PEAT WATER PURIFICATION USING MICROFILTRATION CERAMIC MEMBRANES BASED ON KAOLIN AND ACTIVATED CARBON

Hayu Zuhra[1]*, Alfian Putra[1], Salmyah[1], Selvie Diana[1]
[1]Chemical Engineering, Lhokseumawe State Polytechnic, Jl. Banda Aceh-Medan Km. 280.3, Buketrata, Mosque Punteut, Blang Mangat, Lhokseumawe City, Aceh 24301, Indonesia
*Email: hayuzuhra231@gmail.com

ABSTRACT

Peat water is brown in color, acidic, and contains high levels of organic matter, meaning it does not meet clean water standards. This study used kaolin-based microfiltration ceramic membranes and activated carbon for peat water purification. The membrane composition varied from kaolin (80, 85, 90, 95, 100)% and activated carbon (20, 15, 10, 5, 0)%, sintering at temperatures of 900, 950, 1000, 1050, and 1100°C to determine the effect of composition and sintering temperature on membrane characteristics and filtration performance. Characterization was performed through density, porosity, flux, surface morphology (SEM), and water filtration tests for pH, TDS, and turbidity. The best results were obtained with a membrane composed of 90% kaolin and 10% activated carbon sintered at 1100°C, with a porosity of 40.08%, density of 1.40 g/cm^3, flux of 272.38 L/m^2·hour, and pore size of 0.56–3.44 μm. Filtration tests showed a 94% reduction in turbidity, an increase in pH from 4.5 to 6.8, and a 41% reduction in TDS.

Keywords: Ceramic Membrane, Kaolin, Microfiltration, Peat Water, Sintering

1. INTRODUCTION

1.1 Background

Peat water is a common source of surface water found in swampy areas and lowlands. This water is reddish-brown in color, acidic, and contains high levels of organic matter, meaning it does not meet clean water standards (Risnawati, 2019). If not properly treated, peat water cannot be used for daily needs and can even cause health problems. This condition often poses a challenge for communities in peatland areas and hinders access to safe drinking water (Bella et al., 2022).

One solution for treating peat water is membrane technology. Ceramic membranes have good heat resistance, mechanical strength, and chemical stability. However, conventional ceramic membranes (alumina, zirconia) are expensive and difficult to obtain, so more economical local materials are needed, such as kaolin, which is abundant in Indonesia and has hydrophilic properties that greatly support the filtration process. The addition of activated carbon can function as a pore former and increase the absorbency of the membrane (Nahar et al., 2022).

This also affects the properties of the membrane, such as porosity, density, and flow rate (Yulianto et al., 2024). However, there are still weaknesses, namely the lack of an optimal kaolin-activated carbon formulation that has been specifically tested for peat water filtration and evaluated for its suitability with clean water standards.

Therefore, this study was conducted to examine the effect of kaolin and activated carbon composition and sintering temperature on the characteristics of microfiltration ceramic membranes. This study aims to obtain the best membrane composition with optimal physical properties and good filtration performance so that it can be used as an alternative technology for effective, economical, and environmentally friendly peat water treatment.

2. RESEARCH METHODS

Research methodology

2.1 Research Place

This research was conducted at the Chemical Engineering Unit 1 Laboratory, Lhokseumawe State Polytechnic.

2.2 Tools and Materials

2.2.1 Tools used

The equipment used in this study included analytical scales, 230 mesh sieves, 300 mL glass beakers, laboratory glassware, gloves, grinding mills, Carbolite CWF 1200 furnaces, molds with diameter of 5 cm and a thickness of 0.8 cm, KAP 250/25 kN UTM (ELE) compressive strength testing machine, pH meter, turbidity meter, TDS meter, and scanning electron microscope (SEM).

2.2.2 Materials used

The materials used in this study included kaolin, activated carbon, PVA (polyvinyl alcohol), distilled water, and peat water.

2.3 Experimental Treatment Design

2.3.1 Fixed Variables

1. Mold: D = 5 cm, t = 0.8 cm
2. PVA composition: 5%
3. Sieve size: 230 mesh
4. Mixing time: 10 minutes

2.3.2 Independent Variables

1. Kaolin: 80%, 85%, 90%, 95%, 100%
2. Activated carbon: 20%, 15%, 10%, 5%, 0%
3. Sintering temperature: 900°C, 950°C, 1000°C, 1050°C, and 1100°C

2.3.3 Dependent Variables

1. Selectivity test: pH, TDS, Turbidity
2. Characteristic test: Flux, Porosity, Density, Morphology Structure

2.4 Experiment and Testing Procedures

2.4.1 Production of Kaolin-Activated Carbon-PVA Membrane

1. Sift kaolin and activated carbon with a size of 230 mesh.
2. Weigh 100 grams of kaolin and activated carbon mixture, place it in a beaker, then label it accordingly.
3. Place the mixture in a grinding machine, add PVA, then stir using the grinding machine for 10 minutes. After that, place iron balls in the grinding machine and continue grinding for 10 minutes until all ingredients are evenly mixed.
4. The membrane printing process is carried out by pouring the mixture of kaolin paste, activated carbon, and PVA into a mold. The air trapped inside is removed by pressing slowly using a membrane press machine until the surface is flat.
5. After printing, the membrane is removed from the mold and dried at room temperature for 2 days (2x24 hours).
6. The dried membrane is then gradually heated at temperatures of 900°C, 950°C, 1000°C, 1050°C, and 1100°C, with a heating time of 2 hours for each stage.

2.4.2 Stages of the Filtration Process Using Ceramic Membranes

1. Preliminary tests were conducted by flowing pure water through the membrane to detect possible leaks or damage before use in the main study.
2. The initial pH and TDS parameters of the raw water (peat water) were analyzed, then preliminary filtration was carried out using cloth as a filter medium before the membrane filtration process.
3. Peat water is flowed through the inlet to the membrane surface with

the help of compressed air, which acts as a driving force to pass through the membrane media.

4. The filtrate (permeate) that has passed through the membrane is collected and its volume is measured.
5. Next, the resulting permeate is analyzed to determine the pH, TDS, and turbidity values.

3. RESULTS AND DISCUSSION

3.1 Research Results

Table 3.1 Ceramic Membrane Analysis and Testing Results Data

Composition of Kaolin and Activated Carbon	Temperature Sintering (°C)	Analysis			
		Density (gr/cm³)	Flux (L/m²·h)	Porosity (%)	Morphological Structure (µm)
M1 (80%:20%)	900	1,06	356,42	51,82	-
	950	1,19	306,10	46,60	-
	1000	1,25	296,18	44,85	-
	1050	1,19	312,39	47,56	-
	1100	1,21	274,70	40,42	-
M2 (85%:15%)	900	1,08	319,48	46,45	-
	950	1,28	255,52	38,90	-
	1000	1,32	257,35	38,97	-
	1050	1,28	321,67	48,97	-
	1100	1,35	254,37	37,43	-
M3 (90%:10%)	900	1,24	333,86	48,54	-
	950	1,27	256,37	39,03	-
	1000	1,41	262,17	39,70	-
	1050	1,27	300,32	45,72	-
	1100	1,40	272,38	40,08	0,56 - 3,44
M4 (95%:5%)	900	1,23	281,50	40,93	-
	950	1,40	253,74	38,63	-
	1000	1,48	248,03	37,56	-
	1050	1,40	289,54	44,08	-
	1100	1,49	250,58	36,87	-
M5 (100%:0%)	900	1,24	266,32	38,72	-
	950	1,41	250,92	38,20	-
	1000	1,53	249,48	37,78	-
	1050	1,41	313,27	47,69	-
	1100	1,50	258,31	38,01	1,23 - 3,12

3.2 Discussion

Research on the manufacture of kaolin- and activated carbon-based microfiltration ceramic membranes with varying compositions and sintering temperatures has been conducted. Testing included physical characterization of the membranes (density, porosity, flow rate), pore morphology analysis using SEM, and testing of peat water filtration performance based on pH, TDS, and turbidity parameters.

3.2.1 Density

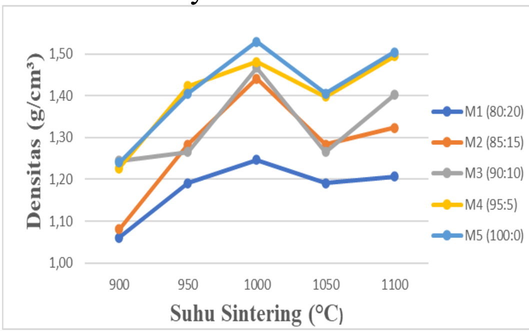

Figure 3.1 Relationship Between Sintering Temperature and Density

Based on the analysis results, the membrane density varies according to the composition of kaolin, activated carbon, and sintering temperature. The higher the kaolin content, the higher the membrane density tends to be because kaolin is inorganic and does not burn during the sintering process, allowing it to form a dense and strong structure (Nisah et al., 2024). Conversely, activated carbon acts as a porogen that burns during sintering, leaving pores and causing the membrane density to decrease (Yulianto et al., 2024).

The results showed that at a temperature of 1000 °C, sample M5 (100% kaolin) had the highest density of 1.50 g/cm³, while sample M1 (80% kaolin and 20% activated carbon) had the lowest density of 1.25 g/cm³. The increase in temperature from 900 °C to 1000 °C also caused an increase in density in all samples. For example, the density of M4 increased from 1.23 g/cm³ (900 °C) to 1.48 g/cm³ (1000 °C), indicating a densification process, namely the combination of kaolin particles that produced a denser structure.

However, at a temperature of 1050 °C, some samples, such as M1 and M3, experienced a slight decrease in density. For example, the density of M1 decreased from 1.25 g/cm³ (1000 °C) to 1.19 g/cm³ (1050 °C). This decrease is believed to be caused by more complete combustion of the activated carbon, which produces additional pores in the membrane. When the temperature is raised to 1100 °C, the density increases again in almost all samples, indicating that the densification process continues and the membrane structure becomes denser and more stable.

Overall, the M5 sample (100% kaolin) maintained the highest density at most sintering temperatures. This proves that increasing the kaolin content and setting the sintering temperature appropriately can produce membranes with better density and mechanical strength for water filtration applications.

3.2.2 Porosity

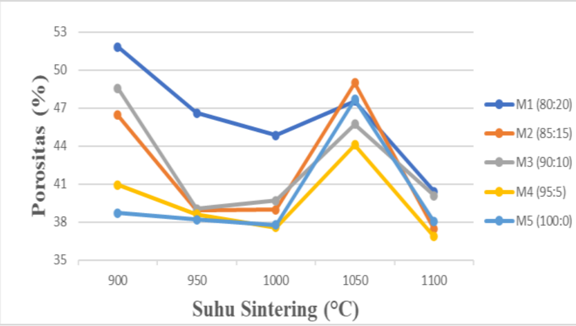

Figure 3.2 Relationship Between Sintering Temperature and Porosity

Based on the analysis results, the porosity value of the membrane differed for each variation in kaolin–activated carbon composition and sintering temperature. Samples with higher activated carbon content, such as M1 (80% kaolin and 20% activated carbon), showed the highest porosity of 51.82% at a temperature of 900 °C. This occurs because activated carbon acts as a porogen that burns during the sintering process, leaving cavities or pores in the membrane structure. Conversely, M5 (100% kaolin), which does not contain activated carbon, has a lower porosity of 38.72% at a temperature of 900 °C because kaolin is thermally stable and does not form new pores.

The sintering temperature also has a significant effect on porosity. An increase in temperature from 900 °C to 1000 °C generally causes porosity to decrease due to the densification process, when the particles begin to fuse more tightly together, closing the pores. For example, the porosity of M2 decreased from 46.45% (900 °C) to 38.97% (1000 °C). Interestingly, when the temperature was increased to 1050 °C, the porosity increased in almost all samples. For example, M5 increased from 37.78% (1000 °C) to 47.69% (1050 °C), even though it did not contain activated carbon. This increase is thought to be due to the release of water vapor or gas from within the kaolin, which creates secondary pores or microcracks.

However, when the temperature was raised again to 1100 °C, the porosity decreased again. At this temperature, the particles fused more completely, closing the pores and producing a denser and stronger membrane. These results are consistent with previous research findings which state that porogenic materials such as activated carbon form pores when burned, but high sintering temperatures can close the pores through a process of further compaction (Azaman et al., 2021).

In the context of peat water purification applications, ideal porosity is very important to maintain a balance between water flow capacity and filtration ability. According to (Sawunyama, Olatunde, et al., 2024), the optimal porosity for microfiltration membranes is in the range of 40% to 50%. In this range, the membrane is capable of producing good flux while filtering colloidal particles, organic compounds, and heavy metals commonly found in peat water.

3.2.3 Flux

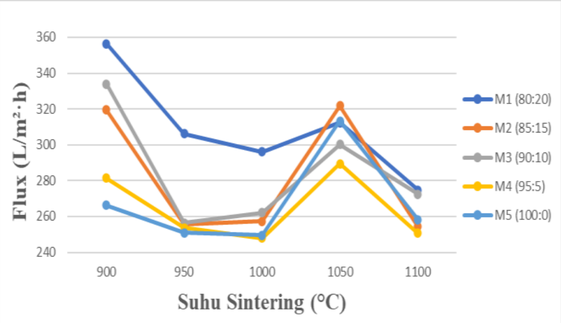

Figure 3.3 Relationship Between Sintering Temperature and Flux

The results of the study show that membrane flux is greatly influenced by material composition and sintering temperature. Compositions with higher activated carbon content, such as M1 (80% kaolin and 20% activated carbon), had the highest flux of 356.42 L/m²·hour at 900 °C with a porosity of 51.82%, while M5 (100% kaolin) only reached 266.32 L/m²·hour with a porosity of 38.72%. This is in accordance with the theory that activated carbon burns during sintering, forming water flow paths that increase flux (Sawunyama, Oyewo, et al., 2024).

However, high porosity does not always result in high flux. For example, at 1050 °C, M5 has a higher porosity (47.69%) than M2 (46.45%), but the flux of M5 (313.27 L/m²·hour) is lower than that of M2 (319.48 L/m²·hour). This shows that pore size, distribution, and connectivity also determine the rate of water flow (Saifuddin et al., 2019).

Sintering temperature also affects the flux. At 1050 °C, most samples experienced an increase in flux, for example, M2 reached 321.67 L/m²·hour, while M5 without activated carbon reached 313.27 L/m²·hour. This increase is thought to be due to the formation of secondary pores from the release of kaolin gas at high temperatures. However, at 1100 °C, the flux decreased, for example, M1 decreased to 274.70 L/m²·hour, because densification narrowed the pores, thereby reducing the permeability of the membrane.

Overall, the membrane flux values in this study ranged from 250.92 to 356.42 L/m²·hour, indicating that the composition of kaolin–activated carbon and sintering temperature are very important for optimizing filtration performance.

3.2.4 SEM (*Scanning Electron Mikroscope*)

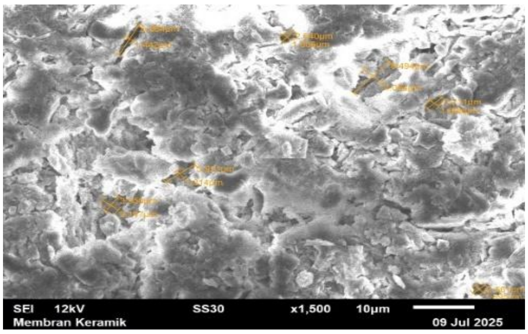

Figure 3.4 SEM Analysis Results on M3 (Kaolin:Activated Carbon) = (90:10)%

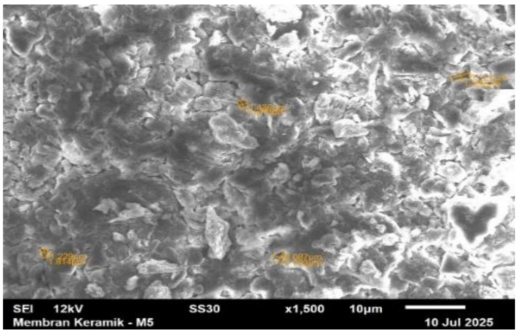

Figure 3.5 SEM Analysis Results on M5 (Kaolin:Activated Carbon) = (100:0)%

SEM testing was used to observe the shape, size, and distribution of membrane pores after sintering to ensure that the characteristics were suitable for microfiltration applications.

The test results showed clear differences between the M3 membrane (90% kaolin + 10% activated carbon) and the M5 membrane (100% kaolin). The M3 membrane has a more porous surface with pore sizes varying from 1.44 to 8.49 µm (average 3.51 µm). The burnt activated carbon leaves voids that increase porosity and filtration rate, but the non-uniform pore size can reduce the ability to filter very fine particles.

In contrast, the M5 membrane has a denser surface and more uniform pores, ranging from 1.23 to 3.12 µm (average 1.80 µm). Since there is no burnt activated carbon, the pores are formed solely from the shrinkage of kaolin particles, resulting in better mechanical strength and more stable filtration, albeit at a lower filtration rate.

In general, the addition of activated carbon increases porosity and filtration speed, while pure kaolin membranes provide consistent pore size and finer filtration.

3.5 Application of Ceramic Membrane Samples for Peat Water Purification

A ceramic membrane composed of 90% kaolin and 10% activated carbon, sintered at 1100 °C, was selected as the best membrane, with a porosity of 40.08%, a flux of 272.38 L/m²·h, and a micropore size of 0.56–3.44 µm. Filtration tests on peat water showed a significant improvement in water quality.

Table 3.2 Peat Water Test Results

Parameter	Before Filtration	After Filtration	Quality Standard (Ministry of Health Regulation No. 492/2010)
pH	4,5	6,8	6,5 – 8,5
TDS (mg/L)	530	312	Maks. 500
Turbidity (NTU)	30,21	1,91	Maks. 5
Color	Brown	Clear	Colorless / transparent

The filtration results showed an increase in pH from 4.5 to 6.8, a 41.13% decrease in TDS, and a 93.68% reduction in turbidity. The activated carbon in the membrane absorbs organic acid compounds and dissolved substances, while the micro pores trap colloidal particles and large molecules (Goswami & Pugazhenthi, 2020).

The most obvious change was in the color of the water, from cloudy brown to clear, proving the effectiveness of the combination of activated carbon adsorption and micro pore filtration. This membrane meets microfiltration criteria and can efficiently improve peat water quality.

4. CONCLUSION

4.1 Conclusion

Based on the results of the research conducted, the following conclusions can be drawn:

1. The composition of kaolin and activated carbon affects the physical properties of ceramic membranes. Higher kaolin content increases density and decreases porosity, while the addition of activated carbon results in more pores and higher filtration flux.
2. Sintering temperature affects the size and structure of membrane pores. Too low a temperature prevents optimal particle bonding, resulting in a brittle and less dense membrane, while too high a temperature causes pore narrowing or closure due to excessive densification.

4.2 Suggestions

Further research is recommended to explore variations in operating pressure, duration of repeated use, and the use of other local materials to improve membrane efficiency and extend its service life. Furthermore, the optimal sintering temperature should remain within the range of 900–1100°C.

BIBLIOGRAPHY

Azaman, F., Al, M., Muhamad Nor, A., Rafizah, W., Abdullah, W., Razali, H., Zulkifli, R. C., Abbas, M., Zaini, A., & Ali, A. (2021). Review on natural clay ceramic membrane: Fabrication and application in water and wastewater treatment. / *Malaysian Journal of Fundamental and Applied Sciences*, *17*(1), 62–78.

Bella, A. sinam, Marlina, S., & Santoso, A. I. (2022). Processing Peat Water into Clean Water Using Simple Technology in Sabangau District, Bangkirai Village, Palangka Raya City. Scientific Journal of Environmental Engineering, *7*(2), 56–62.https://doi.org/10.33084/mitl.v7i2.3554

Goswami, kakali P., & Pugazhenthi, G. (2020). *Treatment of poultry slaughterhouse wastewater using tubular microfiltration membrane with fly ash as key precursor*. https://doi.org/10.1016/j.jwpe.2020.101361

Nahar, Sariadi, Nanang R.W., Novi Q.R., & Diana, S. (2022). Synthesis of Ceramic Membranes Based on Zeolite, Kaolin, and Activated Carbon Nano Particles from Palm Kernel Shells Using the Sintering Method. Proceedings of the National Seminar of Lhokseumawe State Polytechnic. *6*(1), A187–A190.

Nisah, F. A., Suci, F. C., Safariyani, E., Febriyani, P., Wahid, T. N., & Sena, M. R. (2024). The Effectiveness of Tubular Ceramic Membrane Made from Seashell and Clay for Groundwater Filtration. *Journal of Physics: Conference Series*, *2733*(1). https://doi.org/10.1088/1742-6596/2733/1/012025

Risnawati. (2019). *Purification of Peat Water Color Using Acid and Base Activated Microfiltration Membranes.*

Saifuddin, S., Elisa, E., Sami, M., Nahar, N., & Habibah, U. (2019). Improving River Water Quality Using Ceramic Membranes from Clay and Zeolites. *IOP Conference Series: Materials Science and Engineering*, *536*(1). https://doi.org/10.1088/1757-899X/536/1/012117

Sawunyama, L., Olatunde, O. C., Oyewo, O. A., Bopape, M. F., & Onwudiwe, D. C. (2024). Application of coal fly ash based ceramic membranes in wastewater treatment: A sustainable alternative to commercial materials. *Heliyon*, *10*(2), e24344. https://doi.org/10.1016/j.heliyon.2024.e24344

Sawunyama, L., Oyewo, O. A., Bopape, M. F., & Onwudiwe, D. C. (2024). Fabrication and characterization of low-cost ceramic membranes from coal fly ash and natural sand. *Sustainable Chemistry for the Environment*, *8*(August). https://doi.org/10.1016/j.scenv.2024.100165

Yulianto, B., Wahyudi, K., Sudiapermana, E., & Saepudin, A. (2024). Ceramic Membrane Made from Clay and Kaolin with a Mixture of Coconut Shell Activated Charcoal as a Groundwater Filter. *Jurnal Riset Teknologi Pencegahan Pencemaran Industri*, *15*(1), 10–14.