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Effect of River Sand and Rice Husk Charcoal Filter Media Thickness on the Purification of River Water

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Abstract

River water quality in Indonesia has declined due to rising domestic, industrial, and agricultural pollution, resulting in elevated suspended solids and reduced suitability for domestic use. This study aimed to evaluate the effects of the thickness of river sand and rice husk charcoal filter media on the purification of Krueng Aceh River water by analysing the pH, Total Suspended Solids (TSS), and Dissolved Oxygen (DO) parameters. A laboratory-scale experimental method was conducted using four filtration media with varying thicknesses: river sand, rice husk charcoal, gravel, and coral stones. The results showed that the initial TSS concentration of 100 mg/L decreased significantly to 30.17–43.78 mg/L after filtration, with the highest removal efficiency of 69.83% obtained in Filter 3. The pH values remained stable within the acceptable quality standard range of 6.50–6.66, indicating that the filtration media did not cause excessive acidity or alkalinity. In addition, DO decreased after filtration but remained within the permissible water-quality limit. These findings indicate that the combination of river sand and rice husk charcoal is effective in reducing suspended solids, maintaining pH stability, and improving river water quality. Therefore, this filtration system can be considered a simple, low-cost, and environmentally friendly alternative for treating river water for non-potable domestic purposes.

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1. Introduction

Water is an essential resource for all living organisms; however, its availability is increasingly limited due to pollution. Although 71% of the Earth's surface is covered by water, only about 2.5% is freshwater (Tan et al., 2020). In Indonesia, approximately 70–75% of rivers across 33 provinces are polluted, with a national Water Quality Index (WQI) score of 55.4 (KLH, 2023). River pollution generally originates from industrial, agricultural, and domestic waste. One important parameter of water quality is turbidity, which, although not directly harmful to health, affects aesthetics and comfort and indicates the presence of suspended particles [1–3].

Turbidity is caused by suspended organic and inorganic materials, including fine sand, clay, cellulose, fats, proteins, bacteria, and algae [4–6]. The turbidity standard for clean water is ≤ 25 NTU. If turbidity exceeds this threshold, treatment is required—one such method is filtration. Filtration separates solids from liquids using porous media [7–9], with common methods being rapid and slow filtration (Ristiyanto, 2020). A combination of filtration media, such as river sand and rice husk charcoal, has been proven effective: rice husk charcoal functions as both a flocculator and an adsorbent [10], while river sand possesses physical properties that support effective filtration [11–13].
River sand contains approximately 40.7% silica [14], which helps reduce pollutant levels, while rice husk charcoal contains 16.98% silica and has a high surface area for adsorption [15,16]. Given their abundant availability in Aceh, this study utilises river sand and rice husk charcoal as filtration media for treating Krueng Aceh River water, focusing on the effect of media thickness on the removal of pH, TSS, and DO.

2. Methodology

This study employed a quantitative descriptive method to analyse the filtration effectiveness of water from the Krueng Aceh River using a combination of river sand and rice husk charcoal. Water samples were collected from a location beneath the Titi Lambaro Bridge, Siron Village, Aceh Besar, during the period of November 2024 – January 2025, in accordance with SNI 8995:2021.
The filter units were constructed from PVC pipes with a diameter of 3 inches and a height of 130 cm, filled with a combination of river sand and rice husk charcoal in thicknesses of 20 cm, 25 cm, and 30 cm, complemented by layers of gravel and river stones. The independent variables included media thickness and filtration time, while the dependent variables were pH, Total Suspended Solids (TSS), and Dissolved Oxygen (DO). Control variables included the type of media, pipe dimensions, and grain size.
Water quality tests were conducted at the Environmental Engineering Laboratory of Universitas Serambi Mekkah, comprising pH measurement (potentiometric method), TSS (SNI 06-6989-26-2005), DO (SNI 06-6989.14-2004), and turbidity (spectrophotometer at 390 nm). Data analysis involved calculating the pollutant removal efficiency using the percentage change in concentration before and after filtration.

3. Result & Discussion

Before Filtration

The water quality test of the Krueng Aceh River showed a pH of 6.86, TSS of 100 mg/L, and DO of 7.56 mg/L. The pH and DO values were within permissible limits (pH 6–9; DO ≥ 4 mg/L), while the TSS exceeded the 50 mg/L threshold stipulated in Government Regulation No. 22 of 2021.
The relatively neutral pH indicates a stable aquatic condition, although it is close to the lower limit of the standard. Natural minerals, biological activity, and the input of organic matter influence this value. The high TSS indicates a significant sediment load, potentially originating from erosion, sand mining, or domestic solid waste, which could degrade aquatic ecosystem quality. The high DO suggests that the water body still supports aquatic life, driven by natural aeration and phytoplankton photosynthesis. Overall, although the pH and DO parameters met the quality standards, the elevated TSS indicates the need for further management to reduce turbidity and sediment load in the Krueng Aceh River.

After Filtration

The water quality test of the Krueng Aceh River after the filtration process was conducted for three main parameters: pH, Total Suspended Solids (TSS), and Dissolved Oxygen (DO). The data are presented in tables and graphs to illustrate the changes before and after filtration.

pH

The river water pH before filtration was 6.86, while after filtration it ranged from 6.50 to 6.66 (Table 4.2). All results remained within the quality standards set by Government Regulation No. 22 of 2021 (pH 6–9). Variations in media thickness led to differences in pH among the filters. Thicker media tended to enhance the effectiveness of ion adsorption, thereby stabilising pH (Pontiani et al., 2023). Rice husk charcoal acts as an adsorbent with silica and activated carbon content that neutralises pH (Nurhayati et al., 2017), while river sand functions as a natural buffer (Fauzi & Handayani, 2021).
The initial pH of the water, 6.80, decreased to 6.50–6.66 after filtration, with a filtration efficiency of 2.06–4.41%. Although the reduction was not significant, the layered filtration media helped maintain pH stability through the adsorption process of rice husk charcoal and the buffering effect of river sand (Nurhayati et al., 2017; Fauzi & Handayani, 2021). Maintaining pH stability within the range of 6–9 complies with the quality standard PP No. 22 of 2021 and is essential for the safety of distribution and consumer health (WHO, 2017).

Table 1: Test Results of River Water Quality After Filtration for pH Parameter

No	**Sample Krueng Aceh River Water**	**pH Parameter**		
		Filter 1	**Filter 2**	**Filter 3**
1	Test Result	6,5	6,66	6,63
2	Efficiency (%)	4,41%	2,06%	2,50%
Quality Standard PP No. 22 of 2021		6-9	6-9	6-9

Based on the results presented in the table, the combination of river sand and rice husk charcoal filtration media demonstrated a significant improvement in the quality of Krueng Aceh River water. The data indicate that increasing the thickness of the filtration media enhanced the removal efficiency of suspended solids while maintaining the measured water quality parameters within the permissible limits established by Government Regulation No. 22 of 2021. The thickest filtration configuration (Filter 3) produced the best overall performance, achieving the highest removal efficiency, suggesting that greater media depth provides longer contact time and a larger adsorption surface area for trapping suspended particles and organic contaminants. River sand primarily functioned as a mechanical filter by retaining coarse particles, whereas rice husk charcoal contributed through adsorption due to its porous structure and silica-rich composition. These findings confirm that the synergistic effect of both natural materials provides an effective, low-cost, and environmentally friendly filtration system for improving river water quality, making it suitable for non-potable domestic applications and supporting the sustainable utilisation of locally available filtration media.

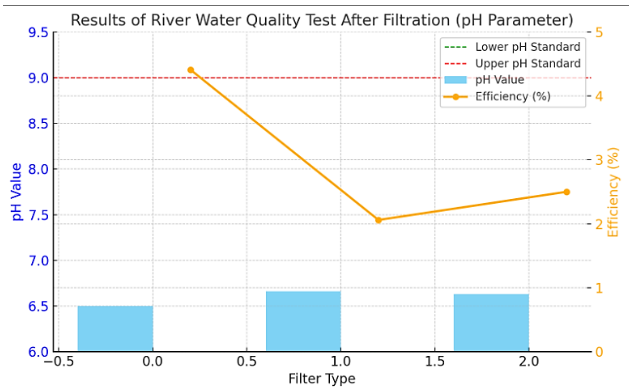

Figure 1: Test Results of River Water Quality After Filtration for pH Parameter

Figure 1 illustrates the pH values and filtration efficiency of the three filter configurations after the treatment of Krueng Aceh River water. The results show that the pH values ranged from 6.50 to 6.66, remaining well within the water quality standard of 6–9 established by Government Regulation No. 22

of 2021. Filter 1 produced the lowest pH value (6.50) with the highest pH reduction efficiency (4.41%), while Filter 2 recorded the highest pH value (6.66) with the lowest efficiency (2.06%), and Filter 3 achieved a pH of 6.63 with an efficiency of 2.50%. Although the pH reduction was relatively small, the filtration system effectively maintained pH stability without causing excessive acidity or alkalinity. This indicates that the combination of river sand and rice husk charcoal serves as an effective natural filtration medium, in which river sand provides buffering capacity and rice husk charcoal adsorbs dissolved impurities, thereby preserving the chemical stability of the treated water. Consequently, the filtration system is considered suitable for improving river water quality while maintaining pH levels within the acceptable range for non-potable domestic applications.
TSS is measured by filtering a specific volume of water through filter paper, drying the residue in an oven, weighing the filter paper before and after filtration, and then calculating the mass of particles per litre of sample.

$$TSS = \frac{(\mathrm{W2} - \mathrm{W1})\ \mathrm{x}\ 1000}{\mathrm{V}}$$

Where:

W2 = weight of the filter paper after filtration and drying (mg)
W1 = weight of the filter paper after filtration and drying (mg)
V = volume of the water sample (mL)

Example Calculation:

Weight of filter paper before filtration = 0,9500 g = 950 mg
Weight of filter paper after filtration = 1,0250 g = 1025 mg
Sample volume = 250 mL

$$TSS = \frac{(\mathrm{W2} - \mathrm{W1})\ \mathrm{x}\ 1000}{\mathrm{V}}$$

$$TSS = \frac{(1025 - 950)\ \mathrm{x}\ 1000}{250}$$

$$TSS = 25075 \times 1000 = 300\ \mathrm{mg/L}$$

Result: TSS = 300 mg/L
The initial TSS level reached 100 mg/L and significantly decreased to 30.17–43.78 mg/L after filtration (Table 4.3), which is below the quality standard of 50 mg/L. The greatest reduction occurred in Filter 3, which consisted of 20 cm river sand, 30 cm rice husk charcoal, 20 cm gravel, and 10 cm coral stones. This layered media design maximised mechanical filtration and adsorption (Putri & Santoso, 2019), where river sand trapped larger particles, rice husk charcoal captured fine particles and organic matter, and gravel with coral stones maintained stable water flow.
The initial TSS concentration of 100 mg/L dropped sharply to 30.17–43.78 mg/L, with the highest efficiency of 69.83% (Filter 3). This significant decrease indicates the media's effectiveness in capturing suspended particles, thereby reducing turbidity and the potential for pathogen growth (EPA, 2012). These findings are consistent with Nurhayati et al. (2017), who reported that the combination of rice husk charcoal and sand effectively reduces TSS and organic matter, which are responsible for odour.

Efficiency Calculation Formula :

$$\text{Efficiency}\ \% = \frac{(C_{Initial} - C_{Final})}{C_{Initial}}\ \mathrm{x}\ 100\%$$

Where:

$C_{Initial}$ = Parameter concentration before filtration (TSS)
C_{Final} = Parameter concentration after filtration (TSS)

TSS Calculation for Filter:

$C_{Initial}$ = 100 mg/L
C_{Final} = 30,2 mg/L

$$\text{Efficiency} = \frac{(C_{Initial} - C_{Final})}{C_{Initial}} \text{ x } 100\%$$

$$\text{Efficiency} = \frac{(100 - 30{,}2)}{100} \text{ x } 100\%$$

$$\text{Efficiency} = 0{,}698 \times 100\% = 69{,}8\ \%$$

Interpretation:
The filter media successfully reduced turbidity by 69.8%.

Table 2: Test Results of River Water Quality After Filtration for TSS Parameter

No	Sample River Water Krueng Aceh	TSS Parameter			
		Filter 1	Filter 2	Filter 3	Satuan
1	Test Results	30,2	43,7833	30,166	mg/L
2	Efficiency	69,80	56,22	69,83	%
Quality Standard PP No. 22 of 2021		50	50	50	mg/L

Table 2 shows that the filtration process effectively reduced the TSS concentration of Krueng Aceh River water from the initial value of 100 mg/L to below the quality standard of 50 mg/L. Filter 3 produced the best result, with a TSS value of 30.166 mg/L and the highest removal efficiency of 69.83%, followed closely by Filter 1 with 30.2 mg/L and 69.80% efficiency. Filter 2 showed a lower performance, with a TSS value of 43.7833 mg/L and 56.22% efficiency, but it still met the required standard. These findings indicate that the combination of river sand and rice husk charcoal is effective in trapping suspended particles, reducing turbidity, and improving river water quality for non-consumptive domestic use.

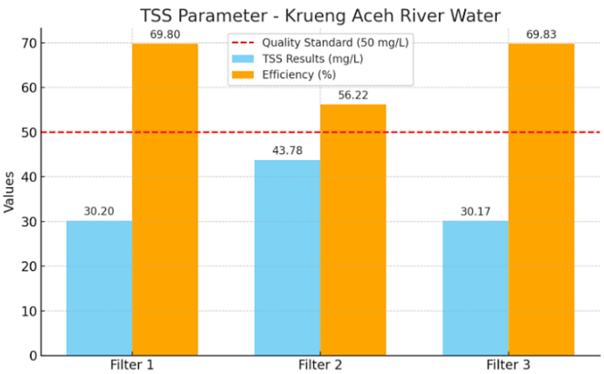

Figure 2: Test Results of River Water Quality After Filtration for the TSS Parameter

Figure 2 illustrates the Total Suspended Solids (TSS) concentrations and removal efficiencies achieved by the three filtration media configurations after treating Krueng Aceh River water. The results demonstrate that all filter configurations successfully reduced the TSS concentration below the quality standard of 50 mg/L established by Government Regulation No. 22 of 2021. Filter 3 exhibited the highest performance, reducing the TSS concentration to 30.17 mg/L with a removal efficiency of 69.83%, followed closely by Filter 1, which achieved a TSS concentration of 30.20 mg/L and an efficiency of 69.80%. In contrast, Filter 2 produced a higher residual TSS concentration of 43.78 mg/L with a lower removal efficiency of 56.22%, although it still complied with the regulatory standard. The superior performance of Filter 3 can be attributed to the greater thickness of the rice husk charcoal layer, which enhanced the adsorption of fine suspended particles, while the river sand provided effective mechanical filtration of larger particles. These findings demonstrate that the combination of river sand and rice husk charcoal is an efficient, low-cost, and environmentally friendly filtration medium that significantly reduces suspended solids and improves river water quality for non-potable domestic applications.

4. Conclusion

This study demonstrated that the combination of river sand and rice husk charcoal is an effective natural filtration medium for improving the quality of Krueng Aceh River water. Variations in filtration media thickness influenced the purification performance, particularly in reducing Total Suspended Solids (TSS), while maintaining the pH within the quality standards established by Government Regulation No. 22 of 2021. The filtration process reduced the TSS concentration from 100 mg/L to 30.17–43.78 mg/L, achieving a maximum removal efficiency of 69.83%, with Filter 3 providing the best overall performance. Meanwhile, the pH remained stable between 6.50 and 6.66, indicating that the filtration media effectively preserved the chemical balance of the treated water. These findings confirm that the synergistic action of river sand as a mechanical filtration medium and rice husk charcoal as an adsorbent significantly improves river water quality by removing suspended solids without adversely affecting pH. Therefore, the proposed filtration system represents a simple, low-cost, environmentally friendly, and locally available technology that can be applied for non-potable domestic water treatment, particularly in rural and riverine communities. Future studies are recommended to investigate the long-term performance of the filtration media, optimise media composition and thickness, and evaluate additional water quality parameters such as turbidity, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), microbial contamination, and heavy metals to enhance the applicability of this filtration system further.

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