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STUDY ON THE EFFECTIVENESS OF ACTIVATED CARBON FOR REDUCING HARDNESS AND IRON (FE) CONTENT IN WELL WATER

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Abstract

One source of clean water for communities is well water, which originates from groundwater. Groundwater typically has higher hardness levels compared to surface water and contains iron, as it percolates through rocks and subsurface soil. To address the issue of hardness and iron content in well water, one effective method is the adsorption process using activated carbon. This study investigates the effectiveness of activated carbon in reducing both hardness and iron (Fe) concentrations in water. The research tested different carbon thicknesses (60 cm, 70 cm, and 80 cm) to assess their impact on reducing hardness and iron (Fe) levels. The initial hardness level was 580 mg/l, and the iron (Fe) content was 2.08 mg/l. After treatment with activated carbon, the reduction in hardness at thicknesses of 60 cm, 70 cm, and 80 cm was 69.31%, 77.13%, and 82.87%, respectively. The reduction in iron (Fe) content at these thicknesses was 92%, 96%, and 97%, respectively. The results indicate that increased thickness of the activated carbon improves its effectiveness in reducing both hardness and iron (Fe) levels. As the thickness of the activated carbon increases, its efficiency in treating water also increases, showing that thicker layers of activated carbon enhance processing effectiveness.

Keywords: *Well Water, Hardness, Levels of Iron (Fe), Activated Carbon, Thickness*

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1. Introduction

Humans need clean water for their activities; inadequate water availability can significantly impact health, the economy, and social life (Anjeli, 2023). One source of clean water for communities is well water, which is considered more affordable, cleaner, and sufficient in quantity compared to water from municipal water services (PDAM) (Umayasari et al. 2022). Well water originates from groundwater, which generally has higher hardness levels than surface water. This is because groundwater interacts with limestone in soil layers, causing it to become contaminated with calcium (Ca) and magnesium (Mg) ions, leading to hard water (Rosyi, 2020). Hard water also contains high levels of minerals, including iron. The presence of iron in well water results from groundwater dissolving iron present in the Earth's crust. Iron is a relatively abundant metal in the Earth's crust, found in nearly all geological layers and bodies of water (Ulfa and Samik 2022). Excessive iron concentrations in water can cause various issues, such as yellow discoloration, a metallic taste, and corrosion of metal materials.

To reduce hardness and iron (Fe) content in water, adsorption processes can be employed. Adsorption is economically advantageous, offers higher efficiency, and provides effective metal binding, making it a reliable method (Rachman et al., 2024). Activated carbon acts as an adsorbent, capable of absorbing both organic and inorganic substances due to its chemical and physical properties, and can also serve as a catalyst in various reactions. Given these conditions, this study aims to analyze the initial characteristics of hardness and iron (Fe) content in well water, assess the effectiveness of activated carbon in reducing these parameters, and examine the impact of activated carbon on lowering hardness and iron (Fe) levels in well water.

Wells are sources of water obtained through excavation or drilling into aquifer layers to access clean water (Alam et al. 2024). Types of wells include artesian wells, pump wells, dug wells, drilled wells, and seepage wells. Drilled wells are located between impermeable layers, and their water quality is not affected by seasons or environmental conditions but is influenced by the mineral and metal content in the soil it traverses, such as iron (Fe).

Adsorption is the process of aggregating dissolved substances onto the surface of an adsorbent, causing the substances to adhere to and accumulate on the adsorbent. The adsorption mechanism involves cohesive forces, hydrostatic forces, and hydrogen bonding occurring between adsorbate molecules and the adsorbent material. These unbalanced forces lead to changes in molecular concentration at the solid-fluid interface (Nadir 2021). When molecules leave the solution and adhere to the adsorbent surface due to chemical and physical reactions, adsorption is taking place.

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The effectiveness of adsorption depends on the properties of the adsorbing solid, the nature of the adsorbed molecules, concentration, temperature, and other factors (Lestari et al. 2024). In addition to adsorption, iron (Fe) levels can also be reduced using coagulation and flocculation methods, which involve adding chemical coagulants like alum or natural coagulants such as moringa seeds (Fajar, 2020).

2. Method

This study was conducted from May to June 2023. Water samples were collected from a single point in Pidada Village, Panjang District, Bandar Lampung, Lampung Province. The research employed an experimental design, where well water was tested to determine its hardness and iron (Fe) content. The samples were then divided into two groups: the first group served as the treatment unit, and the second group acted as the control. The reactor used in this study was made of acrylic with dimensions of 12 cm x 12 cm x 120 cm, and it was fitted with a faucet at the bottom to serve as the outlet for the treated water.

The independent variables in this study were the thicknesses of the activated carbon: 60 cm, 70 cm, and 80 cm. The dependent variables were the concentrations of hardness and iron (Fe) in the water samples. The control variable was the size of the activated carbon, which was 20 mesh. Gravel with a thickness of 15 cm was used as a support layer before the treated water was discharged. The gravel used was sized at 4 mesh. Prior to being placed in the reactor, the gravel was crushed, sieved through 4 mesh (4.75 mm), washed with clean water, and then sun-dried. Similarly, the activated carbon was crushed, sieved through 20 mesh, washed with clean water, and sun-dried before being placed in the reactor.

Water samples were collected from a household using well water in Pidada Village and transferred into 10-liter jerrycans. Sampling was conducted according to SNI 6989.58:2008 using the grab sampling method, where the well water tap was opened, and the water was allowed to flow for 1 to 2 minutes before being collected. The jerrycan was rinsed, filled with water, and sealed. The samples were then transported to the laboratory for treatment and analysis of hardness and iron (Fe) content. The data were processed using descriptive analysis, which involved presenting the results with graphs and tables to examine the effect of activated carbon thickness on reducing hardness and iron (Fe) levels in well water. The effectiveness of the treatment was calculated using the following equation:

$$Effectiveness(\%) = \frac{before\ treatment - after\ treatment}{before\ treatment} \times 100\%$$

In this formula:

Before Treatment is the concentration of the parameter (e.g., hardness or iron content) before the treatment is applied. After Treatment is the concentration of the parameter after the treatment process.

3. Result and Discussion

3.1 Initial Characteristics of Well Water

The initial test results for hardness and iron (Fe) content in the well water are shown in Table 1.

Tabel 1. Initial characteristics of well water before treatment

No.	Parameter	Test Results	Standard Quality
1	Hardness	580 mg/l	-
2	Iron	2.08 mg/l	0.2 (PMK No. 2 of 2023)

The initial test results for the hardness parameter in the well water showed a value of 580 mg/l. This value indicates extremely high hardness. High hardness in water can lead to several issues, such as excessive soap usage due to poor solubility and foaming, formation of deposits when the water is boiled, and potential health problems including arterial blockages and kidney stones. The initial test results for iron (Fe) concentration in the well water were 2.08 mg/l.

According to PMK No. 2 of 2023, the standard quality limit for iron (Fe) is 0.2 mg/l, indicating that the iron content exceeds the acceptable limit. High iron levels can cause water to have a yellowish color and result in corrosion of metal materials. Based on the initial test results, treatment is necessary for the well water. One effective method is the use of activated carbon adsorption to reduce both hardness and iron (Fe) levels in the water. During the adsorption process, molecules are effectively absorbed by the surface of the adsorbent or by the surface of the solution (Cendekia and Afifah, 2023).

3.2 Effectiveness of Activated Carbon in Reducing Hardness and Iron (Fe) Content

3.2.1 Effectiveness of Activated Carbon in Reducing Hardness

The results of the well water treatment through activated carbon adsorption are shown in Table 2.

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Tabel 2. Hardness Test Results

No	Carbon Thickness	Before Treatment	After Treatment (mg/l)			Average (mg/l)	Effectiveness
			1	2	3		
1	60 cm		194	184	156	178 ± 19.69	69.31%
2	70 cm	580 mg/l	138	140	120	132.66 ± 11.01	77.13%
3	80 cm		108	86	104	99.33 ± 11.71	82.87%

For each thickness variation, the treatment was conducted three times to minimize data errors. Variations in the hardness test results across experiments resulted in high standard deviations. These discrepancies are attributed to factors such as imprecise solution sampling, inaccurate burette readings, and rapid titration. The 60 cm activated carbon thickness reduced hardness to 178 mg/l, achieving an effectiveness of 69.31%. The 70 cm thickness reduced hardness to 132.66 mg/l with an effectiveness of 77.13%, and the 80 cm thickness reduced hardness to 99.33 mg/l, achieving an effectiveness of 82.87%.

The reduction in hardness is due to the adsorption of CaCO3 by activated carbon. Activated carbon is processed to open its pores, which enhances its ability to absorb particles from the water, such as hardness-causing compounds. The adsorption process involves the absorption of CaCO3 molecules onto the surface of the activated carbon due to the attractive forces between the carbon molecules and the adsorbed substances.

3.2.2 Effectiveness of Activated Carbon in Reducing Iron (Fe) Content

The initial test result for iron (Fe) concentration was 2.08 mg/l. The results of the iron (Fe) concentration after treatment with activated carbon adsorption are shown in Table 3.

Tabel 3. Iron (Fe) Content Test Results

No	Carbon Thickness	PMK No. 2/2023 Quality Standard	Before Treatment	After Treatment (mg/l)			Average (mg/l)	Effectiveness
				1	2	3		
1	60 cm			0,22	0,11	0,14	0,156 ± 0,05	92%
2	70 cm	0,2 mg/l	2.08 mg/l	0,05	0,07	0,14	0,086 ± 0,04	96%
3	80 cm			0,06	0,09	0,06	0,07 ± 0,01	97%

The treatment of well water for each thickness variation was conducted three times to minimize data errors. Variations in test results were due to environmental factors such as temperature, humidity, and calibration errors. The average concentrations for each thickness variation were obtained from the three trials. The 60 cm activated carbon thickness reduced iron (Fe) content to 0.156 mg/l, achieving an effectiveness of 92%. The 70 cm thickness reduced iron to 0.086 mg/l with an effectiveness of 96%, while the 80 cm thickness reduced iron to 0.07 mg/l with an effectiveness of 97%.

From this study, the iron (Fe) concentration in the treated well water is now below the quality standard required by PMK No. 2 of 2023. The use of activated carbon adsorption effectively reduces the iron (Fe) content in the water. The high capacity of activated carbon to absorb iron (Fe) is due to the numerous pores within the carbon, which facilitate the breaking of hydrocarbon bonds or the oxidation of surface molecules. Porous solid materials absorb surrounding substances, enabling activated carbon to efficiently remove iron (Fe) from the water.

3.3 Effect of Activated Carbon Thickness on Reduction of Hardness and Iron (Fe) Content

The thickness of activated carbon significantly impacts the reduction of both hardness and iron (Fe) content. The test results indicate that increased thickness of the activated carbon leads to more substantial reductions, resulting in higher processing effectiveness. To observe the effect of thickness on hardness reduction, refer to Figure 1.

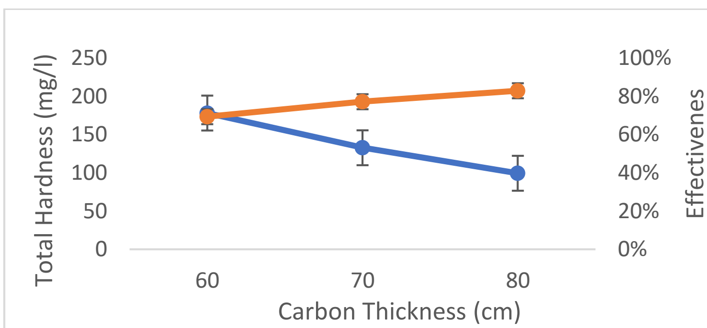

Figure 1. Reduction of hardness

The graph above shows an inverse relationship between the treatment results and the effectiveness of the process. As the treatment results decrease, the effectiveness of the treatment increases. The variability in hardness reduction values is due to differences in the thickness of the activated carbon media. The highest thickness of activated carbon demonstrates the greatest efficiency in reducing hardness. Specifically, the 80 cm thickness of activated carbon is the most effective in lowering hardness, achieving a treatment effectiveness of 82.87%. The impact of activated carbon thickness on reducing iron (Fe) levels is illustrated in Figure 2.

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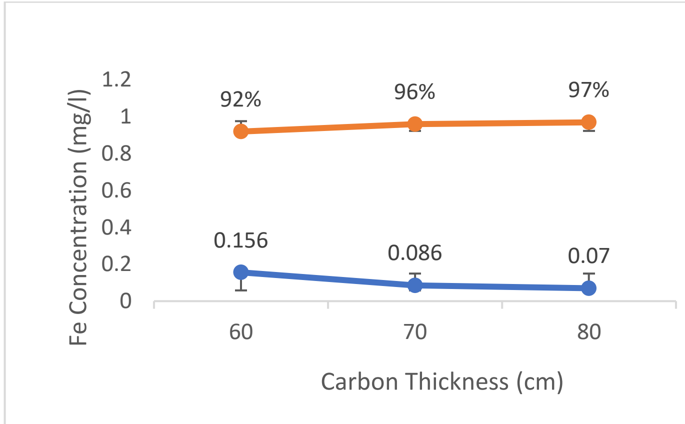

Figure 2. Iron (Fe) Reduction

This graph demonstrates the relationship between the thickness of activated carbon and the reduction in iron (Fe) concentration in the treated water. It shows that as the thickness of the activated carbon increases, the iron concentration decreases, resulting in higher treatment effectiveness. The highest thickness of 80 cm achieves the most significant reduction, with an iron level of 0.07 mg/l and an effectiveness of 97%. The study indicates that the thickness of activated carbon has a significant impact on reducing both hardness and iron (Fe) levels in water. Greater thickness of activated carbon results in higher reductions in hardness and iron (Fe). The activated carbon used in this study is derived from coconut shells, known for its low ash content, high microporosity, high absorption capacity, and environmental safety.

Activated carbon contains 87%-97% carbon, with the remainder being minerals, sulfur, oxygen, and nitrogen (Danardono 2020). Activated carbon from coconut shells has the ability to purify and absorb bacteria from water, addressing environmental waste issues (Sari and Kusniawati 2022). Increased thickness of activated carbon provides more particles, enhancing pore density and surface area, which improves adsorption efficiency (Aji, 2022). A greater thickness results in a larger surface area and more pores, allowing for more effective contaminant binding. Additionally, thicker carbon requires longer contact time, which enhances contaminant adsorption within the carbon pores.

In the adsorption mechanism observed in this study, hardness and iron (Fe) molecules are absorbed by the pores of the adsorbent as water flows through them. These molecules are trapped inside the pores and adhere to the carbon pore walls. As the thickness of the activated carbon increases, more pores are available for the water to pass through, resulting in more effective binding of hardness and iron (Fe) molecules to the adsorbent. The number and size of the pores in activated carbon contribute to its surface area for adsorption, with a larger surface area resulting in higher adsorption efficiency (Purnamawati, 2023).

4. Conclusion

Based on the discussion, the following conclusions can be drawn The initial characteristics of well water indicate a hardness level of 580 mg/l, which is classified as very high hardness. The initial iron (Fe) concentration in the well water is 2.08 mg/l, which exceeds the quality standard set by PMK Number 2 of 2023. The effectiveness of activated carbon in reducing hardness at thicknesses of 60 cm, 70 cm, and 80 cm were 69.31%, 77.13%, and 82.87%, respectively. For reducing iron (Fe) concentration, the effectiveness at these thicknesses were 92%, 96%, and 97%, respectively. This indicates that the thickness of activated carbon significantly affects the reduction of hardness and iron (Fe) levels. The efficiency values increase with greater thickness of the activated carbon media, showing that thicker carbon leads to higher treatment effectiveness. For future research, it is recommended to explore variations in the residence time of water in the media. Additionally, further studies should include testing other parameters, such as manganese (Mn) and turbidity, to assess the effectiveness of activated carbon in reducing these concentrations.

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