International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 14, Issue 11 [November 2025] PP: 120-124

The Effect of Heat Activation on Bagasseen Charcoal (Saccharum Officinarum L) As an Adsorbent to Reduce Iron (Fe) Levels in Well Water (Case Study: Fajar Baru Jati Agung South Lampung)

Hardoyo[1], Natalina[2], Azahra Sabila[3]
Faculty of Engineering, Environmental Engineering study program, Malahayati University, Indonesia.

Abstract: *The use of adsorbents in water treatment is a widely developed method because it is considered effective and efficient in reducing the content of pollutants, especially heavy metals. One of the heavy metals that often pollutes water is iron (Fe), high iron levels can cause discoloration, unpleasant odors, stains on fabrics, and have negative impacts on human health. This study aims to analyze the effect of sugarcane bagasse (Saccharum officinarum L.) charcoal that is activated by heat at temperatures of 225°C, 250°C, and 275°C as a natural adsorbent in reducing the iron content of drilled well water in Fajar Baru Village, Jati Agung District, South Lampung Regency. Charcoal is made through a pyrolysis process and heat activation for 30 minutes. The study was conducted in a laboratory using a batch method, with a water volume of 1000 ml and 20 grams of activated charcoal. Samples were taken at contact times of 0, 15, 30, and 45 minutes to analyze iron (Fe) levels. The results showed that activation at 275°C provided the most optimal results, with a reduction in Fe content from 1.83 mg/L to 0.113 mg/L in 45 minutes, and a reduction efficiency of 95.82%. High-temperature activation increases the surface area and pore structure of the charcoal, thereby accelerating the adsorption process. Heat-activated bagasse charcoal has the potential to be an environmentally friendly and economical solution to address iron contamination in well water.*
Keywords*: Sugarcane Bagasse, Activated Carbon, Adsorption, Adsorbent, Physical Activation, Iron (Fe) Conten*

Date of Submission: 12-11-2025 Date of acceptance: 24-11-2025

I. INTRODUCTION

The use of adsorbents in water treatment is one of the methods widely developed due to its effectiveness and efficiency in reducing pollutant content, particularly heavy metals. Adsorption is a process in which dissolved substances (adsorbates) are captured by the surface of solid materials (adsorbents), and it can occur either physically or chemically. Natural materials such as coconut shell charcoal, rice husk charcoal, banana peel charcoal, and sugarcane bagasse charcoal have been proven to possess good adsorption capabilities because of their porous structure, which enables the removal of iron contaminants in water [7].

One natural material with great potential as an adsorbent is sugarcane bagasse (Saccharum officinarum L). According to the Indonesian Central Bureau of Statistics (BPS), sugarcane bagasse waste is abundantly available in Indonesia, with sugarcane production reaching 2.27 million tons in 2023. Utilizing sugarcane bagasse waste helps reduce environmental waste while supporting environmental sustainability. Sugarcane bagasse has been proven effective for producing activated carbon due to its high lignin, cellulose, and hemicellulose content, which makes it suitable for removing contaminants, odors, and color. Moreover, it allows agricultural waste to be used as an efficient and economical carbon source in water purification processes [1].

Water contamination caused by high concentrations of iron can result in changes in water color, unpleasant odor, and staining on fabrics. Although iron (Fe) is needed by the human body in very small amounts, excessive concentrations can negatively impact health due to its tendency to accumulate in organs. This accumulation can lead to several health problems, including impaired heart function, cancer, and vascular disorders. Therefore, water contaminated with high iron (Fe) levels must be treated before consumption [2].

One commonly used source of clean water is groundwater extracted from wells. Well water originates from rainwater that infiltrates the ground and forms underground reservoirs. During infiltration, rainwater passes through several layers of soil, causing it to absorb various minerals at certain concentrations. Some of the minerals commonly found include calcium (Ca), magnesium (Mg), and iron (Fe) [5].

Based on preliminary observations, residents of Fajar Baru Village, Jati Agung District, South Lampung Regency face issues related to the quality of their well water. The water is only used for daily household needs such as washing and bathing. For drinking purposes, residents prefer to purchase refillable bottled water. Initial observations suggest that well water in the area contains high levels of iron.

From the explanation above, it is necessary to conduct research on the effect of thermal activation of sugarcane bagasse charcoal (Saccharum officinarum L) as an adsorbent. Adsorption using natural materials is an effective method for reducing iron levels in water. To enhance adsorption capacity, sugarcane bagasse charcoal requires an activation process, such as heat activation, to increase its pore surface area and adsorption capability for heavy metals.

This study aims to determine the effect of thermal activation of sugarcane bagasse charcoal on reducing iron levels in well water in Fajar Baru Village, Jati Agung District, South Lampung Regency. It is also expected to provide an environmentally friendly and economical alternative solution for improving water quality.

II. RESEARCH METHODS

This type of research is a true experimental study, which is conducted to determine the effect of specific variables under controlled conditions. In this study, the influence of activation temperatures—225°C, 250°C, and 275°C—on sugarcane bagasse charcoal (Saccharum officinarum L.) in reducing iron levels in bore well water is examined.

The water samples were collected from a household bore well in Fajar Baru Village, Jati Agung District, South Lampung Regency. The experimental work was carried out at the Laboratory of the Faculty of Engineering, Malahayati University, Bandar Lampung, and sample testing was conducted at the Non-Food Laboratory, Sub. Dept. Head (PT. Great Giant Pineapple). The research was conducted from January to July 2025.

The tools and materials used in this study include a furnace, beaker glass, 100-mesh sieve, spatula, gloves, filter paper, magnetic stirrer, digital balance, sample bottles, and a stopwatch. The materials used were sugarcane bagasse, water samples, and distilled water.

Steps for Preparing the Charcoal:

1. Prepare the sugarcane bagasse (Saccharum officinarum L.).
2. Clean the bagasse to remove dirt or residue from its surface.
3. Cut the bagasse into small pieces (1–2 cm) to accelerate the drying process.
4. Sun-dry the bagasse for approximately seven days (until completely dry) to remove moisture.
5. Conduct the pyrolysis process to convert the bagasse into active charcoal at 200°C for 1 hour.
6. After pyrolysis, cool the resulting charcoal at room temperature.
7. Heat the charcoal using a furnace at temperatures of 225°C, 250°C, and 275°C for 30 minutes.
8. Grind the sugarcane bagasse charcoal into fine particles and sieve using a 100-mesh sieve.
9. Test the activated charcoal by mixing it with the water sample to evaluate its adsorption capacity for heavy metals such as iron.

Adsorption Process:

1. Prepare 1000 ml of bore well water containing Fe and pour it into separate beaker glasses.
2. Add 20 grams of activated sugarcane bagasse charcoal into each beaker.
3. After adding the activated charcoal, mix the charcoal and water sample using a magnetic stirrer at 100 rpm and allow it to stand for the contact times of 0, 15, 30, and 45 minutes to allow the adsorption process to occur optimally.
4. Repeat the procedure twice and submit the samples to the laboratory for the required analytical testing.

III. RESULTS AND DISCUSSION

3.1. Research Design

The groundwater used as the sample in this study was obtained from a household bore well in Fajar Baru Village, Jati Agung District, South Lampung Regency. The iron (Fe) concentration in the bore well water was 1.83 mg/L, which exceeds the clean water quality standard as stated in the Minister of Health Regulation (Permenkes) No. 32 of 2017.

The adsorbent used in this research was sugarcane bagasse charcoal. To enhance its adsorption capacity, the sugarcane bagasse charcoal was thermally activated at temperatures of 225°C, 250°C, and 275°C. The experiment was conducted on a laboratory scale using 1000 ml of bore well water, with 20 grams of adsorbent added under a batch system. Sample collection was carried out at 0, 15, 30, and 45 minutes, with two repetitions for each contact time. The parameter analyzed was the iron concentration (mg/L).

3.2. The Effect of Thermal Activation of Sugarcane Bagasse Charcoal on the Reduction of Iron (Fe) Levels in Bore Well Water

The results of the three physical (heating) test conditions with activation at 200 °C, 225 °C, 250 °C, and 275 °C can be seen in the following figure.

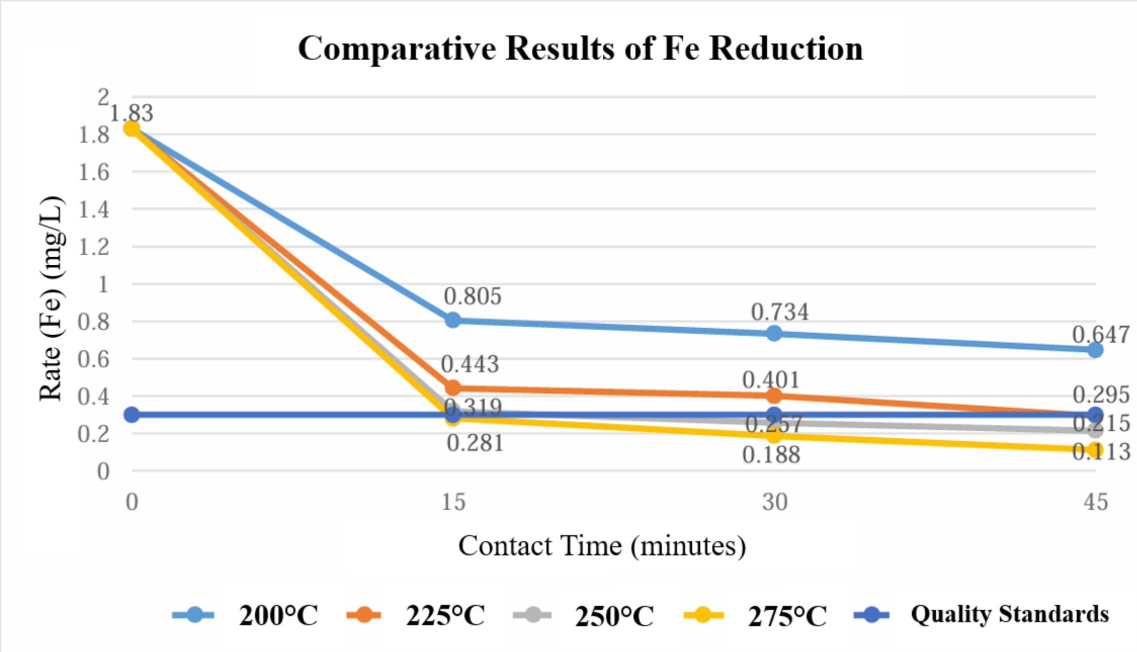

Fig. 1 Comparison Between Iron (Fe) Concentration and Contact Time Using Adsorbents Activated at 200°C, 225°C, 250°C, and 275°C.

Based on the comparison of the four activation conditions, it can be concluded that the higher the activation temperature of the sugarcane bagasse charcoal, the better its Fe adsorption performance. However, although Fe removal increases with higher activation temperatures, the magnitude of improvement becomes smaller as the temperature increases.

In the contact time interval of 0–15 minutes, sugarcane bagasse charcoal activated at 200°C and 225°C showed a decrease in Fe concentration of 0.362 mg/L. When the activation temperature was increased from 225°C to 250°C, the Fe reduction became smaller, reaching only 0.124 mg/L. Furthermore, increasing the activation temperature from 250°C to 275°C resulted in an even smaller Fe reduction of 0.038 mg/L.

At activation temperatures of 200°C to 225°C, significant expansion occurs within the pore structure of the activated sugarcane bagasse charcoal, leading to an increase in surface area and pore volume. This expansion allows more Fe-containing liquid to enter and be effectively absorbed into the pores of the charcoal, resulting in a substantial reduction in Fe concentration within this temperature range.

As the activation temperature increases to 250°C and 275°C, the pore expansion begins to diminish, reducing the volume of liquid that can be accommodated within the charcoal pores. Consequently, the improvement in Fe removal efficiency becomes smaller at these higher temperatures [4]. This indicates that higher activation temperatures can enhance the surface area and number of active pores in sugarcane bagasse charcoal, thereby improving its Fe adsorption capacity.

High-temperature activation helps improve the structure of sugarcane bagasse charcoal by forming more effective pores capable of trapping Fe. Therefore, although higher activation temperatures increase adsorption capacity, the incremental improvement in Fe adsorption becomes smaller at higher temperatures [3].

3.3. Adsorption Rate Using Sugarcane Bagasse Charcoal as an Adsorbent for Reducing Iron (Fe) Levels in Bore Well Water

The adsorption rate can be determined by dividing the reduction in iron (Fe) concentration over a specific time period. In this study, measurements were taken at 15-minute intervals, and the adsorption rate was calculated for each corresponding contact time.

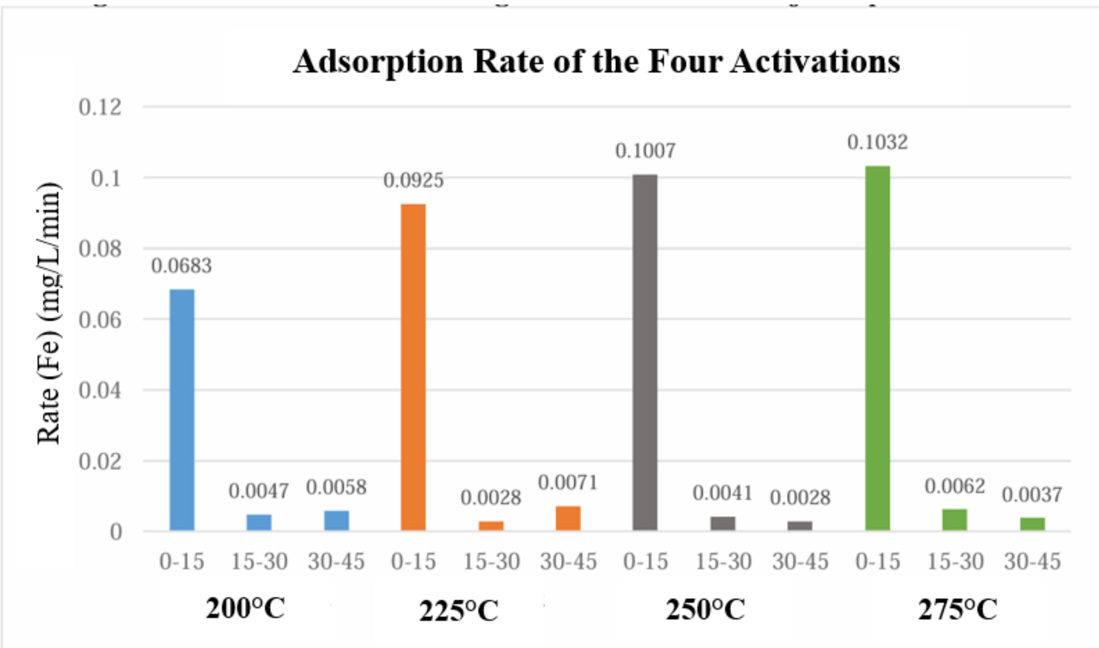

Fig. 2 Adsorption Rate Using Activated Adsorbents

In the figure above, it is shown that the adsorption rate of Fe using sugarcane bagasse charcoal varies significantly depending on the activation temperature. At 200°C, the adsorption rate in the first 15 minutes reaches 0.0683 mg/L, then decreases to 0.0047 mg/L at 30 minutes, and increases again to 0.0058 mg/L at 45 minutes. This occurs because the pores of the charcoal at lower temperatures are not yet fully opened. During the first 15 minutes, iron is quickly adsorbed because some pores have already opened, but due to the limited number of active adsorption sites, the process slows down. As the contact time increases, additional pores that were previously inactive begin to open, causing the adsorption rate to rise again.

Activation at 225°C begins to open the pores and increase the surface area, resulting in an adsorption rate of 0.0925 mg/L in the first 15 minutes. However, the rate decreases to 0.0028 mg/L at 30 minutes and rises again to 0.0071 mg/L at 45 minutes. This indicates that although the pores are beginning to open, the structural stability of the charcoal is not yet sufficient to maintain a consistent adsorption rate.

Furthermore, increasing the activation temperature to 250°C and 275°C further optimizes the adsorption process. The adsorption rates in the first 15 minutes increase to 0.1007 mg/L and 0.1032 mg/L, respectively. After that, the rates decline gradually, indicating a stable and efficient adsorption process. At higher temperatures, the pores of the charcoal are fully opened, allowing rapid adsorption at the beginning, followed by a gradual decrease as the material approaches saturation.

Based on these results, the activation temperature of 275°C is considered the most optimal because it produces the highest initial adsorption rate and demonstrates the greatest stability over time compared to lower temperatures.

IV. CONCLUSION

Based on the research findings and data analysis, the following conclusions can be drawn:

1. Sugarcane bagasse charcoal (Saccharum officinarum L.) can be used as an adsorbent to reduce iron (Fe) concentrations. The iron concentration in the bore well water, which was initially 1.83 mg/L, was successfully reduced through the adsorption process using sugarcane bagasse charcoal.
2. The adsorption process using sugarcane bagasse charcoal activated at 200°C was able to reduce the iron concentration from 1.83 mg/L to 0.647 mg/L after 45 minutes, with a removal efficiency of 64.64%.
3. Physical activation of sugarcane bagasse charcoal at different temperatures (225°C, 250°C, and 275°C) effectively increased adsorption efficiency. The best results were obtained at 275°C, reducing the iron concentration from 1.83 mg/L to 0.113 mg/L after 45 minutes, achieving a removal efficiency of 93.82%.

The adsorption process indicates that longer contact time (45 minutes) and higher activation temperature (275°C) improve the efficiency of iron removal.

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