OPTIMIZATION OF BENTONITE THERMAL ACTIVATION FOR REDUCING FE METAL AND ORGANIC SUBSTANCE IN PEAT WATER

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Abstract

Peat water is water produced from decaying trees and plants that contain Fe metal with a high content of organic substances. Therefore, effective and efficient peat water treatment is needed to make it suitable for consumption. Bentonite is a natural source of adsorbent but has a fairly low adsorption activity, so bentonite needs to be activated to increase its adsorption ability. Thermal activation was chosen due to its environmentally friendly process and can increase the surface area and adsorption ability of bentonite. This study was conducted to see the effect of bentonite thermal activation with temperatures of 200, 300, 400 and 500˚C in reducing Fe metal content, organic matter, TDS and pH of peat water. The results show that thermal activation of bentonite can reduce the content of these compounds. Thermal activation of bentonite at 500˚C reduced Fe metal content with 66% efficiency and 0.08 mg/g adsorption capacity, 89.6% organic matter with 24,60 mg/g adsorption capacity and TDS 27 mg/l.

Keywords: *Bentonite thermal activated, Fe metal adsorption, organic matter, peat water*

Introduction

Peat water is one of the sources of water for those who live in peatland areas. Peat water is the surface of water that hits an area that is derived from organic material deposits for a long time, peat water has a brown color and is acidic with a pH of around 5.2 (Kuokkanen et al., 2015; Rusdianasari et al., 2019). In addition, peat water also contains organic matter and heavy metals such as Fe (Iron) and Mn (Manganese) which are harmful to health (Harfinda, 2020 ; Notodarmojo et al., 2017).

Peat water contains heavy metals such as Fe and Mn, which if consumed or used in daily life can cause disease. Fe content causes health problems such as nausea, damage to the intestinal wall and irritation to the eyes and skin (Trisetyani & Sutrisno, 2014). Meanwhile, Manganese (Mn) can cause disorders of the vascular, heart and nervous system (Zairinayati & Maftukhah, 2019). In addition, peat water can also cause disorders of the digestive system, tooth decay, skin irritation in humans (Błońska-Sikora et al., 2024; Misnawati et al., 2017)

Efforts can be made to make peat water safe and suitable for use by reducing the iron metal and natural organic matter contained in it. Adsorption is one method that is often used in absorbing many materials or compounds in a mixture or solution. Adsorption has several advantages such as economical, non-toxic, able to remove organic substances, easy to use and environmentally friendly (Kusumawardani et al., 2018 ; Rahmi & Sajidah, 2017). Adsorption is

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the capture of adsorbate on the surface of an adsorbent caused by the attractive force between gas, vapor or liquid molecules (Anggriawan et al., 2019). Adsorption is a process of separating a substance from a mixture into an absorbing material called an adsorbent. Adsorbent is a material that has the ability to absorb components in a mixture.

In line with this, Indonesia has abundant natural adsorbent sources, one of which is bentonite. Bentonite is a clay with the main component being montmorillonite which has a sandy structure and can expand in water (Darmadinata et al., 2019). Bentonite has superior adsorption properties because the colloidal particle size is very small and has a high surface ion capacity (Permana et al., 2024). Bentonite is able to absorb organic compounds and inorganic compounds such as Cd^{2+}, Pb^{2+} and Cu^{2+} ions. Mn^{2+}, NO_3, Ni, Fe. So bentonite is considered capable as an adsorbent in peat water (Naswir et al., 2019). However, natural bentonite still has impurities and low activity so bentonite needs to be activated to improve the performance of bentonite. Thermal activation with high temperatures can remove water molecules and impurities in bentonite. In addition, thermal activation can increase the surface area of bentonite in line with the increasing temperature used in bentonite activation (Yanti & Mukhtar, 2015).

Based on these problems, research is needed to determine the effect of temperature in bentonite thermal activation to reduce Fe metal, Total Organic Material and Total Dissolved Solid (TDS) in peat water.

Research Methodology

Preparation of bentonite as adsorbent

Natural bentonite obtained from nature was dried at 105˚C for 1 hour. Next, bentonite was pulverized using a crusher and sieved with a size of 150 mesh. Bentonite was then thermal activated at 200, 300, 400 and 500°C for 3 hours.

Adsorption in Peat Water

A total of 1.5 grams of natural bentonite without any treatment and thermally activated bentonite (200, 300, 400, 500˚C) was put into a glass beaker containing 200 ml of peat water and then stirred using a magnetic stirrer at 600 rpm for 15 minutes. Then the mixture was separated using centrifugation at 3800 rpm for 10 minutes.

Total Organic Matter (TOM) Analysis

Analysis of total organic matter in peat water is conducted using the titrimetric method (SNI 06-6989.22-2004). In the 50 ml of peat water sample was put into an erlenmeyer then 10 ml of 4N H_2SO_4 solution was added. Then the solution was heated to boiling, added 10 ml of $KMnO_4$ 0.01 N. The solution was simmered for 10 minutes then added 10 ml of oxalic acid solution ($H_2C_2O_4$) 0.01 N and simmered again until the red color disappeared. The solution is then titrated with 0.01 N $KMnO_4$ in hot conditions until a pink color is formed.

Data Analysis

Adsorption Efficiency

The adsorption efficiency is obtained using he measurement results from the AAS instrument for Fe metal analysis and titration for Total Organic Matter, then calculated the percent of adsorption efficiency using equation (1) (Kusumkar et al., 2021)

$$\% = (Co - Ce)/Co \times 100\% \quad (1)$$

The adsorption capacity of bentonite in absorbing Fe metal and Total Organic Matter is calculated using equation (2) (Wiranti et al., 2018).

$$Qe = (Co\text{-}Ce \times V)/(m) \quad (2)$$

Where Co is Initial concentration (mg/l), Ce is Final concentration (mg/l), Qe is Adsorption capacity (mg/l), V is Volume (ml), m is Adsorbent mass.

Determination of the concentration of Total Organic Matter (TOM) is conducted in accordance with the provisions of SNI 06-6989.22-2004 using equation (3).

$$TOM = ([(10+a) \times f-10] \times 0.316 \times 1000)/(b) \quad (3)$$

Where a is ml of $KMnO_4$ 0.01 N used, f is factor of $KMnO_4$ 0.01 N, b is ml sample.

Results and Discussion

Characteristics of Peat Water

Peat water samples obtained from Gambut Jaya Village, Muaro Jambi District, Jambi were analyzed to determine the feasibility of water according to PERKENKES No. 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Sanitary Hygiene, swimming pools, Solus per aqua and public baths. Peat water was analyzed to determine the initial concentration with the parameters Iron (Fe), Organic Matter, Total Dissolved Solid (TDS) and pH which aims to determine the effect of bentonite in adsorbing these compounds.

Table 1. Characteristics of Peat Water

Parameters	Unit	This Research	PERMENKES No. 32 in 2017 years
Iron (Fe)	mg/g	0.9342	1
Organic matter	mg/g	206	10
TDS	mg/l	51	500
pH	-	3	6.5 – 8.5

Peat water has a characteristic red-brown color caused by the high content of dissolved organic substances in peat water in the form of humus acids and their derivatives (Hamid et al., 2023). Humus acids found in peat water come from the decomposition of organic matter from trees, wood and leaves (Said et al., 2019).

Adsorption Fe Metal

Metal iron content be one of important parameters in peat water. High Fe content has adverse effects on the intestinal wall and decreased lung function (Rusdianasari et al., 2019). Fe metal removal using natural bentonite and thermally activated bentonite showed a significant decrease in Fe metal content after the sorption process.

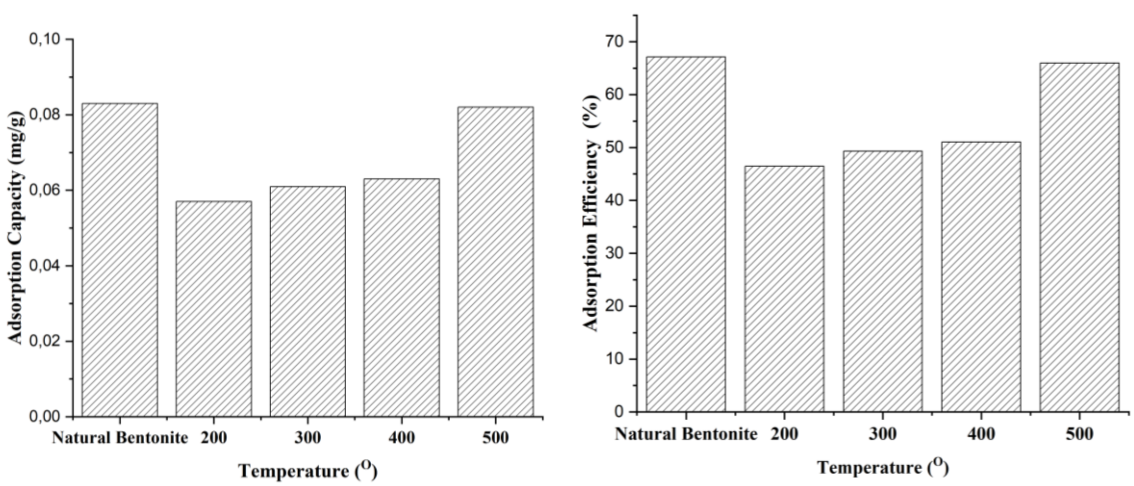

Figure 1. Bar diagram of Fe metal adsorption, adsorption efficiency and adsorption capacity (temperature in °Celcius)

Based on the diagram above, it is explained that the increase in temperature in bentonite activation affects the performance ability of bentonite. The higher the temperature used in activation, the higher the ability of bentonite to adsorb Fe metal content in peat water. It can be seen that the lowest adsorption efficiency occurred at 200˚C of 48% with an adsorption capacity of 0.05 mg/g and the highest adsorption capacity occurred in bentonite activation with a temperature of 500˚C of 66% with an adsorption capacity of 0.08 mg/g. However, natural bentonite has a higher adsorption ability than bentonite activated at 500˚C. Natural bentonite has a 1% higher adsorption efficiency of 67% with an adsorption capacity of 0.08 mg/g.

The decrease in bentonite performance in adsorbing Fe metal in peat water can occur because bentonite loses some functional groups such as -OH and -OH_2 on the bentonite surface which play a role in interaction with metal ions. Thermal activation also causes changes in the structure of solids that have an impact on changing the chemical and physical properties of a material. Research (Nafsiyah et al., 2017) shows that bentonite has active sites such as Si-OH and Al-OH which play a role in metal ion adsorption.

However, thermally activated bentonite has a higher surface area when compared to natural bentonite so that it still has good performance, even though the adsorption process of metal ions such as Fe does not occur due to the loss of some functional groups that can attract metal ions. Adsorbent surface area has a close relationship with adsorbent activity because adsorption reactions will occur on the adsorbent surface. A large surface area will cause more molecules of the reagent to be adsorbed on the adsorbent surface so that the activity is even greater (Wulan Sari et al., 2018).

Total Organic Matter (TOM)

Total Organic Matter (TOM) is a complex matrix of organic matter in water that significantly affects aspects of water treatment including process performance, disinfectant application and biological stability (Matilainen et al., 2002). The high organic matter content in peat water is in the form of humic acid and its derivatives.

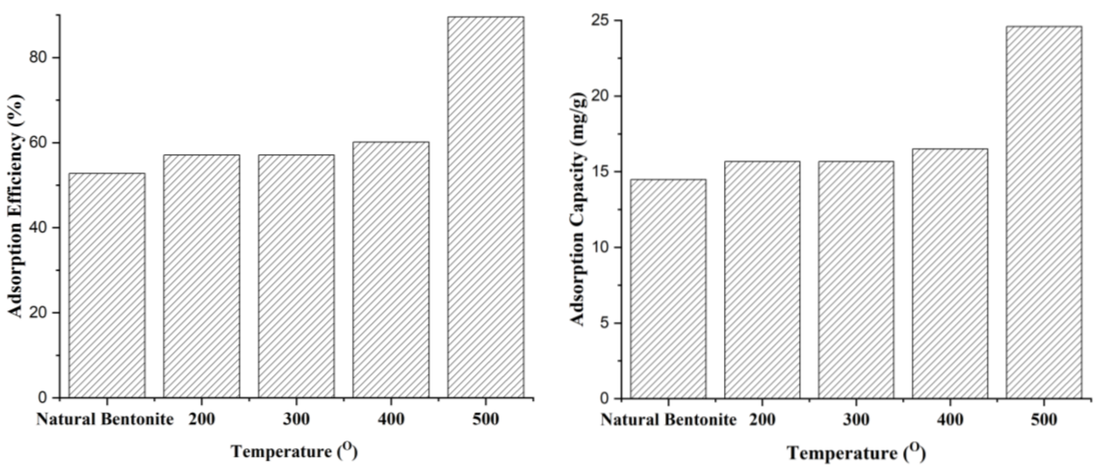

Figure 2. Bar diagram of TOM adsorption, adsorption efficiency and adsorption capacity (temperature in °Celcius)

Based on the diagram above, it can be seen that temperature has an effect in reducing the organic substance content in peat water. The decrease in organic substances in peat water is in line with the increase in temperature in bentonite activation, the higher the temperature used in activation, the more organic substances are adsorbed. The lowest adsorption efficiency was 52.7% for natural bentonite with an adsorption capacity of 14.99 mg/g. While the highest efficiency occurred in 500˚C activation with 89.6% with an adsorption capacity of 24.60 mg/g. This shows that activated bentonite is effective in reducing the content of organic substances in peat water. According to (Yusnimar et al., 2010), bentonite with its layered structure and large surface area allows bentonite to adsorb complex compounds such as humic acids that contribute to the reddish-brown color of peat water.

The results of this study show that the lower the organic matter content, the clearer the water color. The ability of bentonite to absorb organic matter and Fe is because bentonite has strong colloidal properties and expands when mixed with water, allowing adsorption to occur in each layer of bentonite. This process occurs due to the very small colloidal particle size and high ion surface capacity of bentonite (Atikah, 2018).

Total Dissolved Solid (TDS)

Total Dissolved Solid (TDS) is the total amount of dissolved substances in water which is expressed by the amount of material dissolved in a solution with mg/l units. Total Dissolved Solid (TDS) has a size of less than one nanometer with units of mg/l or ppm (Said et al., 2019). Total Dissolved Solid (TDS) is directly proportional to the amount of organic matter in peat water. The higher the organic matter content, the higher the Total Dissolved Solid (TDS) in peat water. According to (Said et al., 2019) that Total Dissolved Solid (TDS) comes from organic substances in peat water in the form of peat decomposed by water. Based on the diagram above, it can be seen that the Total Dissolved Solid (TDS) in peat water has decreased in line with the increasing use of temperature in bentonite activation. The lowest Total Dissolved Solid (TDS) occurred in 500˚C activation with a value of 27 mg/l while the highest occurred in natural bentonite at 33 mg/l. In general, both activated and unactivated bentonite are able to reduce the content of organic substances and Total Dissolved Solid (TDS). However, thermally activated bentonite was able to increase the adsorption ability of bentonite in reducing organic matter and TDS in peat water.

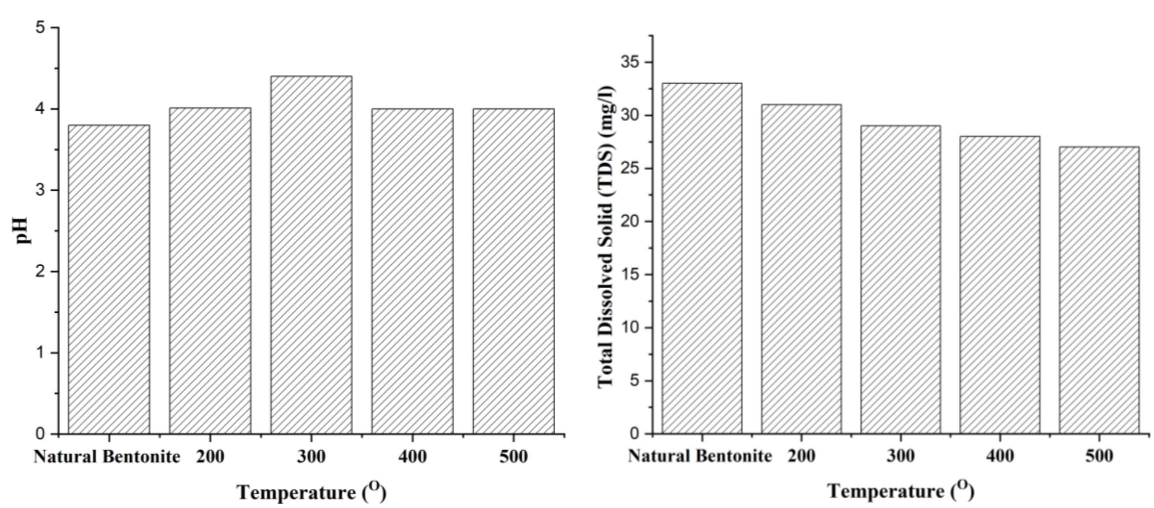

Figure 3. Bar diagram of Total Dissolved Solid (TDS) and Reduction of acidity in peat water after adsorption in Peat Water after adsorption (temperature in °Celcius)

Acidity Reduction

Decreasing the acidity of water (increasing the pH of water) is an important process in neutralizing water so that the water is suitable for consumption. Peat water generally has acidity in the pH range of 3-5. Meanwhile, the standard set by PERMENKES No. 32 of 2017 is 6.5 - 8.5. A pH that is too acidic can cause digestive system disorders, skin irritation and eyes.

In general, natural bentonite and thermally activated bentonite are not able to reduce the acidity of peat water. Natural bentonite and activated bentonite were only able to reduce the pH 1 level lower than before. Activated bentonite with a temperature of 300˚C had the best performance in reducing the pH of peat water to 4.4. Research (Naswir, 2013) shows that bentonite has less significant effect in reducing the pH of peat water. According to (Ruskandi et al., 2020) that the surface of bentonite has acidity related to Bronsted acid and Lewis acid. Therefore, bentonite is not able to reduce the acidity of peat water, because a decrease in acidity can only occur if there is an addition of base to a solution.

Conclusions

Based on the research that has been done, it can be concluded that temperature affects the decrease in Fe metal content and total organic matter, the higher the temperature in the activation process in line with the increasing efficiency of bentonite in reducing Fe metal content and total organic matter. The highest decrease occurred in activated bentonite with a temperature of 500˚C with an efficiency of 65.96% on Fe metal and 89.6% on total organic matter. However, natural bentonite was able to reduce the content of Fe metal and total organic matter with an efficiency of 67.10% and 52.70%. So the adsorbent with the best adsorption ability is bentonite with activation at 500˚C because it is able to significantly reduce the content of Fe metal and Total Organic Matter.

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