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Effect of Coconut Shell Activated Carbon Adsorbent Media Particle Size on Reducing Iron (Fe) Content in Clean Water in Garut Food Industry, West Java

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A B S T R A C T

Excessive iron (Fe) concentrations in groundwater remain a major concern in the food industry because they can compromise water quality and lead to noncompliance with regulatory standards. Water quality analysis in a food processing facility showed an Fe concentration of 1.075 mg/L, exceeding the permissible limit of 0.2 mg/L. This study investigated the effect of coconut shell activated carbon particle size on the reduction of Fe levels in groundwater. Coconut shells, an abundant food-industry by-product, were used as a sustainable raw material for the production of activated carbon. A true experimental study with a pretest and posttest design without a control group was conducted. A total of 30 kg of activated carbon was produced and physically activated at 600°C for 1 hour. Three particle sizes (25, 30, and 35-mesh) were applied in filtration columns with a volume of 11,304 cm^3. Groundwater samples were collected using the grab sampling method, with six replicates per treatment (18 paired samples). Fe concentrations were determined using Atomic Absorption Spectrophotometry (AAS) according to SNI 6989.4:2009. Data were analyzed descriptively using the Shapiro–Wilk test, One-Way ANOVA, and post hoc analysis. Fe concentrations decreased by 75.1%, 81.6%, and 88.4% with 25- mesh, 30- mesh, and 35-mesh activated carbon, respectively. The 35-mesh treatment achieved the highest removal efficiency. One-Way ANOVA and post hoc tests showed significant differences in Fe removal among the three particle sizes ($p < 0.001$). Activated carbon particle size significantly affected Fe removal from groundwater, with 35-mesh coconut shell activated carbon exhibiting the highest adsorption efficiency.

Konsentrasi besi (Fe) yang berlebihan dalam air tanah tetap menjadi perhatian utama dalam industri makanan karena dapat mengganggu kualitas air dan menyebabkan ketidakpatuhan terhadap standar peraturan. Analisis kualitas air di fasilitas pengolahan makanan menunjukkan konsentrasi Fe sebesar 1,075 mg/L, melebihi batas yang diizinkan yaitu 0,2 mg/L. Studi ini menyelidiki pengaruh ukuran partikel karbon aktif tempurung kelapa terhadap pengurangan kadar Fe dalam air tanah. Tempurung kelapa, produk sampingan industri makanan yang melimpah, digunakan sebagai bahan baku berkelanjutan untuk produksi karbon aktif. Studi eksperimental sejati dengan desain pra-uji dan pasca-uji tanpa kelompok kontrol dilakukan. Sebanyak 30 kg karbon aktif diproduksi dan diaktivasi secara fisik pada suhu 600°C selama 1 jam. Tiga ukuran partikel (25, 30, dan 35-mesh) diaplikasikan dalam kolom filtrasi dengan volume 11.304 cm^3. Sampel air tanah dikumpulkan menggunakan metode pengambilan sampel acak, dengan enam replikasi per perlakuan (18 sampel berpasangan). Konsentrasi Fe ditentukan menggunakan Spektrofotometri Serapan Atom (AAS) sesuai dengan SNI 6989.4:2009. Data dianalisis secara deskriptif menggunakan uji Shapiro–Wilk, ANOVA Satu Arah, dan analisis post hoc. Konsentrasi Fe menurun sebesar 75,1%, 81,6%, dan 88,4% dengan karbon aktif berukuran 25- mesh, 30- mesh, dan 35-mesh, berturut-turut. Perlakuan 35-mesh mencapai efisiensi penghilangan tertinggi. ANOVA Satu Arah dan uji post hoc menunjukkan perbedaan signifikan dalam penghilangan Fe di antara ketiga ukuran partikel ($p < 0,001$). Ukuran partikel karbon aktif secara signifikan memengaruhi penghilangan Fe dari air tanah, dengan karbon aktif tempurung kelapa 35-mesh menunjukkan efisiensi adsorpsi tertinggi.

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1. Introduction

Environmental health is one of the important indicators in efforts to improve public health. One of the main aspects of environmental health is the availability of clean water that meets the quality requirements for consumption and daily needs, but the problem of heavy metal pollution, such as iron (Fe) in clean water, is often found, especially in areas that use groundwater as the main source (Miarti, 2020). This phenomenon is widely observed in residential environments, especially in areas with specific geological characteristics, such as peatlands or high-mineral-content soils (Edwinsyah et al., 2022). Iron content that exceeds the threshold in clean water can cause a variety of problems, both aesthetically and health-wise (Asmawati et al., 2021).

Clean water is one of the most important needs in human life and is a natural resource that has a vital function. Humans use clean water for daily activities such as drinking, bathing, cooking, and washing. When viewed against the set standards, water eligible for use must comply with the applicable requirements. Another common problem is high iron (Fe) levels. These levels of content are easily dissolved in water and are very difficult to find with the naked eye (Zulhilmi, 2019; Purwono & Karbito, 2013)

A company engaged in the food production sector is located in Garut. The company obtains clean water from the Regional Drinking Water Company (PDAM) and from drilled wells, which are used for food production and for workers' hygiene and sanitation. Raw water obtained from PDAM and drilled wells is pumped and channeled into a reservoir, then distributed to the food processing process.

The results of the initial examination conducted at the West Java Regional Health Laboratory in March 2025 indicated that the Food Industry clean water test showed an iron (Fe) content of 1.075 mg/L. The results of the inspection showed that the Food Industry's clean water exceeded the threshold value stipulated in the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning the Implementation Regulation of Government Regulation Number 66 of 2014 concerning Environmental Health. The chemical parameter for iron (Fe) levels is 0.2 mg/L.

Iron content exceeding 1 mg/l can irritate the eyes and skin. Physical disturbances caused by dissolved iron in water include changes in color, smell, and taste (Febrina & Ayuna, 2015). Iron (Fe) levels in water that exceed quality standards will affect human health and the environment. Water containing iron (Fe) that exceeds the quality standard must undergo filtration to reduce iron levels. One method is the use of coconut shells (Kesumaningrum, Ismayanti, and Muhaimin 2019). Activated carbon made from coconut shells is effective as an adsorbent because it contains materials that act as filters. The chemical composition of coconut shells includes 34% cellulose, 21% hemicellulose, 27% lignin, and 18% ash (Ramadhani, 2020).

Activated carbon can be made from coconut shells because coconut shells have a higher carbon content when compared to corn stalks, rice grains, and cocoa bean shells. Coconut shells have high absorbency, produce less ash, have a large surface area, are highly pure, are cheaper, and are more environmentally friendly. Coconut shell activated carbon filter media with a cross-sectional area of 4 inches can reduce iron (Fe) content by 63.81% (Abas et al., 2022), so further adjustments are still needed to achieve Fe levels below the set quality standards. The thickness of the filter media layer effectively used is 80-120 cm (Masriatini & Fatimura, 2019; Stuart et al., 2014), which is the basic consideration of the research.

This study accounts for the variation in the thickness of activated carbon with the Fe level in clean water used in the Food Industry. The purpose of the study was to determine the effect of variations in activated carbon adsorbent particles derived from coconut shells on reducing iron (Fe) levels in clean water used in the food industry. Size variations of 25-mesh, 30-mesh, and 35-mesh were used with coconut shell activated carbon filter media thickness of 100 cm.

2. Methods

This study is a true experiment with a pretest-posttest design without a control group. Water samples come from the food industry in Garut, which uses water from drilled wells. The filter material used is coconut shells, a by-product of the food industry, converted into activated carbon. The produced activated carbon, weighing up to 30kg, was activated by conventional physical methods at 600 °C for 1 hour. Activated carbon adsorbent media are divided into three particle size variations: 25-mesh, 30-mesh, and 35-mesh, with a tube volume of 11,304 cm3, a height of 100 cm, and a diameter of 12cm. The population in this study is all water in the food processing site, and the sample is water sourced from drilled wells. Each variation was tested 6 times, with pretest and posttest samples of 18 each. The water requirement for water sampling is: 36 samples x 1,000 ml = 36,000 ml, or 36 liters. The sampling technique is grab sampling. Contact time is 15 minutes with the batch downflow system.

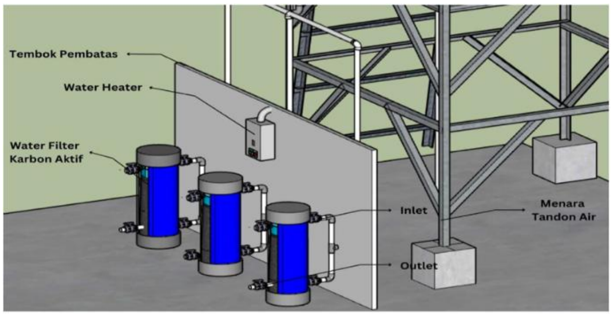

Figure 1. Side-View Tool Engineering

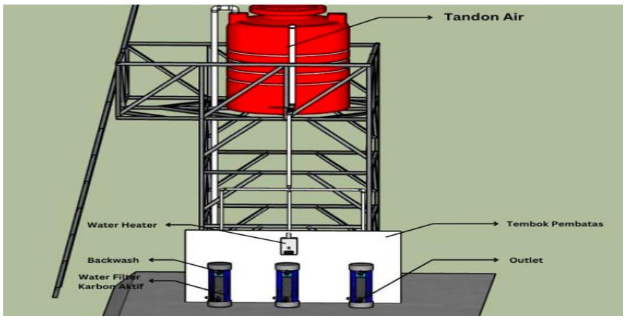

Figure 2. Front View

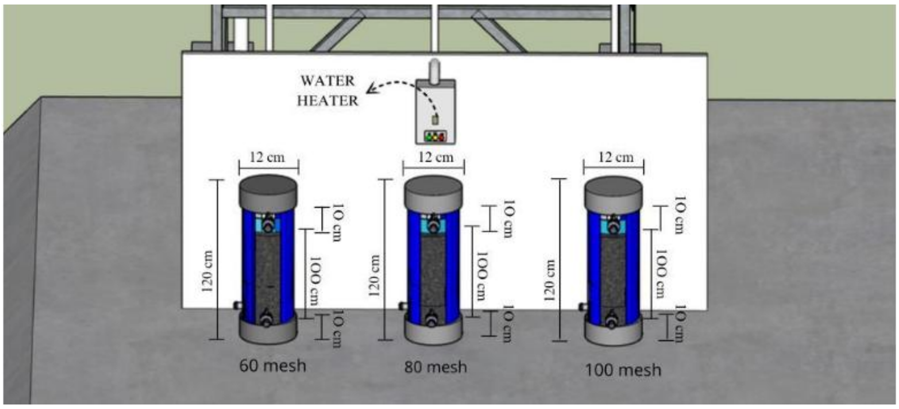

Figure 3. Headshell Activated Carbon Absorbent Media

Fe levels were checked before and after the filtration process using Atomic Absorption Spectrophotometry (SSA) SNI 6989.4:2009 method at the West Java Provincial Health Laboratory with mg/L units. Data were analyzed using a descriptive test to determine the distribution of the hail frequency distribution of the measurement of the average decrease in Fe levels, the shapiro wilk test to determine the normal distribution data, and One Way ANOVA to determine the effect of variations in the size of coconut shell perticels (thickness 25, 30, and 35-mesh) against the reduction of Fe levels in clean water in the Food Industry.

3. Results

3.1. Iron (Fe) examination results

The average result of the iron content (Fe) of food processing water before going through the variation in the particle size of coconut shell activated carbon adsorbent media (pretest) at the particle size of 25-mesh was 1.04 mg/L, at the particle size of 30-mesh was 1.05 mg/L, and at the particle size of 35-mesh was 1.04 mg/L.

The average results of the iron (Fe) content examination of food processing water after going through the variation in the particle size of coconut shell activated carbon adsorbent media (posttest) at the particle size of 25-mesh are 0.26 mg/L, at the particle size of 30-mesh are 0.19 mg/L, and at the particle size of 35-mesh are 0.12 mg/L. The pre-posttest temperature is in the range of 27.4-27.5 °C, and *the pre-posttest* pH is 7.18-7.29, tending to increase.

Table 1. Pre-Post test results

Particle Size Variations		Repeat Results Fe (mg/L)						Average (mg/L)	SD
		1	2	3	4	5	6		
P1 25-mesh	Pretest	1.05	1.07	1.04	1.01	1.05	1.04	1.04	0.0236
	Postest	0.29	0.24	0.23	0.25	0.28	0.27	0.26	
	Differences	0.76	0.83	0.81	0.76	0.77	0.77	0.78	
P2 30-mesh	Pretest	1.02	1.03	1.05	1.08	1.06	1.04	1.05	0.273
	Postest	0.15	0.19	0.20	0.21	0.18	0.23	0.19	
	Differences	0.87	0.84	0.85	0.87	0.88	0.81	0.85	
P3 35-mesh	Pretest	1.03	1.04	1.02	1.06	1.02	1.05	1.04	0.0228
	Postest	0.10	0.14	0.10	0.13	0.10	0.15	0.12	
	Differences	0.93	0.9	0.92	0.93	0.92	0.90	0.92	

The difference in iron (Fe) content before and after the adsorption process was obtained, with an average decrease at particle sizes of 25-mesh (0.78 mg/L), 30-mesh (0.85 mg/L), and 35-mesh (0.92 mg/L L. Permenkes of the Republic of Indonesia No. 2 of 2023 concerning Environmental Health states that the standard quality of chemical parameters for iron (Fe) content is 0.2 mg/L; the 30-mesh variation has a posttest average of 0.19 mg/L (the maximum limit), and the 35-mesh variation has a posttest average of 0.12 mg/L (safe variation).

3.2. Effect of activated carbon variation on decreased Iron (Fe) content

The iron (Fe) content in food processing water after the adsorption process at the 25-mesh particle size was obtained with a decrease percentage of 75.1%; at the 30-mesh particle size, a decrease percentage of 81.6%; and at the 35-mesh particle size, a decrease percentage of 88.4%. Percentage decrease in iron levels.

Table 2. Percentage decrease in Iron (Fe) levels

Particle Size Variations	Fe Decrease (%)						Average (%)
	1	2	3	4	5	6	
P1 25-mesh	72.4	77.6	77.9	75.3	73.3	74.03	75.1
P2 30-mesh	85.2	81.6	81%	80.6	83.01	77.9	81.6
P3 35-mesh	90.3	86.5	90.1	87.7	90.2	85.7	88.4

Based on the homogeneity test, the p-value is 1.00. This shows that the p-value > 0.05; therefore, the variation in the particle size of the coconut shell activated carbon adsorbent media is from a homogeneous population so that it can be continued to the one-way ANOVA test.

Table 3. Variation in decrease in Iron (Fe) levels by size activated carbon particles

Particle Size Variations	Shapiro Wilk p-Value	Homogenitas p-Value	One-way Anova *p-Value*	Posthoc Test
P1 25-mesh	0.739*	1.00*	0.000**	0.001**
P2 30-mesh	0.985*			0.001**
P3 35-mesh	0.079*			0.001**

**p-value>0.05 = significant; **p-value<0.05 = significant*

The results of the data normality test with Shapiro wilk on the variation in particle size of 25-mesh, 30-mesh, and 35-mesh were shown to be a significance value or p value > a (0.05), then it can be concluded that the variation in particle size of 25-mesh, 30-mesh, and 35-mesh is categorized as normally distributed, so that the next test step can be carried out, namely using the one-way anova test.

The results of the one-way ANOVA test yielded a *p-value* of 0.00 < 0.05, indicating a significant difference in the variation in particle size of the coconut shell activated carbon adsorption media relative to the decrease in iron (Fe) content in food processing water. The 35-mesh variation showed the optimal reduction of 88.4%, with Fe levels of 0.19 mg/L below the set quality standard.

The *post hoc* test showed a p-value < 0.001 for the comparison among the 25-, 30-, and 35-mesh groups. This indicates a statistically significant difference in iron adsorption (Fe) ability among the three particle-size variations. Therefore, the use of different mesh sizes will result in a noticeably different rate of reduction in iron content in the clean water treatment process. The finer the particle size (the higher the mesh number, i.e., 35-mesh), the larger the contact surface area. So the potential for a decrease in Fe levels will be higher than for the coarser size (25-mesh).

4. Discussion

Iron (Fe) content before the adsorption process in the coconut shell activated carbon adsorbent medium with a particle size of 25-mesh was obtained with an average iron content (Fe) of 1.04 mg/L, at a particle size of 30-mesh an average iron content (Fe) of 1.05 mg/L, at a particle size of 35-mesh obtained an average iron content (Fe) of 1.04 mg/L. The results of the study, which were carried out 6 times for each treatment, show a difference in iron (Fe) content before and after the adsorption process, attributable to variations in the particle size of the coconut shell activated carbon adsorbent. In the 25-mesh particle size, the average iron (Fe) content was 0.26 mg/L, in the 30-mesh particle size, the average iron (Fe) content was 0.19 mg/L, and in the 35-mesh particle size, the average iron (Fe) content was 0.12 mg/L.

Coconut shell activated charcoal has a high carbon content, a large specific surface area, a developed micropore structure, low ash content, and high mechanical hardness (Chacola et al.., 2026). These characteristics cause coconut shell activated charcoal to have a high adsorption capacity against various contaminants, including heavy metals and organic compounds, so it is widely used as an adsorbent medium in water treatment (Yasdi et al., 2021; Basha, Rathinavel & Sridharan, 2023; Saleem et al., 2024)

The standard quality standards for iron (Fe) content are based on the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning the Implementation Regulation of Government Regulation Number 66 of 2014 concerning Environmental Health, that the standard quality standards for chemical parameters for iron (Fe) content is 0.2 mg/L, so it can be concluded that clean water before going through the variation in particle size and contact time of the coconut shell activated carbon adsorbent medium is still above the threshold value of clean water quality standards that has been established.

The decrease in iron (Fe) concentration in the clean water at this food processing company is due to adsorption by activated carbon derived from coconut shells. This activated carbon is charcoal that has been processed through activation, resulting in pores with a very large surface area to increase its absorption capacity (Nurhayati, 2015). The use of activated charcoal in coconut shells as biosorbents in reducing iron (Fe) levels states that, based on the results of the study, it can be concluded that the iron (Fe) content of dug well water decreases after filtration using coconut shell activated charcoal media (Sappewalu et al., 2023).

This study was conducted to determine the percentage decrease in iron (Fe) content in clean water in the Food Industry that occurred after going through coconut shell activated carbon adsorbent media with a variation in particle size of 25-mesh, 30-mesh, and 35-mesh. In the 25-mesh variation, the average decrease in iron (Fe) level was 0.78 mg/L with a percentage of 75.1%; in the 30-mesh variation, the average iron level (Fe) decrease was 0.85 mg/L or 81.6%, and for the 35-mesh variation, the difference in iron level (Fe) decrease was 0.92 mg/L or a percentage of 88.4%.

The decrease in iron (Fe) levels is caused by the use of activated carbon as an adsorbent. The activated carbon medium used in this study is from coconut shells. The selection of adsorption media materials derived from coconut shells is based on their hardness, which makes them easier to handle;

high absorbency; low ash content; large surface area; high purity; low cost; and greater environmental friendliness (Masriatini & Fatimura, 2019). Activated charcoal is a porous adsorbent with a very high specific surface area (500–1500 m^2/g) and contains surface functional groups such as hydroxyl (-OH), carboxyl (-COOH), carbonyl (C=O), and phenolic groups. These clusters act as active sites that bind Fe metal ions via adsorption (Sharma et al., 2022).

Charcoal is a porous solid material composed of 85-95% carbon, produced through high-temperature heating of carbon-containing materials. Absorption is influenced by the large surface area of the particles, and this ability can be increased by activating charcoal with chemical substances or by heating at high temperatures (Jamilatun et al., 2014). The activated carbon used in this study has been activated to meet established standards. Activated carbon is a material in the form of amorphous carbon that has a very large surface area of 300- 2000 m2/gram. This large surface area is due to the pore structure of activated carbon. These pores are what enable activated carbon to absorb (Lestari et al., 2016). Activated carbon has a porous structure and surface functional groups that enable it to bind heavy metal ions through physical adsorption, surface complexation, and ion exchange. These characteristics make activated carbon one of the most effective adsorbents in water treatment (Reynel et al., 2021).

The use of activated carbon to reduce the iron (Fe) content of clean water can be influenced by several factors, including the particle size of the filter media in this study, which includes 25-mesh, 30-mesh, and 35-mesh sizes. The smaller the activated charcoal particles (the finer the mesh), the higher the Fe adsorption efficiency, as the specific surface area increases (Zega et al., 2021). Coconut shell activated charcoal for reducing iron content in well water indicates that the 8-mesh particle size is more effective than the 4-mesh particle size (Rasid et al., 2024). Biomass-based activated charcoal has a high capacity to adsorb heavy metals due to its large porosity, high surface area, and surface functional groups that can form bonds with metal ions. The main mechanisms include physical adsorption, ion exchange, surface complexation, and electrostatic interactions (Wang et al., 2023).

The decrease in iron (Fe) levels is caused by the adsorption process, which occurs due to the presence of a weak attractive force (Van der Waals) between the particles. The adsorption of Fe ions in activated charcoal not only involves the Van der Waals force (physisorption), but can also involve chemisorption through interaction with the surface functional group of activated charcoal (Srivastava et al., 2021). Coconut shell activated carbon, as a filter medium, can absorb iron (Fe) due to its large surface area (Salawudeen et al., 2023). Coconut shells are considered the best adsorbent material among other adsorbents because they have large micropore sizes, high absorbency, are environmentally friendly, and have high reactivity (Apriadi, 2020).

Temperature affects the kinetics of adsorption by increasing the diffusion of ions into the adsorbent pores, but excessively high temperatures do not necessarily increase adsorption capacity, as adsorption capacity depends on the thermodynamic properties of the adsorption process (Abdulsalam et al., 2022). Increasing pH toward neutrality enhances the adsorption efficiency of Fe ions by reducing proton competition at the adsorbent surface and increasing interactions between Fe ions and activated carbon functional groups (Rout et al., 2023). pH has the greatest influence on Fe adsorption compared to temperature. In acidic conditions (low pH), the concentration of H^+ ions is high, so there is competition between H^+ and Fe^{2+}/Fe^{3+} ions to occupy the active site of activated charcoal. As a result, the efficiency of adsorption decreases (Das et al., 2023). Conversely, as the pH increases towards neutral (around pH 5-7), the competition of H^+ ions decreases so that more Fe ions can bind to the surface functional groups of the activated charcoal, such as hydroxyl (-OH), carboxyl (-COOH), and carbonyl (C=O) groups. At pH values that are too high (>7-8), Fe begins to settle as $Fe(OH)_2$ or $Fe(OH)_3$, so that the decrease in Fe is no longer only caused by adsorption, but also by precipitation processes (Gul et al., 2022). A limitation in the study was that it did not measure water discharge during treatment. Activated carbon from coffee shells can be used as an alternative to reducing Fe levels in clean water.

5. Conclusions

Variations in the size of activated carbon particles from coconut shells had a significant effect on the reduction of iron (Fe) levels in clean water ($p=0.000$, $p<0.05$). It is recommended for the food industry to use activated charcoal filter media from coconut shells for clean water with a particle size of 35-mesh and a thickness of 100cm.

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