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APPLICATION OF COCONUT SHELL ACTIVATED CARBON TECHNOLOGY FOR GROUNDWATER TREATMENT IN ROUDLOTUT THOLIBIN ISLAMIC BOARDING SCHOOL

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Abstract:
Groundwater contamination poses challenges for community-based institutions, requiring effective treatment solutions. This study evaluates the efficiency of coconut shell activated carbon (CSAC) in reducing lime content in groundwater at Roudlotut Tholibin Islamic Boarding School. A seven-day filtration experiment was conducted using CSAC thicknesses of 25 cm, 35 cm, and 45 cm, with water quality assessments before and after treatment. Results showed that the 45 cm filter achieved the highest reduction, lowering lime content by 67.86%. However, one-way ANOVA and Tukey's HSD test revealed no significant differences among the three thicknesses.

Additionally, documents and policy analysis examined governance challenges in sustainable groundwater treatment. Findings identified regulatory limitations, financial constraints, and institutional capacity gaps as major barriers. While CSAC technology effectively improves groundwater quality, sustainable implementation requires stronger regulatory enforcement, financial support, and community engagement. This study highlights the potential of CSAC filtration and the need for integrated governance strategies to ensure long-term water sustainability in community-based institutions.

Keywords: Coconut Shell Activated Carbon, Groundwater Treatment, Lime Reduction

INTRODUCTION

Access to clean and safe groundwater remains a pressing challenge in many regions, particularly in community-based institutions such as Islamic boarding schools. Roudlotut Tholibin Islamic Boarding School relies heavily on groundwater for daily consumption and sanitation. However, groundwater quality is often compromised due to contamination from various sources, including industrial discharge, agricultural runoff, and improper waste disposal. As reported by Fahimah et al. (2024), 13% of drinking water sources (7.8% groundwater and 5.2% refill water) in Bandung is considered unfit for consumption due to the presence of heavy metals such as As, Cd, Co, Hg, Mn, and Pb in concentrations exceeding the maximum allowable limits, making it unsuitable for consumption. The presence of pollutants such as heavy metals, organic compounds, and microbial contaminants necessitates an effective and sustainable treatment method to ensure water safety.

One promising solution to this issue is the application of coconut shell-activated carbon (CSAC) technology. Activated carbon derived from coconut shells is widely recognized for its high adsorption capacity, cost-effectiveness, and environmental sustainability. Previous studies have demonstrated its effectiveness in removing a wide range of contaminants from water, including heavy metals, organic pollutants, and microbial pathogens. Research conducted by Packialakshmi et al. (2021) indicated that coconut shell-activated carbon efficiently adsorbs heavy metals like zinc and potassium from industrial effluents, achieving removal efficiencies of up to 97% for zinc. A

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recent study revealed that coconut shell activated carbon has a high capacity to reduce humic acid (HA) from seawater and methyl orange (MO) dye from aqueous solutions (Tigrine et al., 2024). However, despite its potential, there is a gap in research regarding the direct application of CSAC technology in community-based institutions like Islamic boarding schools, where resource limitations and governance structures play a crucial role in the sustainability of water treatment solutions.

Governance aspects are critical in the implementation of water treatment technologies in community service projects. Proper governance ensures that water treatment initiatives are effectively managed, funded, and monitored. Despite the recognized importance of governance in sustainable water treatment, limited studies have addressed how governance structures influence the application of CSAC in community service initiatives, creating a research gap that this study aims to fill.

This research seeks to answer the following key questions: (1) How effective is CSAC technology in improving groundwater quality in Roudlotut Tholibin Islamic Boarding School? (2) What are the governance challenges in implementing sustainable groundwater treatment in community-based institutions? By addressing these questions, this study contributes to water treatment technology in community-based settings, integrating the perspectives of governance. The findings of this research are expected to provide practical insights for policymakers, educational institutions, and community leaders in adopting sustainable groundwater treatment solutions to enhance public health and environmental sustainability.

METHODS

This study employs a mixed-methods approach, integrating experimental field application with document and policy analysis to assess the effectiveness of CSAC in groundwater treatment and examine governance challenges in sustainable water management. The research is conducted at Roudlotut Tholibin Islamic Boarding School in Ponorogo, East Java, Indonesia, where groundwater samples are collected directly from the school's water source. The experimental component involves designing and implementing a simple water treatment system composed of gravel (5 cm), silica sand (32 cm), coconut shell activated carbon (with varying thicknesses of 25 cm, 35 cm, and 45 cm), and natural zeolite (35 cm) to evaluate adsorption efficiency. The primary water quality parameter analyzed in this study is lime content, assessed before and after treatment to determine purification effectiveness. The water analysis is carried out at Ponorogo Regional Health Laboratory, ensuring accurate and reliable testing of the treated water samples. The governance aspect is examined through document and policy analysis, involving a systematic review of government regulations and institutional policies relevant to groundwater management. The data evaluation was conducted using one-way ANOVA, followed by Tukey's HSD test for pairwise comparisons, performed in R software. By integrating empirical water treatment performance with governance insights, this study provides evidence-based policy recommendations to enhance regulatory frameworks and support sustainable groundwater treatment in community-based institutions.

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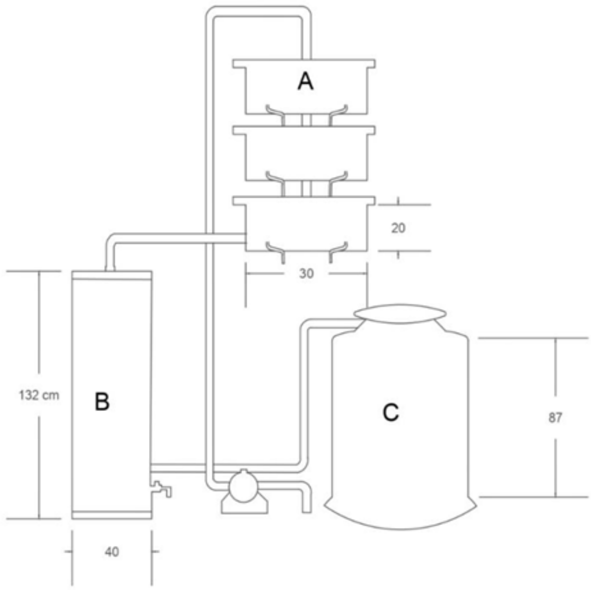

Figure 1. Water Treatment System

RESULT AND DISCUSSION

This study evaluates the effectiveness of different CSAC thicknesses in reducing lime content in groundwater at Roudlotut Tholibin Islamic Boarding School. Water analysis over seven days highlights variations in filtration performance across 25 cm, 35 cm, and 45 cm thicknesses. The results, illustrated in Figure 2, compare untreated and treated water, identifying the most effective filtration conditions for lime content reduction and contributing to improved groundwater management in community-based institutions.

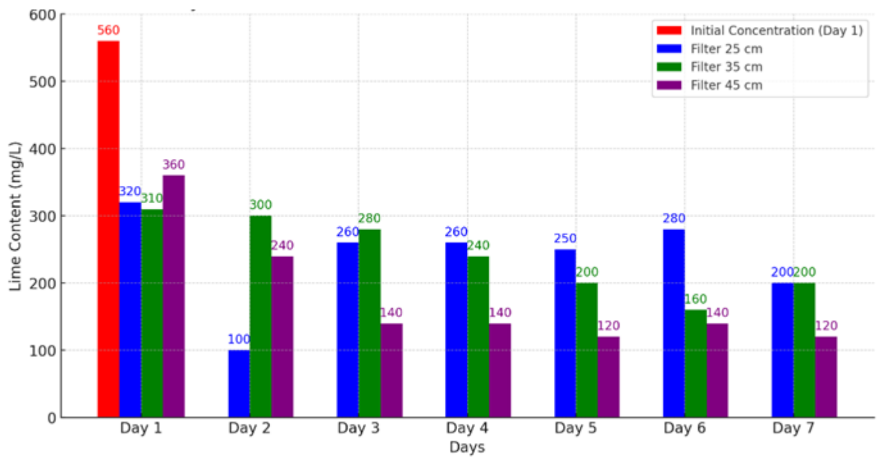

Figure 2. Daily Lime Content Reduction Across Different Filter Thicknesses

This study examines the efficiency of different CSAC thicknesses in reducing lime content in groundwater at Roudlotut Tholibin Islamic Boarding School. A seven-day water analysis reveals fluctuations in filtration performance across 25 cm, 35 cm, and 45 cm thicknesses. The initial lime concentration was measured at 560 mg/L on Day 1 before filtration, serving as a baseline. The 25 cm

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filter showed inconsistent reductions, dropping to 100 mg/L on Day 2 but fluctuating in subsequent days, while the 35 cm filter demonstrated more stability, with lime content decreasing steadily. The 45 cm filter provided the most significant reduction, maintaining lower levels across the seven days and achieving a 67.86% decrease, as shown in Figure 3.

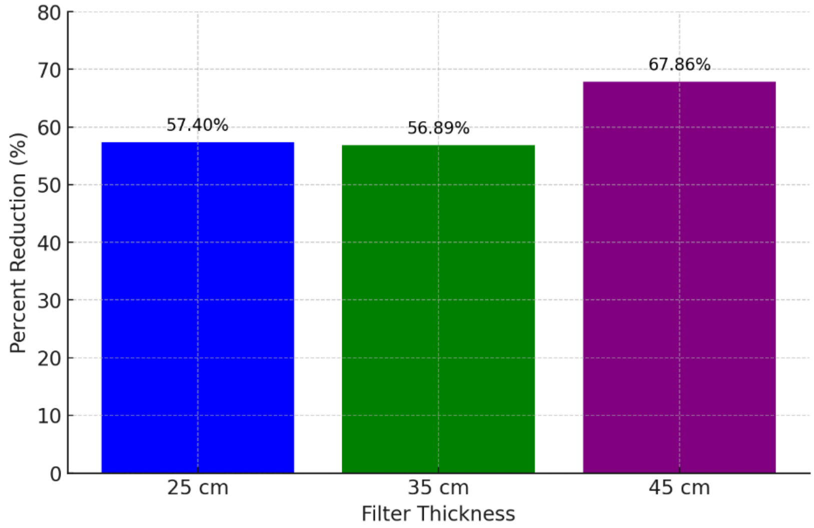

Figure 3. Lime Content Reduction Across Different CSAC Thicknesses

However, statistical analysis using Tukey's HSD test reveals no significant differences in lime content reduction among the three filter thicknesses. Despite the apparent lower lime content in the 45 cm filter, the statistical test suggests that this difference is not statistically significant due to variability in the data.

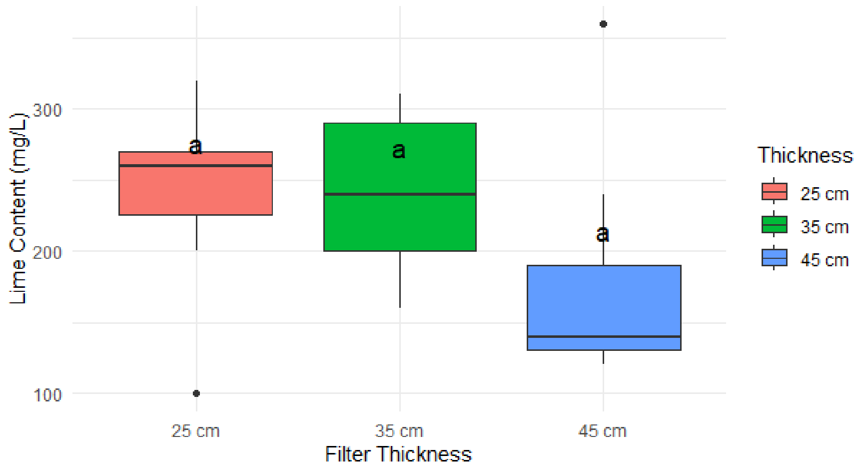

Figure 4. Comparison of Lime Content Reduction Across CSAC Thicknesses

Coconut shell-activated carbon has long been used for pollutant removal and has recently been enhanced by combining it with other parameters to improve its adsorption capacity. A recent study found that coconut shell-activated carbon (AC) achieved maximum adsorption capacities for dye removal, with NaOH-activated AC reaching up to 1000 mg/g (Saleem et al., 2024). Another study demonstrated that coconut shell activated carbon (CSAC) effectively removed 84.43% COD, 81.80%

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BOD, 59.78% zinc, and 78.58% iron from manual car wash wastewater (Saad et al., 2024). Meanwhile, removing water hardness, such as lime, from aquatic systems has been a significant challenge for many researchers. Previous studies have reported varying removal efficiencies, with Rajapaksha et al. (2020) estimating water hardness reduction between 40% and 50%, while Oyekeye et al. (2022) found that treatment had an insignificant effect, achieving only 10.71% hardness removal, along with 10.62% magnesium and 10.78% calcium reduction in water. Our research revealed a higher reduction efficiency, with the 45 cm filter achieving the most significant decrease, consistently maintaining lower lime content over seven days and reaching a 67.86% reduction.

The governance aspect of this study focuses on document and policy analysis, specifically reviewing government regulations and institutional policies related to groundwater management. One key regulation governing water quality in Indonesia is Regulation of the Minister of Health No. 32 of 2017, which sets a maximum permissible lime content in groundwater at 500 mg/L. This standard ensures that groundwater remains safe for consumption and minimizes health risks associated with excessive lime content. By comparing our findings to this regulatory threshold, we can assess whether coconut shell activated carbon (CSAC) filtration effectively reduces lime content to meet compliance standards. The initial lime concentration of 560 mg/L in this study exceeds the regulatory limit, highlighting the necessity of treatment. The 45 cm CSAC filter achieved a 67.86% reduction, bringing the lime content well below the 500 mg/L threshold, demonstrating its potential as a sustainable solution for groundwater purification in community-based institutions.

Implementing sustainable groundwater treatment in community-based institutions presents several governance challenges, including regulatory enforcement, institutional capacity, financial constraints, and community participation. Many institutions lack the technical expertise and trained personnel needed to operate and maintain groundwater treatment systems effectively. A recent study from India highlighted significant governance gaps affecting groundwater management, including ineffective enforcement of laws and regulations, low public awareness, limited institutional capacity, and inadequate monitoring practices, all of which contribute to groundwater vulnerability (Navaneeth et al., 2024). Additionally, financial constraints pose a major challenge, as the high initial cost of treatment infrastructure and ongoing maintenance expenses can hinder long-term sustainability. Institutions must foster collaborative efforts between government agencies, NGOs, and local stakeholders to strengthen regulatory enforcement, provide technical training, and develop sustainable funding mechanisms. By addressing these challenges, community-based institutions can improve water quality management and ensure long-term access to safe and sustainable groundwater resources.

CONCLUSION

This study demonstrates the effectiveness of coconut shell activated carbon (CSAC) in reducing lime content in groundwater at Roudlotut Tholibin Islamic Boarding School. The 45 cm filter thickness achieved the highest reduction, lowering lime content by 67.86%, while the 25 cm and 35 cm filters showed similar performances. However, the statistical analysis test revealed no significant differences among the three thicknesses, indicating that variations in CSAC depth may not significantly impact lime reduction under the tested conditions. Beyond filtration performance, governance challenges remain a critical barrier to sustainable groundwater treatment. Regulatory limitations, financial constraints, and institutional capacity gaps hinder the long-term implementation of effective treatment solutions. Strengthening policy enforcement, increasing financial support, and enhancing community engagement are essential for ensuring the sustainability of groundwater management in community-based institutions. This study

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underscores the potential of CSAC technology as a viable and cost-effective filtration method while emphasizing the need for integrated governance strategies to improve water quality and accessibility.

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