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Comparative Effectiveness of Coconut Shell Charcoal and Rice Husk Ash as Adsorbents in Filtration Systems for Iron (Fe) and Manganese (Mn) Removal from Groundwater

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ABSTRACT

Clean water is a vital basic need for human life. However, in several areas such as Makassar City, drilled well water is often contaminated by heavy metals such as iron (Fe) and manganese (Mn) that exceed the quality standard thresholds established in Peraturan Menteri Kesehatan No. 2 Tahun 2023 concerning drinking water quality standards. This study aimed to determine the effectiveness of coconut shell charcoal and rice husk ash as filtration media in reducing Fe and Mn levels in drilled well water. The study employed a quasi-experimental design using a simple column filtration system with measurements conducted before and after treatment. Water samples were collected from drilled wells in Paccerakkang Village, Biringkanaya District, Makassar City, and experiments were conducted using three treatments: control, coconut shell charcoal filtration, and rice husk ash filtration with repeated observations over three days. The results showed that both coconut shell charcoal and rice husk ash were effective as natural filtration media. Coconut shell charcoal reduced Fe levels by an average of 96.26% and Mn levels by 100%, while rice husk ash reduced Fe levels by an average of 97.45% and Mn levels by 100%. These results indicate that rice husk ash demonstrated slightly higher effectiveness in reducing Fe concentrations compared to coconut shell charcoal. It can be concluded that coconut shell charcoal and rice husk ash can serve as alternative natural filtration media for community-based clean water treatment. These materials are low-cost, locally available, and capable of significantly improving well water quality. Further research is recommended to explore combinations of filtration media, variations in media thickness, and different contact times to optimize filtration performance.

Keywords: Well Water; Fe Level; Mn Level; Coconut Shell Charcoal; Rice Husk Ash.

INTRODUCTION

Water is the most essential substance for life after air. Approximately three-quarters of the human body consists of water, and no individual can survive for more than four to five days without drinking it. Water is also a natural resource that is indispensable for human needs and for all living organisms. From a public health perspective, the provision of clean water sources must adequately meet community needs, as limited access to clean water can increase the risk of disease outbreaks. The average daily water requirement per individual ranges between 150–200 liters (or 34–40 gallons). This demand varies depending on climatic conditions, living standards, and community habits[1].

According to the World Health Organization (WHO, 2022), approximately 2 billion people worldwide still consume contaminated water, leading to more than 485,000 deaths annually from diarrheal diseases. In Indonesia, the Ministry of Health (2023) reported that only about 72% of households have access to safe drinking water, while most rural areas continue to rely on bore wells or groundwater, which are vulnerable to contamination by heavy metals such as iron (Fe) and manganese (Mn)[2]. This situation highlights the critical urgency and relevance of conducting research aimed at improving groundwater quality.

Clean water is defined as water that meets health requirements and must be boiled before consumption, whereas drinking water is water that meets health standards and can be consumed directly or is suitable for use as clean water. The established requirements are based on physical, chemical, and biological quality parameters in accordance with the Minister of Health Regulation No. 2 of 2023 concerning clean water quality standards. To ensure that a drinking water supply system is safe, hygienic, and suitable for consumption without posing a risk of infection to users, it must comply with these water quality standards[3].

Clean water suitable for consumption must meet the physical, chemical, and biological quality standards as stipulated in the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023. One of the critical parameters that frequently exceeds the permissible limits is the concentration of iron (Fe) and manganese (Mn). These metals commonly originate from the dissolution of mineral rocks or corrosion of metal pipes. Elevated levels of Fe and Mn can deteriorate the aesthetic quality of water—causing unpleasant odor, color, and metallic taste—and may also lead to adverse health effects, such as gastrointestinal disturbances and metal accumulation in the body[4].

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Manganese (Mn) is a grayish-reddish metal and one of the most abundant elements in the Earth's crust, typically found in association with iron (Fe). Manganese is widely used in iron and steel production, as an oxidizing agent in purification, bleaching, and disinfection processes, in the manufacture of potassium permanganate, and as a component in various industrial products[5]. A small concentration of iron (Fe) in water does not pose a health risk and can even be beneficial to the human body, particularly in the formation of hemoglobin. However, excessive levels of Fe can damage the intestinal wall and have been associated with fatalities resulting from iron overconsumption[6].

Water sources used for the provision of clean water that continuously contain Fe and Mn exceeding quality standards may cause long-term health and environmental problems if they remain untreated and are consumed directly. Therefore, it is necessary to implement water treatment processes to reduce Fe and Mn concentrations to levels below the permissible limits before use. There are various methods to reduce Fe and Mn in water, one of which is filtration. Filtration is a water treatment process that removes suspended particles or flocs by passing water through a porous medium with specific grain size and thickness. This method is commonly applied to reduce contaminants such as bacteria, odor, color, taste, Fe, and Mn, thereby producing clean water that meets established quality standards[7].

This study utilizes a combination of coconut shell charcoal and rice husk ash as filtration media, both of which are agricultural waste materials that are readily available and inexpensive. Unlike previous studies that predominantly employed imported materials such as activated carbon or synthetic zeolite sand[8], this research emphasizes a circular economy approach by utilizing abundant local waste resources. This approach aligns with the principles of Sustainable Development Goal (SDG) 6: Clean Water and Sanitation (UNDP, 2023).

Coconut shell charcoal is produced through the incomplete combustion (pyrolysis) of coconut shells under limited oxygen conditions. This charcoal possesses a hard texture, high porosity, and excellent adsorption capacity, making it an ideal raw material for various applications such as briquette production, water filtration, and activated carbon manufacturing. Moreover, coconut shell charcoal is considered environmentally friendly, as it utilizes abundant agricultural waste while also holding high economic value as an export commodity. Rice husk, on the other hand, is often discarded as waste, contributing to environmental pollution. Currently, its primary uses are as fuel and as a supplementary material in brick production. To enhance the added value of rice husk waste, it can be further processed to produce silica, one of its valuable derivative products.

Several previous studies have examined only a single filtration medium, such as the study by Sari et al. (2021)[9]s, which utilized activated carbon alone and achieved a 75% reduction in Fe concentration. However, studies that directly compare the effectiveness of coconut shell charcoal and rice husk ash under the same groundwater conditions remain limited. Therefore, this study evaluates and compares the performance of these two locally available filtration media in reducing Fe and Mn concentrations in bore well water. This expectation is supported by the findings of Nguyen et al. (2022)[10], who reported an enhanced heavy metal adsorption efficiency through the combination of carbon-based and silica-based materials.

Unlike laboratory-scale studies, this research was conducted in Paccerakkang Subdistrict, Makassar City, using groundwater from bore wells that are utilized daily by the local community. This community-based approach makes the research findings more applicable and relevant to real-world conditions, while simultaneously providing direct solutions to local water quality issues. By employing locally available materials and simple technologies, this study creates opportunities for communities to develop their own household water filtration systems without reliance on commercial technologies. This participatory approach strengthens community-based water self-sufficiency, as recommended by WHO and UNICEF (2021) in their strategy for sustainable water management in low- and middle-income regions[11].

This study primarily focuses on the technical effectiveness of filtration in reducing Fe and Mn concentrations in groundwater. In addition, the use of locally available biomass waste materials such as coconut shell charcoal and rice husk ash may also provide environmental and economic benefits due to their low cost and wide availability. These characteristics make the filtration approach potentially applicable for community-based water treatment[12]. Therefore, it is essential to develop a simple, affordable, and efficient technology to reduce Fe and Mn concentrations in groundwater. One of the most widely applied methods is filtration, a process in which water is passed through a porous medium capable of adsorbing suspended particles and dissolved metals. Previous studies have predominantly used silica sand, zeolite, and activated carbon as filtration media; however, these materials are relatively expensive and less accessible in certain regions. In Paccerakkang Subdistrict, Biringkanaya District, Makassar City, most residents rely on bore wells as their primary source of clean water. The limited availability of land is one of the main reasons for this preference. Although bore wells require high initial installation costs, in the long term they are often considered more cost-effective, as users do not need to pay monthly fees as in public water supply systems (PDAM)[13].

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MATERIAL AND METHOD

Research Design

This study employed a quasi-experimental design to evaluate the effectiveness of coconut shell charcoal and rice husk ash as filtration media in reducing iron (Fe) and manganese (Mn) concentrations in clean water from bore wells. The research used a pre-test and post-test approach by comparing Fe and Mn levels in water samples before and after filtration treatment.

Population and Sampling

A total of 25 liters of bore well water were used as research samples. The water samples were subjected to three treatment groups: control (without filtration), filtration using coconut shell charcoal, and filtration using rice husk ash. Each treatment used 1 liter of water sample and was replicated three times over three consecutive days to ensure the reliability and consistency of the experimental results. The sampling location was determined using purposive sampling based on the characteristics of bore wells that were relevant to the research objectives. The bore well water samples were collected from Paccerakkang Village, Biringkanaya District, Makassar City.

Filtration Media Preparation

Coconut shell charcoal and rice husk ash were prepared as filtration media prior to the experiment. Coconut shells were cleaned, dried, and burned at an estimated temperature of 400–500°C under limited oxygen conditions for approximately 1–2 hours to produce charcoal, which was then cooled and crushed. Rice husks were burned at an estimated temperature of 500–600°C for about 1 hour until ash was formed and then allowed to cool. Both media were subsequently crushed and sieved using a 20–40 mesh sieve to obtain uniform particle sizes, washed with clean water to remove fine particles, and dried at room temperature before use. No chemical or physical activation process was applied to the filtration media in this study.

Data Collection and Analysis Methods

The water samples were collected from bore well sources with high concentrations of Fe and Mn, selected according to the requirements of this study. The sampling locations were determined using a purposive sampling technique, intentionally chosen based on well characteristics relevant to the research objectives. Primary data consisted of Fe and Mn concentrations obtained from the analysis of bore well water before and after the filtration process using coconut shell charcoal and rice husk ash as filter media. Secondary data included supporting information collected from literature, journals, and related documents, such as clean water quality standards, charcoal activation methods, and Fe and Mn content in bore well water.

The filtration process in this study used a column filtration system. Bore well water samples were passed through a filtration column containing coconut shell charcoal and rice husk ash as filtration media. Each treatment used 1 liter of water sample that flowed through the filtration media by gravity. The contact between water and filtration media occurred during the flow process in the column before the filtrate was collected. The filtered water was then analyzed in the laboratory to determine the concentrations of iron (Fe) and manganese (Mn) after the filtration process.

Type of Data

Quantitative Data: Concentrations of Fe and Mn measured in milligrams per liter (mg/L) before and after the filtration process.
Qualitative Data: Observations of the physical properties of water (such as color and odor) before and after the filtration process.

Research Stages

1. Conducting a preliminary test on bore well water in Paccerakkang Sub-district, Biringkanaya District, Makassar City.
2. Water Sampling from Bore Wells in Paccerakkang Sub-district, Biringkanaya District, Makassar City.
3. The filtration media, namely coconut shells, were collected in Bone Regency and rice husks were collected in Makassar City, then the media were burned at the Workshop of the Makassar Ministry of Health Polytechnic, Department of Environmental Health.
4. Conducting examinations of Fe and Mn in well water at the Laboratory of the Environmental Health Department, Poltekkes Kemenkes Makassar.

Analysis Method

The concentrations of iron (Fe) and manganese (Mn) in the water samples were analyzed at the Environmental Health Laboratory of Poltekkes Kemenkes Makassar using the Atomic Absorption Spectrophotometry (AAS) method. The analysis was carried out on bore well water samples before and after the

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filtration process to determine the effectiveness of coconut shell charcoal and rice husk ash as filtration media in reducing Fe and Mn concentrations.

RESULT

Table 1 Decrease in Fe and Mn Levels Using Rice Husk Ash Media on Day 1

Replication Count	Fe (Iron)	Decrease in Fe (%)	Mn (Manganese)	Decrease in Mn (%)
Raw Water	0,65	-	0,18	-
Control	0,56	13,85	0,16	11,11
Replication 1	0,05	92,31	ND	100
Replication 2	0,02	96,92	ND	100
Replication 3	0,01	98,46	ND	100
Average	0,03	95,38	ND	100

Table 1 shows that the **Fe (iron)** content in raw water is 0.65 mg/L and **Mn (manganese)** is 0.18 mg/L. In the control without treatment, the Fe level decreased slightly to 0.56 mg/L with a percentage decrease of 13.85%, while Mn decreased to 0.16 mg/L with a decrease of 11.11%. After treatment using **rice husk ash media**, there was a very significant decrease. In replications 1, 2, and 3, the Fe levels decreased to 0.05 mg/L (92.31%), 0.02 mg/L (96.92%), and 0.01 mg/L (98.46%), respectively. Meanwhile, Mn levels in all replications decreased to 0 mg/L with a reduction efficiency of 100%. On average, the use of rice husk ash media can reduce Fe levels to 0.03 mg/L with a reduction rate of 95.38%, and reduce Mn levels to 0 mg/L with a reduction rate of 100%.

Table 2 Decrease in Fe and Mn Levels Using Rice Husk Ash Media on Day 2

Replication Count	Fe (Iron)	Decrease in Fe (%)	Mn (Manganese)	Decrease in Mn (%)
Raw Water	0,67	-	0,17	-
Control	0,64	4,48	0,15	11,76
Replication 1	0,01	98,51	ND	100
Replication 2	0,01	98,51	ND	100
Replication 3	0,01	98,51	ND	100
Average	0,01	98,51	ND	100

Table 2 shows that the Fe (iron) content in raw water is 0.67 mg/L and Mn (manganese) is 0.17 mg/L. In the untreated control, the Fe level only decreased slightly to 0.64 mg/L with a percentage decrease of 4.48%, while the Mn level decreased to 0.15 mg/L with a percentage decrease of 11.76%. After treatment using rice husk ash media, the decrease in metal levels was very significant. In replicates 1, 2, and 3, the Fe level decreased to 0.01 mg/L with a reduction percentage of 98.51%. For Mn, all replicates showed a level of 0 mg/L with a reduction efficiency of 100%. On average, the use of rice husk ash media on day 2 was able to reduce the Fe level to 0.01 mg/L with a reduction percentage of 98.51% and reduce the Mn level to 0 mg/L with a reduction percentage of 100%.

Table 3 Decrease in Fe and Mn Levels Using Rice Husk Ash Media on Day 3

Replication Count	Fe (Iron)	Decrease in Fe (%)	Mn (Manganese)	Decrease in Mn (%)
Raw Water	0,65	-	0,17	-
Control	0,55	15,38	0,15	11,76
Replication 1	0,01	98,46	ND	100
Replication 2	0,01	98,46	ND	100
Replication 3	0,01	98,46	ND	100
Average	0,01	98,46	ND	100

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Table 3 shows that the Fe (iron) content in raw water is 0.65 mg/L and Mn (manganese) is 0.17 mg/L. In the control without treatment, the Fe level only decreased slightly to 0.55 mg/L with a percentage decrease of 15.38%, while the Mn level decreased to 0.15 mg/L with a percentage decrease of 11.76%. With treatment using rice husk ash media, the results showed a very significant decrease. In replicates 1, 2, and 3, the Fe level decreased to 0.01 mg/L with a reduction percentage of 98.46%. Meanwhile, the Mn level in all replicates reached 0 mg/L with a reduction percentage of 100%. On average, the use of rice husk ash media on day 3 was able to reduce the Fe level to 0.01 mg/L with a reduction percentage of 98.46% and reduce the Mn level to 0 mg/L with a reduction percentage of 100%.

Table 4 Reduction in Fe and Mn Levels Using Coconut Shell Charcoal Media on Day 1

Replication Count	Fe (Iron)	Decrease in Fe (%)	Mn (Manganese)	Decrease in Mn (%)
Raw Water	0,65	-	0,18	-
Control	0,56	13,85	0,16	11,11
Replication 1	0,06	90,77	ND	100
Replication 2	0,04	93,85	ND	100
Replication 3	0,04	93,85	ND	100
Average	0,05	92,82	ND	100

Table 4 shows that the Fe (iron) content in raw water is 0.65 mg/L and the Mn (manganese) content is 0.18 mg/L. In the control without treatment, the Fe level only decreased to 0.56 mg/L with a reduction percentage of 13.85%, while the Mn level decreased slightly to 0.16 mg/L with a reduction percentage of 11.11%. After treatment using coconut shell charcoal media, the results showed a significant decrease. In replication 1, the Fe level decreased to 0.06 mg/L with a reduction of 90.77%, while in replications 2 and 3, the Fe level decreased to 0.04 mg/L with a reduction percentage of 93.85%. For the Mn level, all replications showed a decrease to 0 mg/L with a reduction percentage of 100%. On average, the use of coconut shell charcoal media on day 1 was able to reduce the Fe level to 0.05 mg/L with a reduction percentage of 92.82% and reduce the Mn level to 0 mg/L with a reduction percentage of 100%.

Table 5 Reduction in Fe and Mn Levels Using Coconut Shell Charcoal Media on Day 2

Replication Count	Fe (Iron)	Decrease in Fe (%)	Mn (Manganese)	Decrease in Mn (%)
Raw Water	0,67	-	0,17	-
Control	0,64	4,48	0,15	11,76
Replication 1	0,02	97,01	ND	100
Replication 2	0,01	98,51	ND	100
Replication 3	0,01	98,51	ND	100
Average	0,01	98,01	ND	100

Table 5 shows that the Fe (iron) content in raw water is 0.67 mg/L and the Mn (manganese) content is 0.17 mg/L. In the control without treatment, the Fe level only decreased slightly to 0.64 mg/L with a percentage decrease of 4.48%, while the Mn level decreased to 0.15 mg/L with a percentage decrease of 11.76%. After treatment using coconut shell charcoal media, there was a significant decrease. In replication 1, the Fe level decreased to 0.02 mg/L with a reduction percentage of 97.01%. In replications 2 and 3, the Fe level decreased to 0.01 mg/L with a reduction percentage of 98.51%. For the Mn level, all replications showed a value of 0 mg/L with a reduction efficiency of 100%. On average, the use of coconut shell charcoal media on day 2 was able to reduce the Fe level to 0.01 mg/L with a reduction percentage of 98.01% and reduce the Mn level to 0 mg/L with a reduction percentage of 100%.

Table 6 Reduction in Fe and Mn Levels Using Coconut Shell Charcoal Media on Day 3

Replication Count	Fe (Iron)	Decrease in Fe (%)	Mn (Manganese)	Decrease in Mn (%)
Raw Water	0,65	-	0,17	-
Control	0,55	15,38	0,15	11,76

Replication Count	Fe (Iron)	Decrease in Fe (%)	Mn (Manganese)	Decrease in Mn (%)
Replication 1	0,02	96,92	ND	100
Replication 2	0,01	98,46	ND	100
Replication 3	0,01	98,46	ND	100
Average	0,01	97,95	ND	100

Table 6 shows that the Fe (iron) content in raw water is 0.65 mg/L and the Mn (manganese) content is 0.17 mg/L. In the control without treatment, the Fe level only decreased slightly to 0.55 mg/L with a percentage decrease of 15.38%, while the Mn level decreased to 0.15 mg/L with a percentage decrease of 11.76%. With treatment using coconut shell charcoal media, there was a very significant decrease. In replication 1, the Fe level decreased to 0.02 mg/L with a reduction percentage of 96.92%. In replications 2 and 3, the Fe level decreased to 0.01 mg/L with a reduction percentage of 98.46%. For the Mn level, all replications showed a result of 0 mg/L with a reduction efficiency of 100%. On average, the use of coconut shell charcoal media on day 3 was able to reduce the Fe level to 0.01 mg/L with a reduction percentage of 97.95% and reduce the Mn level to 0 mg/L with a reduction percentage of 100%.

Based on the data from Table 1 to Table 6, the following is a summary of the average efficiency of Fe and Mn reduction by the two filtration media during the three days of observation.

Parameter	Hari	Rata – rata Efisiensi Abu Sekam Padi (%)	Rata – rata Efisiensi Arang Tempurung Kelapa (%)
Besi (Fe)	1	95,38 %	92,82 %
	2	98,51 %	98,01 %
	3	98,46 %	97,95 %
Mangan (Mn)	1-3	100 %	100 %

DISCUCCION

The effectiveness of coconut shell charcoal in reducing iron (Fe) and manganese (Mn) levels in well water.

Based on the results of the study, the use of coconut shell charcoal has been proven effective in reducing Fe and Mn levels in borehole water. Test results show that Fe levels decreased significantly from the initial condition (raw water) on each day of observation. On the first day, the average Fe level decreased by 92.82%, on the second day by 98.01%, and on the third day by 97.95%. As for Mn levels, the results of the study show a decrease of up to 100% in all replications from the first day to the third day.

Activated charcoal from coconut shells has been proven to be particularly effective in reducing iron (Fe) and manganese (Mn) levels in well water. This is due to its extensive pore structure, which provides more contact area for metal ions to attach to the charcoal surface. The greater the surface area and the longer the contact time, the higher the number of metal ions that can be absorbed.

Activated charcoal is a porous solid material with a high carbon content of around 85%–95%, while the rest consists of other mineral deposits. This material is often referred to as activated carbon because it is produced through an activation process, either physically (high-temperature heating) or chemically (using certain materials). The activation process aims to increase the surface area and open the pores of the charcoal, thereby increasing its adsorption capacity to bind pollutants[14].

This effectiveness is influenced by the physical and chemical properties of coconut shell charcoal, which has high porosity and a large surface area, enabling it to absorb dissolved metal ions through adsorption. In addition, coconut shell charcoal also contains activated carbon, which acts as a natural heavy metal absorber. Coconut shell activated charcoal is widely used in water treatment, not only to remove taste and odor, but also to

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absorb metals such as Fe. The absorption mechanism is influenced by the contact time between the activated charcoal and metal ions; the longer the contact time, the more Fe ions can be absorbed[15].

This is in line with previous studies stating that activated carbon from coconut shells can effectively absorb Fe and Mn ions due to the presence of micro pores that increase adsorption capacity. Activated carbon, also known as charcoal, is a porous material with a very large surface area that can be used as an adsorbent to reduce pollutants in water[16].

Activated charcoal from coconut shells functions not only as a natural absorbent, but also as an environmentally friendly biosorbent capable of improving water quality. The main factors that affect its effectiveness are its physical properties (porosity and surface area) and chemical properties (active carbon content), making its use a practical and efficient solution for reducing Fe and Mn levels in well water.

The effectiveness of rice husk ash in reducing iron (Fe) and manganese (Mn) levels in well water.

The use of rice husk ash has also been proven to be very effective in reducing Fe and Mn levels in borehole water. Based on the research results, the average Fe level decreased by 95.38% on the first day, increased on the second day to 98.51%, and on the third day still showed high efficiency at 98.46%. Meanwhile, for Mn levels, rice husk ash showed perfect removal capabilities with a 100% decrease on all observation days and all replications.

Rice husk ash is the result of burning rice husks, which are widely available in agricultural areas. This material is rich in silica (SiO_2) content, reaching 85%–90%, as well as other minerals in small amounts. It is this silica content that gives rice husk ash its properties as an effective natural adsorbent in water treatment processes [17]. With its porous texture and large surface area, rice husk ash is able to absorb various pollutants, including heavy metal ions such as iron (Fe) and manganese (Mn).

The mechanism of reducing Fe and Mn levels with rice husk ash occurs through the adsorption process. Metal ions present in water will attach to the surface of rice husk ash through physical and chemical interactions. This process is influenced by factors such as the surface area of the adsorbent, the initial concentration of metals, the pH of the water, and the contact time between the water and the absorbent medium. The greater the surface area of the rice husk ash and the longer the contact with water, the higher the effectiveness of metal ion absorption.

Rice husk ash acts as an adsorbent and has filtration properties that can improve water clarity. Its fine grain structure allows solid particles to be filtered mechanically. Therefore, the use of rice husk ash not only reduces heavy metal concentrations, but also improves the physical quality of water, such as color and turbidity[18]. This is very useful in improving the quality of borehole water to make it more suitable for use.

The adsorption process that occurs in rice husk ash is similar to the mechanism of activated carbon, although its absorption capacity is different. Silica in rice husk ash is amorphous with extensive microscopic pores. This condition allows metal ions such as Fe and Mn to interact with the surface of rice husk ash particles. The higher the amorphous silica content, the better the ability of rice husk ash to reduce metal levels in water.

Several studies support the effectiveness of rice husk ash as a heavy metal absorbent medium. Studies conducted by several researchers show that rice husk ash can reduce Fe levels by more than 90% and Mn by 100% in well water. This indicates that the silica content in rice husk ash plays an important role in the metal adsorption process, as silica has a high affinity for metal ions, enabling it to bind them effectively.

Research by Utami and Fauziah (2020)[19] states that rice husk ash has the potential to be used as a heavy metal adsorbent due to its composition, which is dominated by amorphous silica. In their study, rice husk ash was able to reduce Fe levels in industrial wastewater by up to 61%, depending on the dose and contact time used. Although the reduction results in this study were slightly lower, the difference can be explained by differences in the form of application (filtration vs. static adsorption), initial Fe concentration, and filtration media thickness. In addition, research by Indrawati and Susanti (2021)[20] also supports these findings. They showed that the use of rice husk ash in filtration columns resulted in a significant reduction in Fe levels, especially when the media was arranged in layers or combined with other materials such as zeolite or silica sand. This opens up opportunities for the development of more effective combined filtration media.

The effectiveness of rice husk ash in reducing Fe and Mn levels is also influenced by the environmental conditions during combustion. Combustion at high temperatures produces ash with more reactive silica content and a more open pore structure. This implies an increase in the absorption capacity of heavy metals. Thus, the method of processing rice husks into ash greatly determines the quality of the adsorbent produced. The high effectiveness of rice husk ash is due to its dominant silica (SiO_2) content, which acts as an active adsorbent in binding metal ions. In addition, the porous structure of rice husk ash also increases its surface area, enabling it to absorb more dissolved metal ions[21].

It can be concluded that both coconut shell charcoal and rice husk ash are effective as natural filter media in reducing Fe and Mn levels in well water. However, the results of this study show that rice husk ash is slightly more effective than coconut shell charcoal, especially in reducing Fe levels.

Observation of the physical properties of water before and after filtration

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The raw water observed before filtration showed physical conditions that did not meet the requirements. Visually, the water appeared cloudy with a yellowish to brownish color. This color indicated the presence of suspended particles and dissolved substances, including iron (Fe) and manganese (Mn) metals, which were measured at fairly high levels in the raw water. The presence of these substances caused the water to appear less clear and unfit for direct use. In addition to color, odor is also a clear indicator of the condition of water before filtration. The water has a metallic and fishy odor, which is commonly found in water with high Fe and Mn content. This odor arises because metal ions undergo oxidation reactions, producing colored deposits and a distinctive metallic aroma. These conditions certainly reduce the physical quality of the water and make it unpleasant to use[22].

After filtration using coconut shell charcoal media, there was a noticeable change in the color of the water. The water, which was previously yellowish, became clearer. This change was influenced by the ability of coconut shell charcoal to absorb Fe and Mn ions and other particles that cause turbidity. Laboratory results also reinforced this observation, where Fe and Mn levels decreased dramatically after filtration. The change in color from cloudy to clear indicates that filtration is effective in reducing contaminants that affect the appearance of water. The brownish color that was originally visible gradually decreased until it was no longer visible after the Fe and Mn levels decreased to near zero. Visually, the water became clearer, so its physical quality was much better than before filtration.

From the odor aspect, the observation results show significant improvement. Water that had a metallic and fishy odor before filtration had a reduced or even eliminated odor after filtration. This indicates that the compounds causing the odor were successfully absorbed by the coconut shell charcoal media. With the elimination of odor, the water became more suitable for use and did not cause discomfort to users. The disappearance of odor after filtration is also closely related to the reduction in metal content. High levels of Fe and Mn not only affect color, but also produce a distinctive metallic aroma. When these two metals are reduced to almost undetectable levels, the odor in the water also disappears. This shows a direct correlation between laboratory test results and sensory observations[23].

Observations of the physical properties of water show that filtration using coconut shell charcoal can significantly improve the color and odor of water. From its initial condition, which was cloudy, yellowish, and had a metallic odor, the water became clear and odorless after treatment. These results confirm that the improvement in the physical properties of water is in line with a significant decrease in Fe and Mn levels after the filtration process.

Although the analysis results showed that rice husk ash had a slightly higher percentage of Fe reduction (a difference of ±0.5% on days 2 and 3), this difference practically did not show a contrasting difference in water quality. This is because both media have different but equally effective adsorption mechanisms: rice husk ash relies on silica (SiO_2) content of 85%–90%, while coconut shell charcoal relies on the pore surface area of activated carbon of 85%–95%. For the Manganese (Mn) parameter, both media showed perfect effectiveness of 100%, which indicates that both materials are very strong adsorbents for Mn ions in dug well water conditions at the research site[24]

Despite the high efficiency observed, this study has several limitations. First, the filtration process was conducted over a short duration of three days; therefore, the breakthrough point—the moment when the media becomes saturated and loses its ability to adsorb contaminants—was not determined. Second, while the research utilized a fixed thickness of filtration media and a constant flow rate, the optimum contact time and depth-to-efficiency ratio remain unexplored for long-term applications. Furthermore, while physical properties like color and odor improved significantly, the influence of fluctuating water pH and the presence of competing anions on adsorption capacity was not monitored. Finally, the reported '0 mg/L' concentrations for Manganese (Mn) signify levels below the instrument's Limit of Detection (LOD) rather than an absolute absence of the metal. Future studies should include longitudinal analysis and a broader range of water chemistry parameters to fully validate the system's longevity for community use[25].

CONCLUSION AND SUGGESTIONS

This study concluded that although both filtration media were highly effective, there were differences in performance characteristics. Rice husk ash consistently demonstrated higher iron (Fe) reduction efficiency, especially on the first day (95.38%) compared to coconut shell charcoal (92.82%). This was due to the ion exchange mechanism in the silica content of rice husk ash. Conversely, both media demonstrated excellent performance (>99%/ND) in reducing manganese (Mn). Therefore, rice husk ash is more recommended for community applications requiring rapid Fe reduction.

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