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Production of ceramic membranes made from porang *(Amorphophallus muelleri B.)* and zeolite and its utilization on jumputan wastewater treatment

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Abstract

Palembang has a rich art of weaving jumputan cloth. Jumputan fabric uses naphthol as a dye which if discharged into the river will affect the water. Porang (*Amorphophallus muelleri B.*) and zeolite have potential as absorbents in absorbing impurities in liquid waste from jumputan cloth through its modification into membranes. The purpose of this study was to determine the formulation and effectiveness of ceramic membranes from porang tubers and zeolites in treating jumputan cloth wastewater, and to characterize the permeate results from the membrane. This research uses ceramic membrane filtration method combined with coagulation using Poly Aluminum Chloride (PAC) and quicklime. Coagulation uses two stirring methods, namely fast and slow stirring. Filtration was carried out for 125 minutes and every 25 minutes the filtrate was sampled. After the filtration process, several parameters were analyzed, namely turbidity, color, TSS, and pH. The best turbidity value reduction was shown in membrane variation 2 at 50 minutes with a decrease of 68.71 %, a decrease in color concentration was shown in membrane variation 2 at 75 minutes operating time with a decrease of 69.19%, the decrease in TSS value is shown in membrane 2 at an operating time of 125 minutes with a decrease of 81.03 %. The highest pH increase was found in membrane variation 1 at an operating time of 125 minutes with an increase of 42.67 %. The filtration process with ceramic membranes is effective in reducing turbidity, color concentration, TSS, and increasing the pH of the waste.

Keywords: ceramic membrane, coagulation, jumputan wastewater, porang, zeolite.

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1. INTRODUCTION

Each region in Indonesia has its own cultural diversity which symbolizes the characteristics of each region. Palembang, the capital of South Sumatra, has a rich and diverse culture, one of which is the art of weaving jumputan cloth (Marintika & Melwita, 2021). Jumputan fabric is a type of fabric whose processing is done using a tie-dye technique which produces certain motifs from the dye. Jumputan fabric in Palembang City generally uses naphthol as a dye (Marintika & Melwita, 2021). Naphthol ($C_{10}H_8O$) is a type of synthetic dye consisting of the naphthol group AS (Anilid Acid) and a color generating component, namely diazonium (salt/cation). The

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release of these Color Concentration into river bodies will prevent the penetration of sunlight into the water, thus affecting the photosynthesis process of plants and ecosystem structure (Atirza & Soewondo, 2018). Apart from that, the fabric weaving industry uses a lot of Color Concentration that contain Fe (iron), Pb (lead), Cu (copper), and Cr (chrome) (Handes et al., 2021). Liquid waste used from jumputan production which is directly thrown into rivers without prior processing has an impact on reducing environmental quality and damaging the ecosystem because it affects the turbidity, temperature, taste and smell of the water. There are strategic steps to reduce waste by utilizing the potential of porang and zeolite as absorbents in absorbing impurities.

Porang tubers (*Amorphophallus muelleri B*.) are not trusted by farmers from South Sumatra for cultivation and are only limited to buying and selling seeds (Wulandari, 2021). Porang is usually only processed as raw material for flour, making glue and jelly, as well as animal feed. This is very unfortunate because there are 10 hectares of porang cultivation land in South Sumatra where the commodity can be utilized (Widyastuti, 2021). Porang has potential as an adsorbent because it contains glucose and mannose which can form strong hydroxyl bonds so that it absorbs cations (R. Wulandari et al., 2019). Porang has the potential to be used as a filtration medium. Related research is the processing of porang tubers as a lead ion biosorbent carried out (Lestari et al., 2022). Natural zeolite is a mineral mined directly from nature which is often an alternative absorbent in waste processing and a clarifier in the decoloration process (Triana & Ariana, 2023). Modification of natural zeolite in this research with an H_2SO_4 catalyst to obtain a different cation ratio. The use of porang as a filtration tool is still limited as an adsorbent and has not been used in making ceramic membranes. Ceramic membranes are membranes formed from a combination of metals and non-metals in the form of oxide compounds.

Ceramic membranes are included in inorganic membranes which are resistant to heat, acids and bases. The ceramic membrane made in this research will be mixed with clay as a membrane forming material (Arazaq et al., 2021). This research is focused on testing the optimal formulation for making ceramic membranes from porang and zeolite to adsorb jumputan fabric liquid waste which contains heavy metals and other impurities, such as BOD, COD, TSS, and turbidity above the threshold (Respati et al., 2022). This research also aims to analyze the effectiveness and characterization of membrane permeate as a waste processing tool. This waste processing does not only depend on coagulation the ceramic membrane adsorption process, but the waste must go through a stage first. Coagulation is a wastewater treatment method by destabilizing colloidal particles (Martina et al., 2018). This coagulation process functions to precipitate small particles that cannot settle on their own with the help of coagulants along with a fast or slow stirring (Husnah, 2019).

The coagulant used is Poly Aluminum Chloride (PAC). PAC is used because it can work at a wide pH level, does not become cloudy if used excessively, has optimal chloride levels so that it reacts quickly to damage organic substance bonds, and has sufficient base content so that extreme pH drops do not occur (Rahimah et al., 2018). Research conducted Heraningsih et al (2023) shows that ceramic membrane from zeolite powder, clay, and corn starch, can reduce the color concentration in batik liquid waste by 67,51 % and reducing turbidity levels by 86.67 %. The novelty of this research is using porang as a raw material for ceramic membranes that has never been done before in other studies. The purpose of this study was to determine the formulation and effectiveness of membranes from porang tubers and zeolites in treating jumputan cloth wastewater, and to characterize the permeate results from the membrane.

2. MATERIALS AND METHODS

2.1. Time and Place of Implementation

This program is implemented from June 16 to October 10, 2023 at the Separation and Purification Laboratory, Department of Chemical Engineering, Universitas Sriwijaya.

2.2. Tools and Materials

The tools used in the research are ceramic membrane housing nanotech 10 inch, furnace Muffle Furnace Digital DAIHAN SCIENTIFIC FHX-03, oven Memmert UN30, flowmeter, pressure gauge, ceramic membrane, pump, scales, glass beaker, 100 mesh sieve, ball mill. The materials used are jumputan cloth waste, zeolite, porang, clay, technical HCl 0,5 M, PAC, quicklime and distilled water.

2.3. Research Procedure

2.3.1. Preparation of Raw Material

Porang activated carbon is obtained by drying porang chips using an oven, then porang is put into a furnace at 400 ^oC for 2 hours and activated using 0.5 M HCl for 24 hours. The mass ratio of carbon and HCl is 1:5. The zeolite used was also crushed first, then activated using 0.5 M HCl for 24 hours with a mass ratio of 1:1.

2.3.2. Manufacturing of Ceramic Membrane

Ceramic membranes are used to re-filter the results of previous coagulation, as well as raising the pH of the waste. The ceramic membrane made is 20 cm long with a diameter of 5 cm. The ceramic membrane that is made is burned in a furnaces at a temperature of 1000 ^oC, for 36 hours.

2.3.3. Manufacturing and Preparation of Coagulation and Filtration

The manufacture of filtration equipment begins with the design of the tool shown in **Figure 1a**. This tool has dimensions of 75 cm high and 70 cm wide. The material used is hollow iron with a thickness of 1 cm. This tool has several parts, namely the part to put the membrane housing, a place for the flow meter and pressure gauge, and a place to put the hose and waste container. The coagulation device uses a reactor in the Sriwijaya University Sewage Treatment Laboratory which has a capacity of 12 L.

2.3.4. Waste Collection Stage and Initial Waste Analysis

The jumputan fabric waste used was taken in Tuan Kentang District, South Sumatra, which is known as a jumputan fabric producing center in Palembang. The jumputan waste used is approximately 50 L (each variation of membrane requires 15 L of waste). Before use, jumputan waste is left for 1 day so that the dirt in the waste can settle. The waste is then analyzed, includes COD, BOD, turbidity, TSS, color, and pH parameters.

2.3.5. Research Running Phase

The methods used are coagulation and filtration. The coagulation method was chosen so that it can precipitate small particles that cannot settle in the waste. The filtration process can be seen on **Figure 1a**. The coagulation method uses chemicals (coagulants). The coagulant used is Poly Aluminum Chloride (PAC) because it has a wide pH range and does not make the waste color cloudy. Apart from that, quicklime is also used to raise the pH of the waste so that PAC can react optimally. The dose of PAC and quicklime used is 1 gr/L of waste. Coagulation uses two stirring methods, namely fast and slow stirring. Fast stirring for 5 minutes at a speed of 200 rpm, while slow stirring for 15 minutes at a speed of 60 rpm. The second method is the filtration method. The filtration is carried out using a membrane derived from activated carbon, zeolite and clay. Filtration was carried out for 125 minutes and every 25 minutes a filtration sample was taken. The filtration process can be seen on **Figure 1b**.

(a)

(b)

Figure 1a. Coagulation Process**; 1b.** Filtration Process

2.3.6. Analysis of Permeate Results

After going through the stages of coagulation and filtration. The waste will be analyzed. The parameters analyzed are turbidity (SNI 06-6989.25-2005), TSS (SNI 6989. 3:2019), color (SNI 6989.80:2011) and pH (SNI 6989.11:2019), COD (SNI 6989.15:2019), and BOD (SNI 6989.72:2009) were not analyzed because the values obtained were already below the standards.

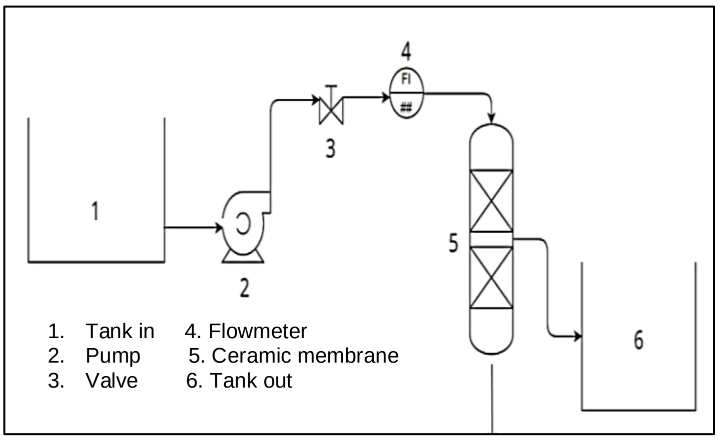
2.3.7. SEM analysis

SEM analysis was carried out to determine the shape of the pores and the composition or elements contained in the ceramic membrane used. The analysis was carried out in the laboratory of Sriwijaya State Polytechnic. The SEM used in this studry is Hitachi Scanning Electron Microscopes SU3800.

3. RESULTS AND DISCUSSION

3.1. Series of Waste Processing Equipment

The manufacturing process includes initial design (flowsheet), making a series of tools, and testing waste processing tools. The initial design for a series of waste processing tools was made using Microsoft Visio software by considering other complementary tools. The following is a series of real waste processing equipment as in **Figure 2.**



(a)

(b)

Figure 2a. Tool Set Schematic; **2b.** Series of Waste Processing Equipment

3.2. Porang Tuber Activated Carbon

The process of making activated carbon includes drying, carbonating, and activating porang tuber carbon. The purpose of making activated carbon is as a raw material for making membranes for processing liquid waste. The appearance of activated carbon from porang tubers can be seen in **Figure 3.**

Figure 3. Porang Tuber Activated Carbon

3.3. Ceramic Membrane

Membranes are made from clay, zeolite and porang activated carbon. The process of making membranes includes raw material preparation, membrane printing, membrane burning, and membrane drying. The ceramic membrane used has three variations in the percentage of materials (zeolite: activated carbon: clay):

a. 100 gr : 100 gr : 800 gr
b. 150 gr : 100 gr : 750 gr
c. 100 gr : 150 gr : 750 gr

Figure 4a. Ceramic Membrane; **4b.** Jumputan Fabric Liquid Waste

3.4. Data on Waste Processing Results

Liquid waste that has been processed using a ceramic membrane and coagulation is then analyzed using various parameters and Scanning Electron Microscopy (SEM) analysis on the ceramic membrane used.

Table 1. Wastewater Parameter Analysis Results Before Processing

Parameters	Results	Units	Methods
Turbidity	9,810	Scale NTU	SNI 06-6989.25-2005
Color Concentration	586,285	ScalePtCo	SNI 06-6989.24-2005
pH	4,03	-	SNI 6989.11:2019
TSS	58,000	mg/L	Gravimetri
COD	81,000	mg/L	*Spectrophotometri*
BOD	31,000	mg/L	Manometri

Table 2. Wastewater Parameter Analysis Results After Processing

Parameters	Results	Units
	Coagulation	
Turbidity	120,000	Scale NTU
Color Concentration	580,480	ScalePtCo
pH	7,18	-
TSS	117,000	mg/L
	Membrane Variations 1 (25 minutes)	
Turbidity	5,770	Scale NTU
Color Concentration	246,960	ScalePtCo
pH	6,82	-
TSS	18,000	mg/L
	Membrane Variations 1 (50 minutes)	
Turbidity	5,710	Scale NTU
Color Concentration	236,670	ScalePtCo
pH	6,90	-
TSS	12,000	mg/L
	Membrane Variations 1 (75 minutes)	
Turbidity	7,510	Scale NTU
Color Concentration	221,810	ScalePtCo
pH	6,97	-
TSS	10,000	mg/L
	Membrane Variations 1 (100 minutes)	
Turbidity	6,880	Scale NTU
Color Concentration	219,260	ScalePtCo
pH	6,98	-
TSS	14,000	mg/L
	Membrane Variations 1 (125 minutes)	
Turbidity	9,640	Scale NTU
Color Concentration	209,990	ScalePtCo
pH	7,03	-
TSS	12,000	mg/L
	Membrane Variations 2 (25 minutes)	
Turbidity	3,420	Scale NTU
Color Concentration	231,180	ScalePtCo
pH	6,84	-
TSS	9,000	mg/L
	Membrane Variations 2 (50 minutes)	
Turbidity	3,070	Scale NTU
Color Concentration	225,680	ScalePtCo
pH	6,76	-
TSS	18,000	mg/L
	Membrane Variations 2 (75 minutes)	
Turbidity	3,600	Scale NTU
Color Concentration	180,660	ScalePtCo

pH	6,64	-
TSS	15,000	mg/L
Membrane Variations 2 (100 minutes)		
Turbidity	4,100	Scale NTU
Color Concentration	162,230	ScalePtCo
pH	6,59	-
TSS	13,000	mg/L
Membrane Variations 2 (125 minutes)		
Turbidity	4,480	Scale NTU
Color Concentration	188,500	ScalePtCo
pH	6,64	-
TSS	11,000	mg/L
Membrane Variations 3 (25 minutes)		
Turbidity	16,300	Scale NTU
Color Concentration	207,850	ScalePtCo
pH	6,77	-
TSS	31,000	mg/L
Membrane Variations 3 (50 minutes)		
Turbidity	23,700	Scale NTU
Color Concentration	193,500	ScalePtCo
pH	6,76	-
TSS	22,000	mg/L
Membrane Variations 3 (75 minutes)		
Turbidity	25,300	Scale NTU
Color Concentration	177,610	ScalePtCo
pH	6,81	-
TSS	36,000	mg/L
Membrane Variations 3 (100 minutes)		
Turbidity	22,600	Scale NTU
Color Concentration	229,650	ScalePtCo
pH	6,87	-
TSS	45,000	mg/L
Membrane Variations 3 (125 minutes)		
Turbidity	33,900	Scale NTU
Color Concentration	240,240	ScalePtCo
pH	6,84	-
TSS	39,000	mg/L

3.4.1. Relationship between Turbidity and Operation Time

Based on **Figure 5a,** there is an increase in turbidity for each variation of membrane along with the length of operation time. The increase in turbidity occurs due to the suspension sticking to the membrane pores which causes blockages (Ayunata et al., 2020). Apart from that, this increase in turbidity can also be caused by an imperfect sintering process during the manufacture of ceramic membranes (Nurhayati & Susanto, 2015). Membrane variations 1 and 2 are on average below the quality standard, while variation 3 is above the quality standard, namely 12 NTU.

3.4.2. Relationship between Color Concentration and Operation Time

Based on **Figure 5b**, there is a fluctuating decrease and increase in color concentration. If the additive composition added is greater to form pores, the membrane porosity will be greater. The larger the membrane pores, the more substances will pass through and the rejection of the dye will be smaller, and vice versa (Mirwan et al., 2018). The best reduction in dye was obtained in membrane variation 2 at 75 minutes, there was a reduction in dye from 225.69 to 180.66 Pt-Co.

3.4.3. The relationship between pH and operating time

Based on **Figure 5c**, pH tends to increase, except for ceramic membrane variation 2. The increase in pH can be caused by water flowing through the filter media experiencing collisions between water molecules which results in the formation of air bubbles (oxygen is released) resulting in an ion reaction which results in the water having an excess of H^+ ions, so that the pH of the water increases (Khoiriah & Stighfarrinata, 2023). In membrane variation 2 there is a decrease in pH levels because the clay content in membrane 2 is less than in other variations. The research results show that ceramic membrane variations 1, 2, and 3 have been able to increase the pH value to reach environmental quality standards.

3.4.4. Relationship between Total Suspended Solid (TSS) and Operation Time

Based on **Figure 5d,** the concentration of suspended solids appears to have decreased quite significantly on membranes 1 and 2. This is because on membrane 2, more zeolite composition is used.

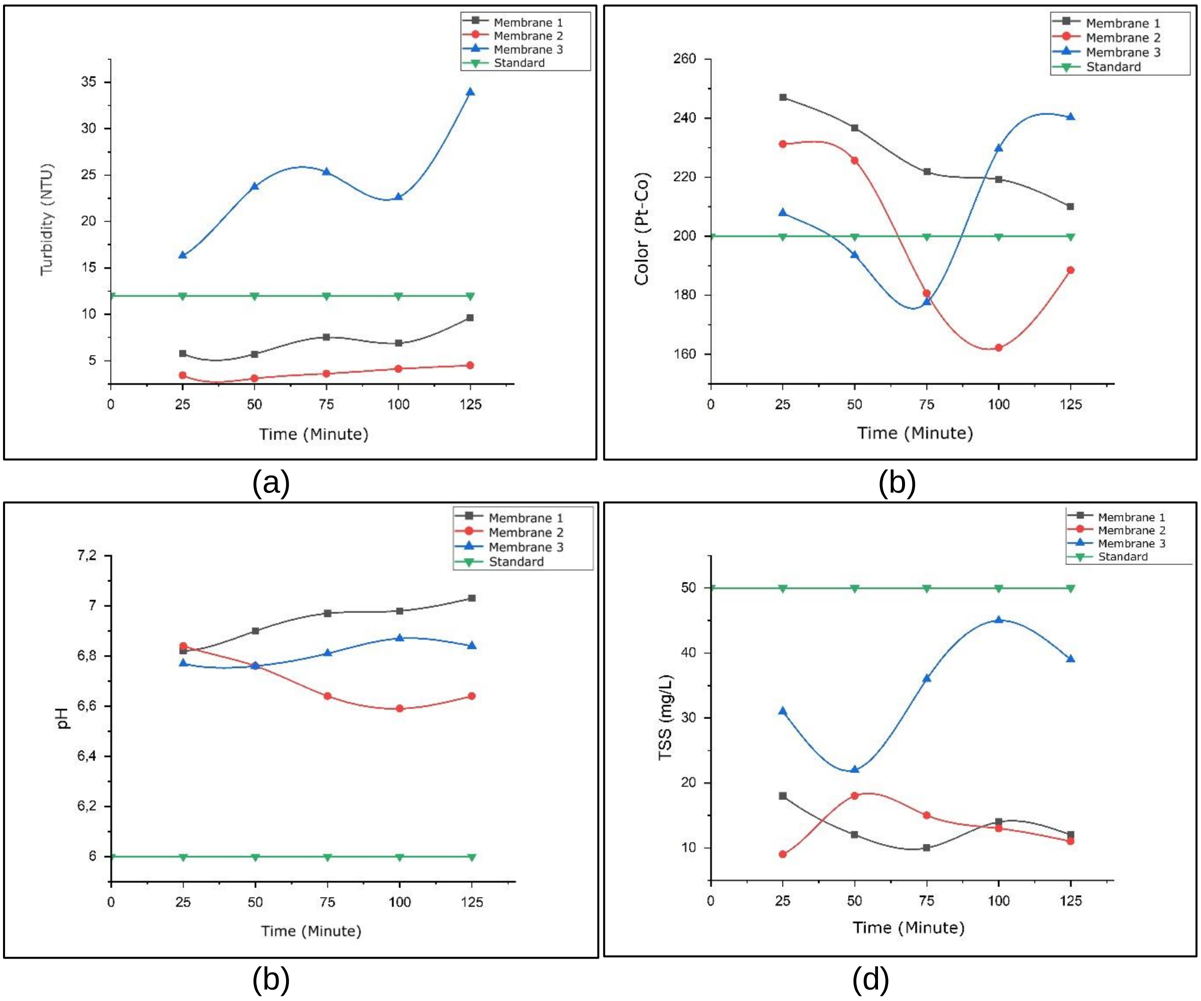


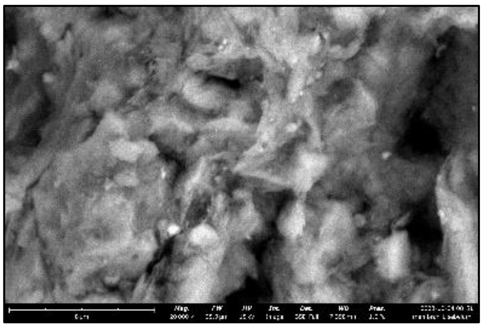
Figure 5. Relationship Between Operating Time and Parameters: (a) Turbidity, (b) Color Concentration, (c) pH, (d) TSS

Zeolites have high adsorption capabilities because they have many pores and high cation exchange capacity (Asmorowati et al., 2023). The decrease in TSS concentration is also influenced by the use of membranes due to filtration and adsorption due to the organic material contained in waste water being filtered and absorbed by the membrane with strong pressure causing the organic material to stick to the membrane (Lista & Da Costa, 2023)

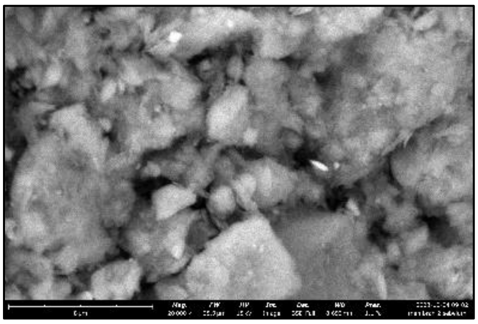
Table 3. SEM Test Results for Ceramic Membranes

Element	**Membrane Variations 1 (% WT)**				**Average**
	Spot 1	**Spot 2**	**Spot 3**	**Spot 4**	
O	58.4	51.2	35.8	62.837	52.05925
Mg	0.2	0.1	0	0.2	0.125
Al	18	13.5	3.6	7.992	10.773
Si	15.2	11.5	2.8	6.793	9.07325
K	0	0.9	0	0	0.225
Element	**Membrane Variations 2 (% WT)**				**Average**
	Spot 1	**Spot 2**	**Spot 3**	**Spot 4**	
O	58.3	54.945	45.9	43.1	50.56125
Mg	0.2	0.3	0.3	0.4	0.3
Al	10.3	22.078	18.7	21.5	18.1445
Si	8.9	20.18	35.1	22.8	21.745
K	0.5	1.399	0	0	0.47475
Element	**Membrane Variations 3 (% WT)**				**Average**
	Spot 1	**Spot 2**	**Spot 3**	**Spot 4**	
O	35.836	51.6	28.1	45.546	40.2705
Mg	0.2	0.1	0.7	0.2	0.3
Al	15.516	11.7	14.1	14.014	13.8325
Si	31.832	28.3	11.2	21.221	23.13825
K	9.409	4.3	0	19.019	8.182

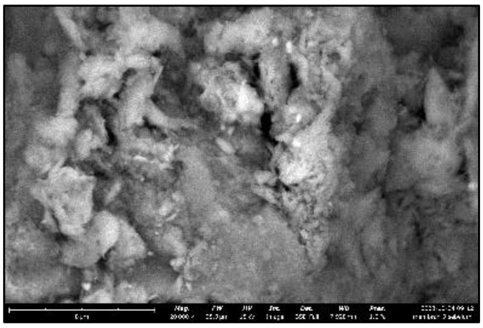
SEM analysis in this study aims to determine the levels of compounds contained in the membrane after production. Membrane 1 has a lot of O elements because the compounds contained in the clay are Al_2O_3 and SiO_2 and the variation in the composition of membrane 1 is higher in the clay used. In membrane 2, the most elements are Al and Si, this is due to the composition of zeolite which consists of alumino silicate crystals.



(a)



(b)



(c)
Figure 9. SEM Analysis of Ceramic Membrane: (a) Membrane 1, (b) Membrane 2, (c) Membrane 3

Membrane 3 has the highest K content among other membranes due to the potassium content in porang. The results of observations using SEM images also show that the morphology of the membrane surface is in the form of irregular clumps that have formed bonds with each other with few visible pores. The same thing also happened in research by Nahar et al (2022) who conducted SEM analysis of ceramic membranes with raw materials of zeolite, kaolin, fly ash and clay. In this membrane, it can be seen that the particles have formed bonds with each other and the porosity formed is also reduced.

4. CONCLUSION

The coagulation and filtration process with ceramic membranes is effective in reducing turbidity, color concentration, TSS, and increasing the pH of jumputan fabric waste. After the coagulation, the waste turbidity value decreased to 120 NTU, the color concentration became 580,480 Pt-Co, the TSS level became 117 mg/L, and the waste pH became 7.18. The best filtration results in reducing turbidity values were shown in membrane variation 2 at 50 minutes with a turbidity value of 3.07 NTU, in decreasing color concentration it was shown in membrane variation 2 at 75 minutes with a value of 180.66 Pt-Co, in decreasing values TSS is shown on membrane variation 2 at 125 minutes with a TSS value of 11 mg/L. The highest increase in pH occurred in membrane variation 1 at 125 minutes with a pH of 7.03. Overall, the most effective membrane to use is membrane variation 2, with the percentage of constituent ingredients in sequence, zeolite: activated carbon: clay (150 gr: 100 gr: 750 gr).

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