Exploring the synergy between biochar and Moringa oleifera seed proteins for greywater remediation

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Highlights:

- Novel combination of biochar and Moringa seed extract for greywater treatment
- Effective removal of heavy metals and CECs achieved; order of application crucial
- The tested approach holds promise for application to developing countries

Keywords: Biochar; Moringa oleifera seed protein; Household greywater

INTRODUCTION

Combating water scarcity and pollution, driven by global challenges such as climate change and urbanization, requires cost-effective, innovative water treatment solutions, especially in resource-limited developing countries. Traditional treatment methods are often too costly, making greywater reuse an appealing option for reducing freshwater demand [1]. Despite its lower pathogen content, greywater's organic micropollutants necessitate effective, affordable treatment technologies [2]. Biochar and activated carbons (ACs), sourced from inexpensive, local materials, are promising for adsorbing these contaminants but face limitations in cost and production efficiency [3].

Pairing biochar with Moringa oleifera (MO) seeds, known for their water purifying properties, could improve greywater treatment efficiency. MO seeds are a low-cost, effective option for flocculating pollutants, although they may increase dissolved organic carbon levels [4]. This combination aims to enhance the removal of emerging contaminants and heavy metals, offering a sustainable solution for areas lacking water treatment infrastructure.

This research explores using biochar and MO seed extracts for greywater treatment, aiming to fine-tune application methods and doses for maximum contaminant removal efficiency. Emphasizing local, nature-based solutions, this strategy seeks to address the critical need for accessible water treatment technologies.

METHODOLOGY

This study, conducted in two parts, encompassed laboratory and field investigations to evaluate the effectiveness of biochar and MO seed extract in treating greywater. In the laboratory phase, biochar obtained from local Kenyan's firewood, pyrolyzed in a gasifier stove, and MO seed extract, prepared using a 0.1 M NaCl solution, were used to treat simulated greywater. This greywater contained six contaminants of emerging concern (CECs) and heavy metals at specified concentrations. The effectiveness of the treatment was assessed by removal rates of CECs and heavy metals determined via HPLC and ICP-MS, alongside evaluations of turbidity, color, pH, TDS, TOC, surfactants and protein content.

The field study in Kwale and Siaya counties, Kenya involved practical greywater treatment using locally produced biochar and MO seed extract, following traditional laundry practices to ensure authenticity. Treatments included batch stirring and filtration methods, with water quality evaluated through on-site and laboratory analyses for various parameters. This comprehensive approach aimed to assess the feasibility and efficiency of using biochar and MO seed extract for greywater treatment under diverse environmental conditions, contributing to sustainable water management practices in Kenya.

RESULTS AND CONCLUSIONS

Results indicated that biochar alone was insufficient in reducing greywater color and turbidity, whereas the addition of MO seed protein significantly improved these parameters. An alkaline pH around 8 persisted across all samples due to residual surfactants, with a noticeable presence of TOC attributed to residual MO proteins. Coagulation was inhibited by humates and surfactants, suggesting their complexation with heavy metals and CECs. A fivefold increase in MO extract dosage markedly enhanced coagulation, reducing color to 72 PCU and turbidity to 56 NTU, underscoring the importance of optimizing MO seed protein concentration based on the contaminant load.

Field studies demonstrated significant contaminant reductions, with color and turbidity decreases of up to 67% and 98%, respectively. Despite increases in TOC and total dissolved solids, effective reductions in phosphates, nitrates, and iron were observed. These methods underscore the practicality of using local resources for greywater treatment, potentially aiding in irrigation, food security, and socio-economic development within these communities.

The findings from both laboratory and field studies highlight the combined use of biochar and MO seed extract as a promising, sustainable solution for greywater treatment. Future efforts should aim to refine treatment protocols, ensuring they are cost-effective, scalable, and integrated with local recovery systems. Additionally, addressing the disposal or recycling of resultant sludge will be crucial for environmental sustainability. This research paves the way for further exploration into effective, community-friendly greywater treatment options that leverage local materials, contributing to global efforts in water conservation and management.

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