additive. Samples were prepared with 3 samples, namely PVDF&S nO_2 (15 wt%), PVDF&SnO2 (17.5 wt%) and PVDF&SnO2 (20 wt%). Each sample was tested for tensile strength using the Zwick Roell Material Testing Machine to analyze the mechanical properties of the membrane, tested the water treatment performance with a clean water permeability (CWP) tool to analyze the strength of the membrane during operation, tested the surface microstructure of the membrane analyzed using a Scanning Electron tool. Microscope (SEM),

Tensile testing was carried out on the PVDF membrane by mixing Tin Dioxide (SnO_2) using the ASTM D638-04 standard. ZWICK ROEL Material Testing Machine (Type BT2-FR020TH.A60) is a tensile tester for this test at the Bangka Belitung Manufacturing Polytechnic. Tensile testing on Tin (IV) Dioxide (SnO_2) membranes was carried out to analyze and determine the durability and ability of these membranes to withstand tensile loads. Tensile testing was carried out at each predetermined membrane concentration, namely 15wt%, 17.5wt%, and 20wt%, with each test 5 times to get the best results.

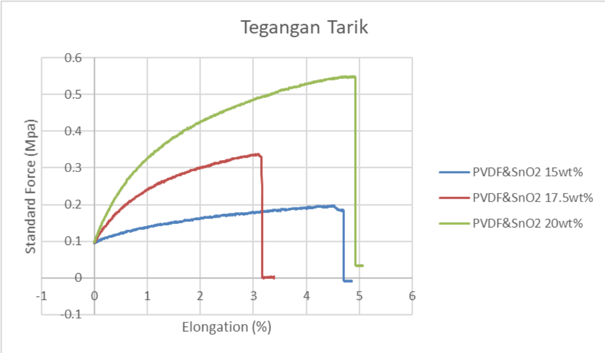

Figure 4. Graph of the average tensile stress of the specimens for each composition

A mixture of PVDF & SnO_2 membranes with concentrations of 15%, 17.5%, and 20% using the Flat Sheet method shows that with increasing concentration, the tensile strength of the membrane or ability to withstand loads increases. The PVDF@SnO_2 membrane with a concentration of 20% has a strength of 0.565 MPa; for a concentration of 17.5% and 15%, it is 0.352 Mpa and 0.192 Mpa, respectively that is directly proportional to previous research that increasing the concentration of PES and PVDF by mixing TiO2 in the membrane-making mixture can increase the tensile strength of the membrane.

Mixed membrane morphology between PVDF and SnO2 using a Scanning Electron. Microscope (SEM), observations of the mixed membrane structure with different weight percentages shown in Figure 6-8.

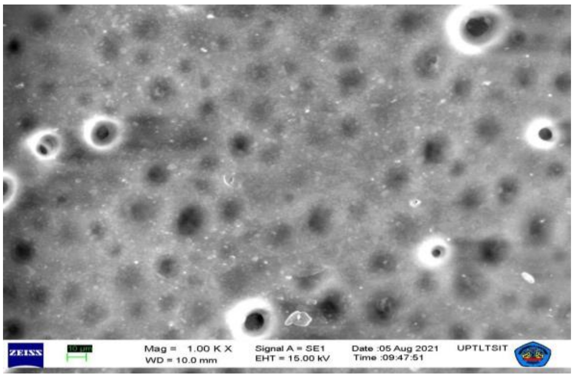

Figure 5. SEM Membrane PVDF & SnO_2 15 wt%

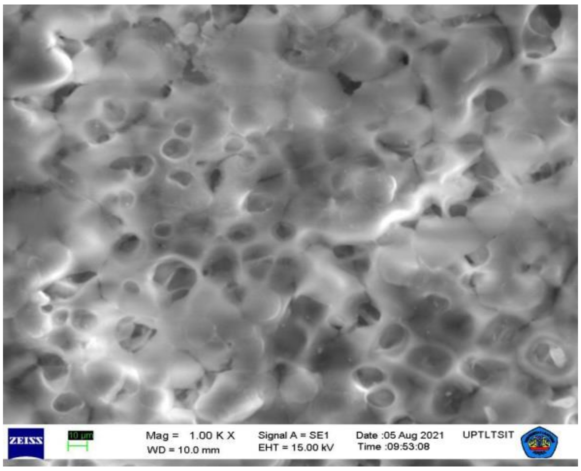

Figure 6. SEM Membran PVDF & SnO_2 17.5 wt%

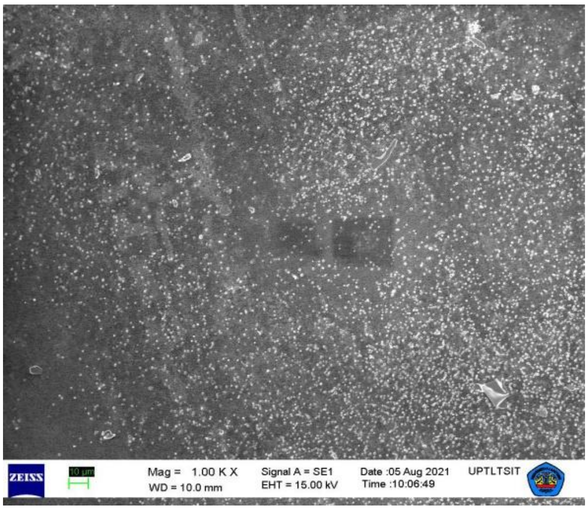

Figure 7. SEM Membran PVDF & SnO_2 20 wt%

The results of Scanning Electron Microscopy (SEM) observations with different concentrations show significant differences between the three concentrations, PVDF and SnO2 with a concentration of 15% have large pores compared to the others and agglomerations are spread over the entire surface, whereas at a concentration of 17.5 % membranes have almost the same surface but little agglomeration occurs.

This agglomeration greatly affects the strength of the membrane in holding the load, because the agglomeration becomes a stress center when the water is filtered. while the pore size that is not dense affects the reduced area of the membrane when the tensile test is carried out. The concentration of Tin (IV) Dioxide (SnO_2) membranes which is 0 makes the fiber braid structure that is formed tighter, this makes the tendency for porosity to be smaller and denser in the membrane.

The formation of mixed membranes between PVDF and SnO_2 polymers with respective concentrations of 15wt%, 17.5wt% and 20wt% carried out due to knowing and analyzing the good processing performance from previous studies. To determine the performance of water treatment from PVDF&SnO2 membranes, Clean Water Permeability (CWP) was used. The membrane was tested for 1 hour, with a membrane area of 0.001809 m^2 using a dead-end system.

Table 2. Membrane Flux Calculation Fluks Membran

Spesimen	Volume Permeat (L)	Luas Membran (m^2)	Waktu (h)	Fluks (L/m^2h)
PVDF & SnO_2 15%	0.042	0.001809	1	23,22
PVDF & SnO_2 17,5%	0.059	0.001809	1	32,614
PVDF & SnO_2 20%	0.086	0.001809	1	47,54

Increase in flux results that occur in the membrane increases significantly. The concentration of 20wt% PVDF and SnO_2 with a flux value of 47.54 Lm-2h-1 was inversely proportional to the 15wt% concentration with the lowest flux value of 23.22 Lm-2h-1. This increase in the 20wt% membrane flux indicated that mixing PVDF and SnO_2 polymers succeeded in increasing the membrane's hydrophilicity because the membrane's flux value also increased with increasing hydrophilicity.

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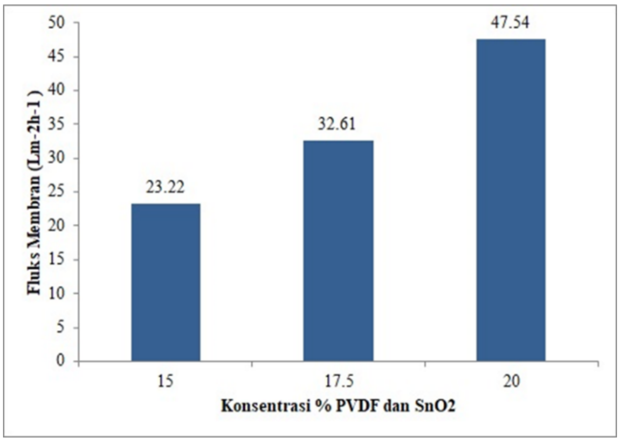

Figure 8. PVDF and SnO_2 flux graphs

This hydrophilicity is one of the properties that a filtration membrane must possess, because PVDF membranes are prone to fouling and low flux, that happens because the flux is the amount of water that passes through the membrane. The longer the time when water passes through the membrane, indicates that the membrane pores are very small.

Conclusion

The average application of the eco airport concept has constraints such as limited land and principal permits. Environmental Impact Analysis certification has been carried out in the form of an environmental management plan and environmental monitoring plan to control environmental pollution due to airport operations. Using a mixed PVDF and SnO_2 membrane, a tensile test carried out using the ASTM D638 standard. This test showed an increase in the average tensile stress of each concentration. With the surface structure of the mixed membrane using SEM showing significant differences at each concentration, agglomeration occurs on the surface of the membrane due to uneven mixing. The membrane's pore size density is directly proportional to the tensile stress that arises in the PVDF membrane. Water treatment performance using Clean Water Permeability (CWP) shows an increase with increasing concentrations of PVDF and SnO_2 which are good for airports.

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