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The Effect of Chemical Activation (Acid and Base) On Sugarcane Bagasse Charcoal (Saccharum Officinarum L.) As An Adsorbent to Reduce Iron (Fe) Levels in Well Water

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Abstract: *The use of adsorbents to reduce metal concentrations in well water is a widely developed method because it is effective and efficient in decreasing pollutant content, especially heavy metals. This study aims to determine the effect of chemical activation (acid and base) on sugarcane bagasse charcoal as an adsorbent to reduce iron (Fe) levels in bore well water in Fajar Baru Village, which has iron concentrations exceeding the quality standard limits. The research was conducted in a batch system on a laboratory scale using 1000 mL of well water sample and 20 grams of adsorbent. Three conditions were investigated: sugarcane bagasse charcoal heated at 200°C, charcoal activated with a strong acid (H2SO4), and charcoal activated with a strong base (KOH). The contact times used were 0, 15, 30, and 45 minutes. The results showed that all types of activation were capable of reducing iron (Fe) levels, with removal efficiencies of 64.48%, 89.07%, and 92.89%, respectively. Activation using a strong base (KOH) produced the best performance with the highest iron removal efficiency of 92.89%. In conclusion, sugarcane bagasse charcoal heated at 200°C, activated with a strong acid (H2SO4), and activated with a strong base (KOH) can all reduce iron (Fe) levels in bore well water, with strong base activation (KOH) being the most effective.*
Keywords*: Adsorbent, Sugarcane Bagasse, Acid Activation, Base Activation, Well Water, Iron Concentration (Fe)*

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I. INTRODUCTION

Adsorbents for reducing metal concentrations are widely developed methods because they are effective and efficient in decreasing pollutant content, particularly heavy metals. Adsorption is a process in which dissolved substances (adsorbates) are captured by the surface of solid materials (adsorbents), involving two phases: solid and liquid. Several natural materials can be utilized as adsorbents, such as coconut shells, rice husks, and fiber-rich fruit peels. These materials are chosen because they are readily available, inexpensive, and environmentally friendly [3].

One natural material with potential as an adsorbent is sugarcane bagasse (Saccharum officinarum L.). Sugarcane bagasse is a solid waste produced from the milling or extraction process of sugarcane and contains important components such as cellulose, lignin, and pentosan [9]. These components support the ability of bagasse to adsorb heavy metals. Through chemical activation using substances such as sulfuric acid (H_2SO_4) or potassium hydroxide (KOH), sugarcane bagasse can be converted into activated charcoal with higher surface area and porosity, thereby enhancing its adsorption capacity. Research by [5] showed that activated charcoal from sugarcane bagasse was able to reduce metal concentrations by up to 97.92%, while the study by [1] reported an iron ion removal efficiency of 99.81%.

Excessive Fe content in water can cause changes in color, odor, and taste, as well as leave stains on household equipment. More importantly, continuous consumption of water with high Fe levels can cause health issues such as hemochromatosis, which may impair the function of the liver, heart, and pancreas [8]. The Government Regulation of the Republic of Indonesia No. 22 of 2021, Annex VI on National Water Quality Standards, sets the permissible Fe concentration in Class I raw water at 0.3 mg/L.

Observations conducted in Fajar Baru Village, Jati Agung Subdistrict, South Lampung Regency showed that residents' well water had an unpleasant odor, a yellowish color, and left dark stains in storage containers. Despite these issues, the water was still used for non-consumption purposes such as watering plants and washing vehicles. Test results indicated that the Fe concentration in the well water exceeded the quality standard, measuring 1.83 mg/L.

Based on this background, this study aims to determine the potential of chemically activated sugarcane bagasse charcoal, treated with H_2SO_4 and KOH, in reducing Fe concentrations in groundwater. This research is expected to contribute to the development of sustainable water treatment technologies based on local biomass waste and support efforts to provide clean water that meets applicable environmental quality standards.

II. RESEARCH METHODS

This research is classified as a true experimental study, which aims to determine the effects and relationships between the variables being examined. In this study, the influence of chemical activation (acid and base) on sugarcane bagasse charcoal used as an adsorbent for reducing Fe levels in groundwater was investigated. The sampling location was in Fajar Baru Village, Jati Agung Subdistrict, South Lampung Regency, Lampung Province. Sample analysis was conducted at the Laboratory of the Faculty of at Malahayati University, Bandar Lampung, and sample testing was carried out at Great Giant Food. The research was conducted in April.Groundwater samples were collected using a 5-liter jerry can and subsequently analyzed to determine iron concentration in order to apply appropriate treatments to reduce Fe levels.

The tools and materials used in this study included beakers, an oven, a 100-mesh sieve, a spatula, a magnetic stirrer, a digital balance, sacks, sample bottles, a stopwatch, a measuring pipette, sugarcane bagasse, water samples, distilled water (aquadest), strong acid (H_2SO_4), and strong base (KOH).

The carbonization process involved drying the sugarcane bagasse (Saccharum officinarum L.) under sunlight until completely dry, followed by oven-drying until the color turned into charcoal. The resulting charcoal was then allowed to cool at room temperature.

The activation process was carried out by mixing the charcoal with acidic solution using a ratio of 1:3 (100 g of charcoal with 300 mL of strong acid solution). Similarly, the base solution was mixed with charcoal using the same 1:3 ratio (100 g of charcoal with 300 mL of strong base solution). The mixtures were left at room temperature (26–31 °C), and finally, the acid-activated and base-activated charcoal were dried under direct sunlight until completely dry.

III. RESULTS AND DISCUSSION

3.1. Research Design

The well water used in this study was obtained from Fajar Baru Village, Jati Agung Subdistrict, South Lampung, which contains a high concentration of Fe, measured at 1.83 mg/L. Based on the analysis results, it can be seen that the quality of the well water in Fajar Baru Village does not meet the clean water standards regulated by the Indonesian Ministry of Health Regulation (PerMenKes RI) No. 32 of 2017, as the Fe content exceeds the permissible limit of 1 mg/L.

The adsorbent used in this study was sugarcane bagasse charcoal. To enhance its adsorption capacity, chemical activation (acid and base) was applied. The experiment was conducted on a laboratory scale using 1000 mL of well water and 20 grams of adsorbent in a batch system. Samples were collected at 0, 15, 30, and 45 minutes, with two repetitions for each sampling time. The parameter analyzed was iron concentration (mg/L).

3.2. Effect of Chemically Activated Sugarcane Bagasse Charcoal on Iron (Fe) Reduction in Groundwater

The results of testing 1000 mL of water sample with 20 grams of adsorbent (acid-activated and base-activated) show that the Fe concentration in the borehole water decreased, as shown in the figure.

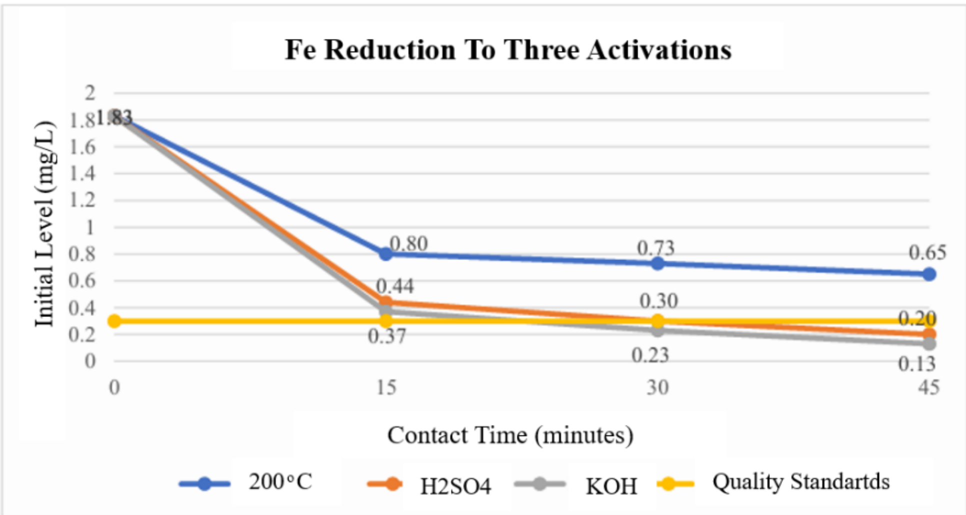

Fig. 1 The Relationship Between Fe Concentration and Contact Time (Minutes) Using Sugarcane Bagasse Charcoal at 200°C Activated with Strong Acid (H_2SO_4) and Strong Base (KOH)

Based on the figure, it can be concluded that the three types of activation applied to sugarcane bagasse charcoal influenced the reduction of iron (Fe) levels in the borehole water samples. The results of the study show that activation using a strong base, namely potassium hydroxide (KOH), was more effective in reducing iron (Fe) concentrations compared to treatment at 200°C or activation using a strong acid such as sulfuric acid (H_2SO_4). This is because KOH contains OH^- ions that function to bind positively charged ions within the pores of the adsorbent [2]. In contrast, H_2SO_4 contains H^+ ions that bind negatively charged ions in the adsorbent pores [4]. Meanwhile, dissolved iron in water may exist in the form of ferrous ions (Fe^{2+}) or ferric ions (Fe^{3+}) [7]. Therefore, the two activation types possess different chemical properties, making KOH activation more effective in reducing Fe ion concentrations in the borehole water samples.

Additionally, the reduction in iron levels increased with longer contact time between the activated material and the water sample. Whether in the untreated condition, acid activation, or base activation, the longer the contact time, the greater the reduction in Fe concentration. This indicates that the adsorption process or chemical reactions involved require a certain duration to reach maximum efficiency.

3.3. Adsorption Rate in the Use of Sugarcane Bagasse Charcoal as an Adsorbent for Reducing Iron (Fe) Levels

The adsorption rate can be determined by dividing the reduction in iron (Fe) concentration by the corresponding contact time. In this study, sampling was conducted at a 15-minute interval, and therefore the adsorption rate was calculated for each contact time period.

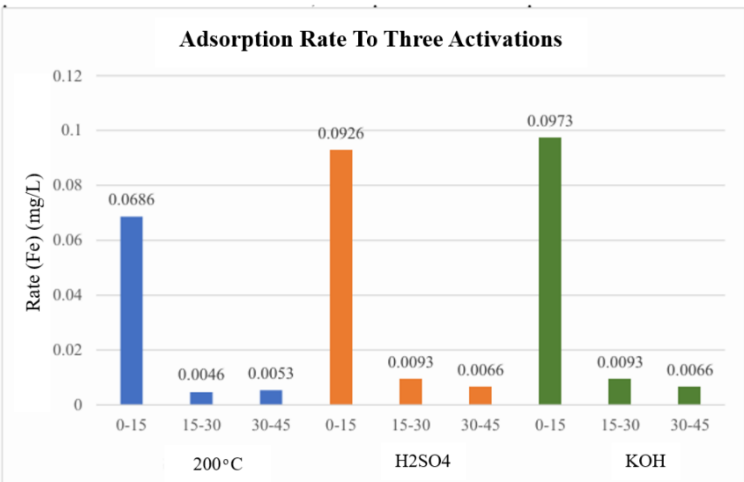

Fig. 2 Adsorption Rate of Sugarcane Bagasse Charcoal as an Adsorbent for Reducing Iron (Fe) Levels

The figure above shows the adsorption rate using sugarcane bagasse charcoal as an adsorbent for reducing Fe levels. The non-activated charcoal exhibited the lowest adsorption rate at all observation times. Sugarcane bagasse charcoal activated with either H_2SO_4 or KOH demonstrated better adsorption performance compared to charcoal that was only heated at 200°C. Activation with KOH showed a higher adsorption rate than H_2SO_4 during the 0–15 minute interval. It can be concluded that the adsorption rate depends on the type of activation and the contact duration, both of which influence the performance of sugarcane bagasse charcoal in reducing Fe levels in borehole water samples.

IV. CONCLUSION

Based on the results of the study on the effect of different activators on the use of sugarcane bagasse as an adsorbent for reducing iron (Fe) levels in well water from Fajar Baru Village, the following conclusions were obtained:

1. Sugarcane bagasse charcoal can be used as an adsorbent to reduce the iron (Fe) content in borehole water.
2. Sugarcane bagasse charcoal heated at 200°C demonstrates the ability to reduce Fe concentration in borehole water; however, its effectiveness can still be improved. Chemical activation of sugarcane bagasse charcoal using a strong base (KOH) was found to be more effective in reducing Fe levels compared to charcoal heated at 200°C or charcoal activated using a strong acid (H_2SO_4). At 200°C and with a contact time of 45 minutes, KOH-activated charcoal was able to reduce Fe levels to 0.13 mg/L, with a removal efficiency of 92.89%, and the result met the established water quality standards. Meanwhile, activation using sulfuric acid (H_2SO_4) resulted in an Fe concentration of 0.20 mg/L with a removal efficiency of 89.07%, and charcoal heated at 200°C alone reduced Fe levels to only 0.65 mg/L with a removal efficiency of 64.48%. The higher

effectiveness of KOH activation is attributed to the presence of OH^- ions, which can interact more optimally with positively charged metal ions such as Fe^{2+}. Therefore, activation using a strong base (KOH) is the most effective method for reducing iron (Fe) levels in borehole water.

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