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Effectiveness of reducing ammonia levels in medical waste using a combination of palm fiber bio adsorbent and nanofiltration membrane

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Abstract

In this study, the management of domestic wastewater from the regional hospital of Ogan ilir district was carried out by combining adsorption methods using palm fiber activated charcoal adsorbent and filtration using nanofiltration (NF) membranes. The palm fiber activated charcoal adsorbent was produced through a combustion process at 100 ºC for ±24 hours which resulted in a moisture content and ash content of 1.179 and 4.012 %, respectively. Palm fiber charcoal was activated using sulfuric acid (H_2SO_4) and then analyzed using Scanning Electron Microscope-Energy Dispersive X-Ray (SEM-EDX). The hospital domestic waste treatment process was carried out with variations in operating time of 20, 40, 60, 80, 100 minutes and flow rates of 2 and 3 L/min which were then analyzed for ammonia levels before and after the management process.

Keywords: adsorption, ammonia, hospital wastewater, nanofiltration, palm fiber

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1. Introduction

The increasing need for health services increases along with the increase in population. The increasing need for health services encourages the growth of hospitals. The increasing number of hospitals causes the potential for environmental pollution resulting from hospital activities to increase. Wastewater from hospital activities is one source of pollution because it contains high organic compounds (Ariyani, 2019). The content of hospital wastewater can cause environmental damage if discharged under conditions that still exceed quality standards, for example ammonia content. High levels of ammonia always indicate water pollution (Akbar et al., 2016).

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One method that can reduce ammonia levels in medical wastewater is adsorption using activated carbon. Activated carbon media is able to remove ammonia compounds in liquid waste. One of the raw materials that can be used as an adsorbent is palm fiber (Ariyani, 2019). The use of palm fiber as a raw material for making adsorbents can also be one way to overcome the problem of waste from oil palm where oil palm (Elaeisguineensis) is one of the commodities with the largest productivity in Indonesia (Rahmasita et al., 2017). Untreated palm oil waste can cause foul odors and can damage the surrounding environment. The production process of 1 ton of oil palm, can produce fiber waste (fiber) of 13 % or 130 kg of fiber (Arifandy, 2021). Palm fiber contains cellulose, lignin, hemicellulose and holocellulose and others have many carbon groups, so it has great potential to be converted into activated carbon bioadsorbents.

Learning from previous research conducted by (Maulana & Marsono, 2021) that a pre-treatment process for medical liquid waste management is carried out so that in the process it will reduce the potential for fouling which can cause the filtration process to be hampered so that an adsorption process with activated carbon is carried out as a pre-treatment stage which is then followed by a filtration process using a nanofiltration membrane. Nanofiltration membranes can cause liquid fractionation to produce two liquids with different compositions. The nature of the membrane can control the components that will be flowed and those that will be retained. This is based on the selectivity of molar mass or particle size. Based on these problems, this thesis is intended to study the effectiveness of reducing ammonia levels in medical waste with a combination of nanofiltration membranes and bioadsorbents from palm fiber.

2. MATERIALS AND METHOD

2.1 Materials

Palm Fiber was provided by PT Golden Oilindo Nusantara. Hospital wastewater was obtained from the wastewater treatment plant (WWTP) of the Ogan Ilir Regional General Hospital, South Sumatera, Indonesia, Kusatsu Toray Nanofiltration Membrane RO Cleaner NF-1812-150, Sulfuric Acid (H_2SO_4), Distilled water and Nessler reagent.

2.2 Methods

2.2.1 Preparation of Palm *Fiber* into Activated Charcoal

The palm fiber is washed and dried first. Then it was crushed with a blender and the resulting powder was taken. Then the biomass was oven at 100 ^oC for 24 hours, then activated by soaking the biomass using 10 % H_2SO_4 for 24 hours. The precipitate was filtered with filter paper and washed with distilled water until the pH reached 4-7. The precipitate was dried in anoven at 100 ^oC for ± 3 hours then the results were crushed using a mortar and then filtered with a 100 mesh sieve (Iswandi and Iskandar., 2023). Then the activated charcoal was molded in the form of pellets.

2.3 Stage Analysis

2.3.1 Moisture Content Analysis of Palm *Fiber* Bioadsorbent Activated Charcoal

A total of 1 gram of activated charcoal was baked at 105 °C until the weight was constant and then cooled in a desiccator and weighed, this was repeated 3 times (Lestari et al., 2016). Calculation of water content using equation 1:

$$\text{Moisture content (\%)} = \frac{a-b}{a} \times 100\ \% \qquad (1)$$

Description:
a : Sample weight before heating
b : Sample weight after heating

2.3.2 Ash Content Analysis of Palm Fiber Bioadsorbent Activated Charcoal

A total of 1 gram of activated charcoal was oven. Then heated in a furnace at a temperature of ± 600 °C for ± 2.5 hours. After that, it was cooled in a desiccator and weighed. Then 3 repetitions were carried out with the same procedure (Lestari et al., 2016). Calculation of ash content using equation 2:

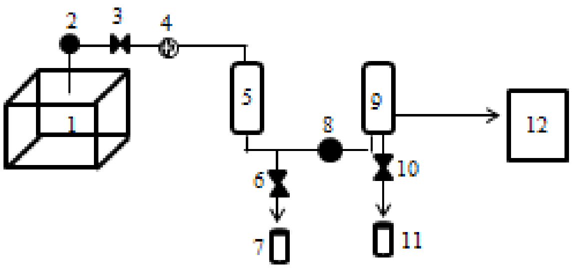
$$\text{Ash Content (\%)} = \frac{b}{a} \times 100 \qquad (2)$$

Description:
a : Sample weight before heating
b : Sample weight after heating

2.3.3 Medical Liquid Waste Management Process

Medical waste is taken from the inlet of the tub of medical liquid waste of the Regional General Hospital of Ogan Ilir Regency, which is analyzed for initial samples with the parameters analyzed (pH and Ammonia). Furthermore, the pump is turned on with a flow rate variation of 2, 3, and 4 L/min and samples are taken every 20, 40, 60, 80, and 100 min. using a sample bottle to analyze pH and ammonia levels.

Medical liquid waste is flowed into an absorption column containing palm fiber bioadsorbent with a variety of adsorbent masses (100, 140, 180 gr) and then pumped tothe nanofiltration membrane which is then analyzed for pH and ammonia levels in medical liquid waste output from the adsorption column and nanofiltration (NF) membrane column (Manaf et al., 2021). The following medical liquid waste management scheme is shown in Figure 1.



1 = Inlet basin of wastewater management plant at RSUD Kab. OI
2 = Suction Pump
3 = Valve 1 (Waste Flow Regulator)
4 = Flow Rate dan Presussure
5 = Adsorbent Column
6 = Valve 2
7 = Sample Bottle
8 = Booster Pump
9 = Nanofiltration Membrane Column
10 = Valve 3
11 = Sample Bottle
12 = Storage tank

Fig. 1. Flowsheet of Hospital Wastewater Treatment

3. RESULTS AND DISCUSSION

3.1 Water Content of Palm Fiber Bioadsorbent (SNI 06 - 3730 - 1995)

Measurement of water content aims to determine the water content in the bioadsorbent obtained. Palm fiber activated charcoal that has gone through the activation and washing process must have water content that still remains for that, palm fiber activated charcoal obtained needs to be characterized, one of which is testing the water content The lower the water content, the less water content that remains and covers the pores on the adsorbent (Hasanah et al., 2021). The results of the water content test can be seen in Table 1.

Table 1. Moisture Content of Palm Fiber Bioadsorbent

Repetition	Initial Charcoal Weight (grams)	Final Charcoal Weight (grams)	Water Content (%)
1	1.0159	0.9979	1.771
2	1.0162	0.9986	1.732
3	1.0149	0.9981	1.655
Avarage			1.719

Based on the measurement of bioadsorbent moisture content, the results obtained are 1.719 % so that it meets the SNI absorbent standard (06-3730-1995) which requires a maximum moisture content of 15 % (Efiyanti et al., 2020).

3.2 Ash Content of Palm Fiber Bioadsorbent (SNI 06 - 3730 - 1995)

The ash content of activated charcoal is tested to determine the metal oxide content in the material. Ash is formed because the material has mineral elements such as calcium, potassium, sodium and magnesium. The content spreads in the active charcoal lattice so that it covers the pores of the active charcoal (Cames et al., 2021). The ash content test results of palm fiber activated charcoal can be seen in Table 2.

Table 2. Ash Content Measuremenet of Palm Fiber Bioadsorbent

Repetition	Intial Charcoal Weight (grams)	Final Charcoal Weight (grams)	Ash Content (%)
1	1.0022	0.033	3.29
2	1.0043	0.035	3.485
3	1.0079	0.053	5.25
Avarage			4.012

The average ash content obtained was 4.012 %. Based on these results, the ash content of the bioadsorbent meets the SNI absorbent standard (06-3730-1995) which requires a maximum moisture content of 10 %.

3.3 Characterization of Palm Fiber Adsorbent using SEM-EDS

Scanning Electron Microscopy (SEM) and Energy Dispersive x-ray Spectroscopy (EDS)are widely used methods to determine the particle size and basic composition of a material (Hidayah, 2018). In this experiment, carbon from palm fiber was characterized before activation, after activation, and activated carbon that has adsorbed medical wastewater. The SEM-EDS test was carried out at the Testing Center Laboratory of the Faculty of Engineering, Sriwijaya University. The results of characterization using SEM on palm fiber carbon before and after activation and palm fiber carbon that has adsorbed can be seen in the following figure 2:

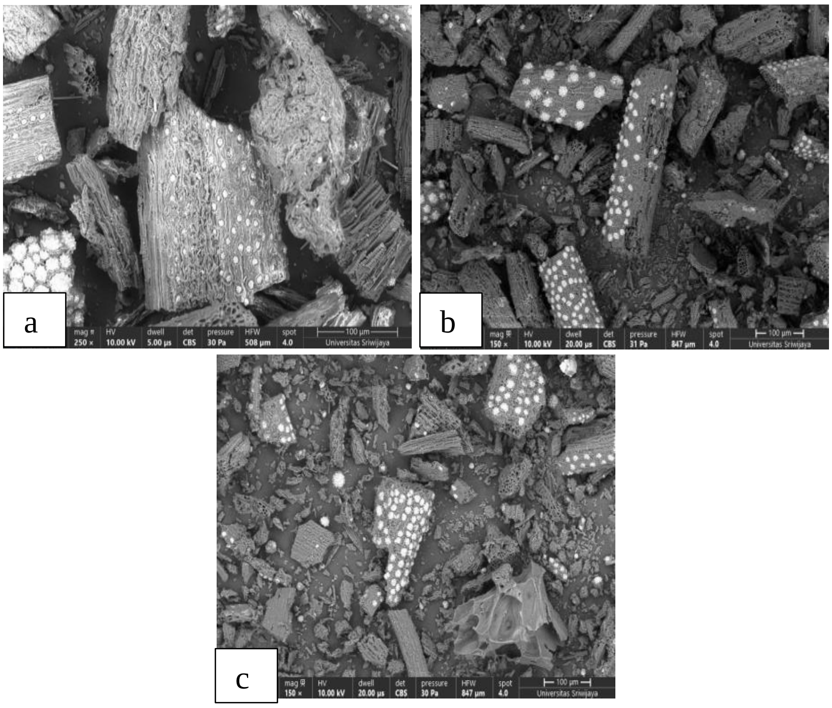


Fig 2. SEM analysis results on palm fiber carbon: (a) before activation; (b) after activation; (c) after adsorption process

Table 3. Elemental Composition of Activated Carbon

Compound	Before Activation (%)	After Activation (%)	After Adsorption (%)
Carbon (C)	50.1	56.1	57.9
Nitrogen (N)	4.7		
Oxygen (O)	41.2	42.1	40.1
Alumunium (Al)	0.1	0.5	0.9
Silica (Si)	3.4		
Phosphor (P)	0.1		
Calcium (Ca)	0.4		

Based on the characterization results using SEM-EDS shown in the figure above. SEM-EDS results of palm fiber adsorbent both before activation, after activation and after experiencing the adsorption process with 150 times magnification of palm fiber carbon showed a rough surface with a diameter of 100 micrometers. The possibility of the rough surface is the presence of a layer of lignin, hemilulose and other impurities which are compounds contained in palm oil, besides that the pores on the rough surface may have silicate compounds covering the pores. From the data results, the compounds contained in the fiber before activation were 50.1 % carbon, 41.2 % oxygen, 4.7 % nitrogen and 3.4 % silicate and a small portion of minerals were detected. This can be caused because palm fiber is a material that is mostly composed of carbon and oxygen elements. Mineral components such as silica, phosphorus and calcium were detected but in relatively small amounts compared to carbon and oxygen. (Dwi Arista Ningsih, 2016).

The morphology of palm fiber material after activation shows a smoother surface, the activation process by adding sulfuric acid regaen can cause the content in the fiber such as lignin, hemulose and silicate to be extracted and the fiber shrinks as evidenced by the results of SEM-EDX analysis of carbon content to 56,1 %, oxygen 42,1 % and the loss of some minerals such as silica, The loss of some minerals such as silica, phosphorus, and calcium is caused by the activation process with the addition of sulfuric acid reagents and the heating process which causes the chemical bonds on palm fiber carbon to weaken. This may cause some minerals to interact with the added reagents which causes the non-detection of some minerals previously detected in palm fiber carbon before the activation process (Puspasari et al., 2017).

The morphology of palm fiber material after the adsorption process shows a rough surface again, this is because the adsorbent has successfully adsorbed the compounds in the medical waste liquid. SEM-EDX analysis results of carbon content to 57.9 %, oxygen 40.1 %.

3.4 Effect of Operating Time, Mass, and Flow Rate on the Degree of Acidity (pH) and ammonia level of Adsorption Column Output Medical Liquid Waste

Medical Liquid Waste Treatment using palm fiber adsorbent affects the pH of the waste and reduces the ammonia content in the liquid waste of the regional general hospital of Ogan Ilir district. Degree of Acidity (pH) is a scale used to inform or state the nature of a liquid whether it is alkaline or acidic (Afrianti, 2022). The pH scale is not an absolute scale where the pH scale is between 0 and 14. Acidic properties have a pH between 0 to 7 and alkaline properties have a pH value of 7 to 14. Medical Liquid Waste before processing has a pH of 9.1 and an ammonia content of 8.26 mg/L. The following are the results of pH and ammonia analysis after the adsorption process.

Table 4. Adsorption Column Output Medical Liquid Waste Analysis Results

No	Adsorbent Mass (gram)	Time (min)	pH			Ammonia Content (mg/L)		
			Flowrate 2 L/Min	Flowrate 2 L/Min	Flowrate 3 L/Min	Flowrate 4 L/Min	Flowrate 3 L/Min	Flowrate 4 L/Min
1.	100	20	7.73	7.92	7.94	0.92	0.99	1.12
		40	7.69	7.87	7.92	0.87	0.94	0.99
		60	7.67	7.83	7.89	0.74	0.86	0.91
		80	7.65	7.79	7.81	0.78	0.89	0.95
		100	7.63	7.73	7.74	0.81	0.91	0.97
2.	140	20	7.64	7.87	7.89	0.84	0.89	0.97
		40	7.61	7.83	7.86	0.79	0.85	0.91`
		60	7.59	7.70	7.80	0.67	0.74	0.85
		80	7.55	7.67	7.73	0.70	0.77	0.87
		100	7.48	7.54	7.71	0.72	0.82	0.89
3.	180	20	7.45	7.68	7.78	0.76	0.83	0.86
		40	7.43	7.54	7.72	0.62	0.77	0.79
		60	7.37	7.50	7.69	0.42	0.67	0.71
		80	7.33	7.47	7.64	0.53	0.72	0.74
		100	7.28	7.36	7.61	0.58	0.75	0.77

From the data obtained, it was concluded that the highest pH reduction occurred at a flow rate of 2 L/min, an adsorbent mass of 180 grams, and an operating time of 100 minutes. So it can be concluded that the more adsorbent used, the higher the pH drop. The faster the flow rate, the lower the pH drop and the longer the operating time shows a higher pH drop. This can occur inseparable from the effect of reduced ammonia levels in wastewater because ammonia is a weak base that can be ionized in solution into ammonium ions and hydroxide ions so that the decrease in ammonia levels also causes a decrease in the pH of hospital wastewater due to the decrease in hydroxide ions (OH-) in hospital wastewater.In this study, the more adsorbents used, the more ammonia is adsorbed and ammonia levels in medical waste will decrease (Wahyuningsih et al., 2020). This decrease is caused by an increase in the number of adsorbents that can increase the rate of the adsorption process which causes ammonia adsorption to be more efficient, and the ammonia concentration in the waste will decrease faster.

The optimum condition for ammonia absorption in this study occurred at a time of 60 minutes and a flow rate of 2 L/min and increased again at an operating time of 80 minutes. This can occur because the adsorption process has reached equilibrium. This is the same as the research conducted by (Pradana et al., 2019) where the results of the percentage reduction in the level of domestic wastewater of PT Topy Palingda Manufacturing Indonesia which has passed through activated carbon media found that the contact time treatment which has the highest percentage in 60 minutes contact time with a percentage value of 85.52 % and the lowest is in the 20-minute treatment of 38.70 %. The decrease in the percentage of ammonia absorption is possible because the adsorbent has been filled by adsorbate because as time increases the surface of the adsorbent begins to be filled by adsorbate so that the ability of the adsorbent to adsorb ammonia slowly decreases (Dwi Arista Ningsih, 2016). In conditions after reaching adsorption equilibrium, a desorption process can occur where ammonia adsorbed on the surface of the adsorbent material can be released back into the wastewater. If there is a change in conditions that encourage desorption, then ammonia levels in the waste will increase (Desfitri et al., 2024).

3.5 Effect of Operating Time, Mass, and Flow Rate on the Degree of Acidity (pH) and Ammonia Level of Medical Liquid Waste Output from the Combination of Palm Fiber Bioadsorbent and Nanofiltration Membrane

Effect of Operating Time, Adsorbent Mass and Flow Rate on the Degree of Acidity (pH) and Ammonia Content of Medical Liquid Waste The results of management with a combination of adsorption process using activated charcoal palm fiber with filtration process using nanofiltration membrane can be seen as follows.

Table 5. Results of Medical Liquid Waste Analysis After the Management Process Using a Combination of Palm Activated Charcoal Adsorbent and Nanofiltration Membrane

No	Adsorbent Mass (gram)	Time (min)	pH			Ammonia Content (mg/L)		
			Flowrate 2 L/Min	Flowrate 2 L/Min	Flowrate 3 L/Min	Flowrate 4 L/Min	Flowrate 3 L/Min	Flowrate 4 L/Min
1.	100	20	7.45	7.54	7.59	0.19	0.29	0.32
		40	7.42	7.51	7.56	0.15	0.24	0.26
		60	7.36	7.47	7.50	0.13	0.18	0.19
		80	7.30	7.39	7.42	0.08	0.15	0.17
		100	7.28	7.33	7.40	0.06	0.09	0.11
2.	140	20	7.28	7.31	7.36	0.15	0.22	0.26
		40	7.19	7.25	7.28	0.09	0.18	0.23
		60	7.14	7.21	7.23	0.06	0.09	0.11
		80	7.09	7.17	7.19	0.04	0.07	0.09
		100	7.03	7, 11	7,16	0.03	0.04	0.06
3.	180	20	7.24	7.28	7.33	0.09	0.12	0.18
		40	7.22	7.26	7.31	0.03	0.05	0.09

	60	7.17	7.21	7.28	0.00	0.01	0.02
	80	7.14	7.15	7.21	0.00	0.00	0.00
	100	7.08	7.10	7.18	0.00	0.00	0.00

From the results of this study, it can be seen that the longer the operating time, the more ammonia levels are reduced and cause ammonia levels to not be detected. This is because reducing ammonia levels using nanofiltration membranes is one of the effective methods in water and waste treatment. Nanofiltration (NF) is a membrane technology that has a pore size of about 1-10 nanometers, and works based on the mechanism of size exclusion and charge interaction, which is effective for removing certain ions, including ammonia in the form of ammonium ions (NH_4^+), because NH_4^+ ions are larger than the pore size of the NF membrane and have a positive charge, the membrane can reject or filter ammonium ions, so ammonia can be removed from water (Hamdil Mukhlishin, Winda Rahmalia, 2020).

From the data obtained, it is concluded that the faster the flow rate, the lower the rate of pH decrease and the longer the operating time shows the higher the rate of pH decrease. This may also be due to the increasing number of absorbed substances such as ammonia absorbed in adsorbents and nanofiltration, causing the pH to decrease.

3.6 Effectiveness of Medical Liquid Waste Treatment

The results of management by combining the adsorption process using palm fiber activated charcoal with the filtration process using nanofiltration membranes can be seen in Figure 3.

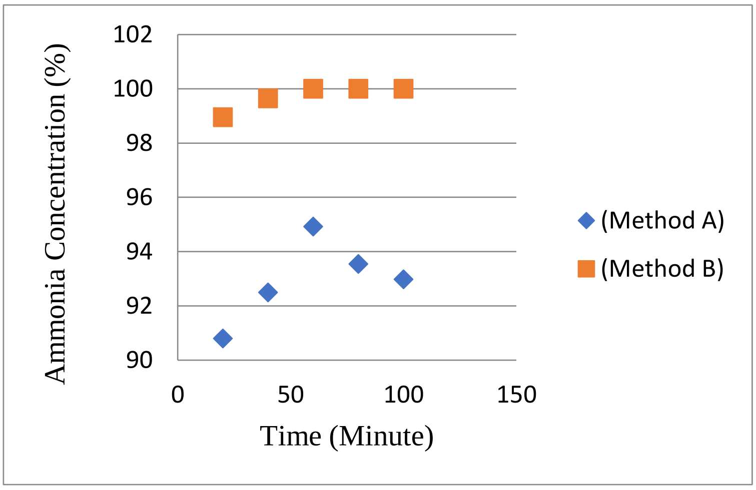


Fig 3. Effectiveness of Treatment Methods (Adsorbent mass 180 g, flowrate 2 L/min) using Method : (A) Adsorption (B) Adsorption + Nanofiltration

From the results of this experiment, the highest effectiveness was achieved at 94.92 %, namely in the condition of flow rate of 2 L/min, operating time of 60 minutes with the amount of adsorbent 180 grams. The increase in the effectiveness of ammonia adsorption on the number of membranes 180 grams, this is due to the effect of the more adsorbents used, the more effective the adsorption process. Where the increase in adsorbent mass causes an increase in surface area on the adsorbent which can increase the adsorption ability so that ammonia reduction is more effective (Hamdil Mukhlishin, Winda Rahmalia, 2020). The effectiveness of reducing ammonia levels in the use of nanofiltration membranes reached 100 %, where the original reduction level was 8.26 mg/L to 0 mg/L. The optimum condition to achieve 100 % effectiveness is at a flow rate of 2 L/min with a production time of 60, 80, 100 minutes at a mass of 180 grams.

3.7 Adsorption Isotherm

The data obtained from the optimum concentration was used to determine the type of adsorption isotherm. Based on the experimental data, the Freundlich and Langmuir adsorption isotherm graphs can be seen in Figures 4 and 5.

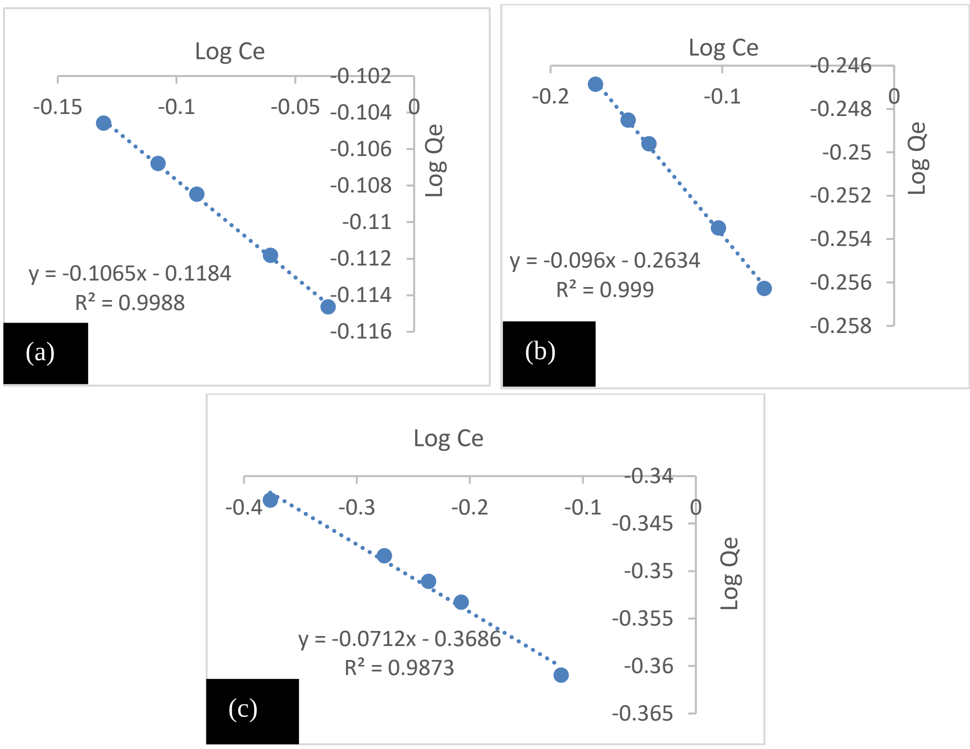


Fig.4. Freundlich Isotherm graph with variations in adsorbent mass; (a) 100 grams; (b)140 grams; (c) 180 grams

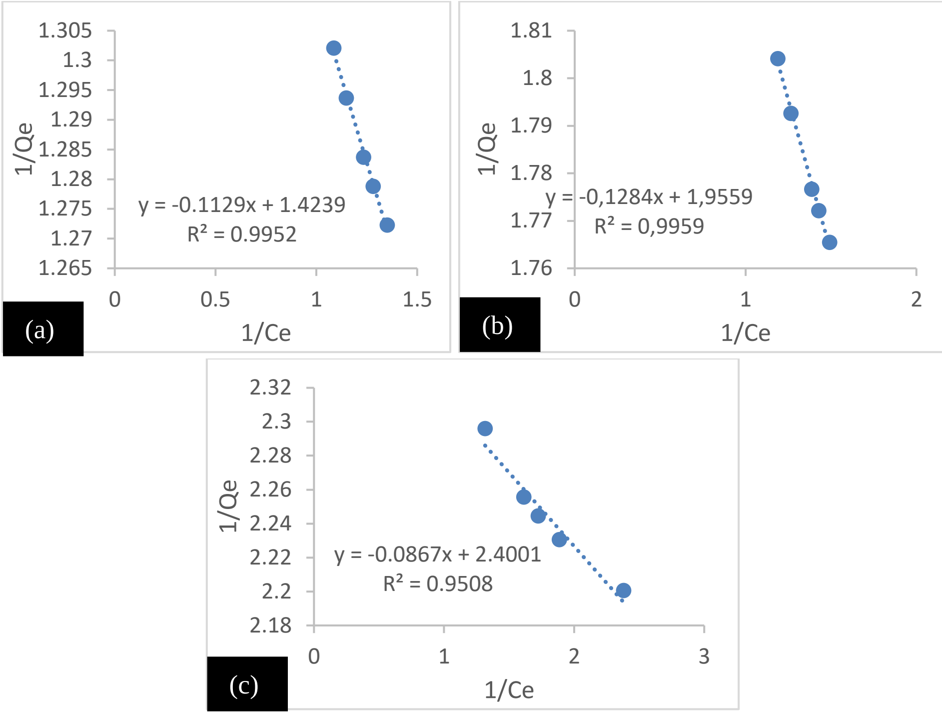


Fig 5. Langmuir Isotherm graph with variations in adsorbent mass; (a) 100 grams; (b)140 grams; (c) 180 grams

In the Freudlich adsorption isotherm graph, the regression coefficient (R^2) is obtained in the range of 0.9873-0.990 while in the Langmuir adsorption isotherm, the R^2 value is in the range of 0.9508-0.9959. Judging from the R^2 data, it can be concluded that the ammonia adsorption isotherm in hospital wastewater using palm fiber carbon adsorbent follows the Langmuir isotherm pattern. The R^2 value can be used as a simple linear regression analysis where if the R^2 value is closer to 1, it can be said that there is a greater influence and the relationship between variables is getting stronger (John Zysman & Arnaud Costinot, 2022). This indicates that the adsorption process that occurs is chemisorption and there is a layer on the surface of the adsorbent at a constant temperature (Bakalár et al., 2020).

The adsorption capacity values and constants for each isotherm model can be seen in Table 6.

Tabel 6. Isoterm adsorpsi Langmuir and Freundlich

Component	Isoterm Freudlich			Isoterm Langmuir		
	Adsorption Capacity	R^2	Konstanta Freudlich	Adsorption Capacity	R^2	Konstanta Langmuir
Ammonia	9.390-14.045	0.9873-0.990	1.313-2.3668	8.857-11.534	0.9508-0.9959	12.61-27.68

The Langmuir graph shows a better match with the experimental data where the regression value is closer to 1 and the maximum adsorption capacity value of the

Freudlich isotherm is also greater than the adsorption capacity of the Langmuir isotherm, meaning that monolayer adsorption that occurs on homogeneous surfaces is more dominant in the ammonia adsorption process in wastewater using activated charcoal from palm fiber.

4. Conclusion

The characteristics of palm fiber carbon adsorbents activated using H_2SO_4 based on the analysis results have a moisture content of 1.179 % and ash content of 4.012 % meeting the quality standards according to SNI 06-3730-1995 where moisture content should not be more than 15 % and ash content should not be more than 10%. The characteristics of palm fiber carbon adsorbent using SEM-EDS showed a difference in the character of carbon before and after activation and carbon after adsorption due to chemical bonding between sulfuric acid reagent and palm fiber charcoal and combustion reactions due to the heating process resulting in the addition of carbon and oxygen and the reduction of several minerals including phosphorus, silica and calcium. The effectiveness of ammonia reduction in the adsorption stage using palm fiber adsorbent is 95.11 %, where the more adsorbent mass used, the higher the effectiveness of ammonia absorption. The reduction in ammonia levels also causes a decrease in pH because ammonia is a weak base that can be ionized in solution into ammonium ions and hydroxide ions so that the reduction in ammonia levels also causes a decrease in the pH of hospital wastewater due to the decrease in hydroxide ions (OH-) in hospital wastewater. In the advanced process using nanofiltration membranes, the effectiveness of ammonia absorption reaches 100% this is because nanofiltration membranes are effective for removing ions including ammonium ions (NH_4^+), because NH_4^+ ions are larger than the pore size of the nanofiltration membrane and have a positive charge, so the membrane can reject or filter ammonium ions, which causes ammonia to be removed from medical wastewater. The results of hospital wastewater management using carbon fiber adsorbents and nanofiltration membranes at ammonia levels meet the quality standards in accordance with the Regulation of the Governor of South Sumatra Province Number 8 of 2 012.

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