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Development And Performance Evaluation Of Low cost Water Filtration System Utilising Locally Available Natural Materials

Dr. Kishor Subramanaim[1*]

[1]Professor, Chemical & Materials Engineering Annamalai University, Tamil Nadu, India

[*]Authors Email: Kishor121@annamalaiuniv.edu

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Abstract: Clean and safe drinking water remains inaccessible to millions of people worldwide, especially in rural and low-income regions where modern purification technologies are too costly or difficult to maintain. Natural-material-based filtration systems offer a viable alternative by utilizing widely available, renewable, and inexpensive resources. This study presents an original experimental design of a low-cost water filtration system developed using locally available natural materials such as coconut-shell activated charcoal, river sand, gravel, and powdered Moringa oleifera seeds. The aim was to assess the system's effectiveness in reducing turbidity, microbial contamination, color, and odor in contaminated surface water. Three prototype systems were constructed and tested using standardized water-quality indicators. Results demonstrated significant improvements across all parameters, including an 89.3 percent reduction in turbidity and a 96.1 percent reduction in total coliform levels, with prototype three performing the best due to improved charcoal activation and a refined sand layer arrangement. The results suggest that natural-material filtration systems provide an affordable, sustainable, and practical option for household-level water treatment when combined with post-filtration disinfection. The study concludes that this approach can help bridge critical gaps in safe-water access in underserved communities while promoting environmental sustainability.

Keywords: low-cost filtration, natural materials, water purification, Moringa oleifera, rural water treatment

1. Introduction

Ensuring universal access to potable water remains a major global challenge. According to global assessments, over two billion people worldwide still consume contaminated water, resulting in widespread waterborne diseases and preventable mortality [1]. Rural communities face the greatest burden due to economic limitations and the unavailability of modern purification technologies such as reverse osmosis and UV disinfection systems [2]. Natural material–based filtration, which utilizes resources such as sand, charcoal, and organic coagulants, has gained renewed interest due to its low cost, environmental compatibility, and minimal maintenance requirements [3]. Studies show that Moringa oleifera seeds contain cationic proteins that act as effective natural coagulants, helping reduce turbidity and microbial loads [4]. Similarly, activated charcoal produced from agricultural waste, including coconut shells, exhibits strong adsorption capabilities that make it suitable for decentralized water treatment [5]. Building upon these insights, this study aims to develop and scientifically evaluate a simple, low-cost filtration unit using locally available natural materials. The research not only provides empirical performance data but also contributes to scalable solution models for improving water accessibility in resource-limited settings.

2. Methodologies

The study involved designing three filtration prototypes composed entirely of natural materials sourced locally. Activated charcoal was produced by controlled carbonization coconut shells, followed by manual grinding to increase surface area, drawing on methods recommended in previous low-cost

adsorption studies [6]. River sand and stream gravel were thoroughly washed, sieved, and dried to ensure uniformity. Moringa oleifera seeds were harvested, dried, de-hulled, and ground to a fine powder, following established coagulation protocols [4]. Each prototype consisted of a vertically layered structure: coarse gravel at the bottom for drainage support, followed by fine sand for particulate removal, then activated charcoal for adsorptive purification, and a Moringa-based pre-treatment stage to enhance microbial reduction. Contaminated surface water samples were collected from a natural stagnantsource, consistent with methods used in field-based filtration studies [7]. Pre- andpost-filtration water samples were analyzed for turbidity, pH, electrical conductivity, total coliform count, and general visual characteristics. WHO standards served as the benchmarkfor evaluating output water quality [1]. Multiple trials were conducted for each prototype to minimize experimental bias. Flow-rate measurements were included to determine practical household applicability.

Fig. 1 Low Cost Water Filtration System

3. Results

All prototypes showed significant improvements in water quality. Turbidity dropped from 52 NTU to an average of 5.6 NTU, consistent with reductions observed in other natural filtration studies [3]. Prototype three achieved the highest turbidity reduction at 91.4 percent due to optimized charcoal activation and a double-layered sand arrangement. Total coliform loads decreased by an average of 96.1 percent, aligning with earlier findings on. theantimicrobial action of Moringa oleifera proteins [4]. Physical attributes—including odor, color, and visible sediments—displayed substantial improvements after filtration. Flow-rate testing showed that prototypes one and two exhibited relatively faster filtration but slightly lower purification efficiency, whereas prototype three had optimal purification but moderately slower flow. The pH remained within acceptable limits throughout all experiments, indicating no harmful chemical interference. Although the system did not achieve complete sterilization, its efficiency makes it suitable as a primary filtration stage prior to boiling or solar disinfection

4. Discussion

The results confirm that natural-material filtration systems are highly effective for low-cost household water purification. The combination of gravel, sand, activated charcoal, and Moringa oleifera produces a multi-stage

purification effect similar to conventionalmulti-barrier systems but at a fraction of the cost. The charcoal produced from coconut shells exhibited strong adsorption properties, supporting existing literature onagricultural-waste-derived carbon adsorbents [5], while Moringa powder effectively reduced suspended particles and microbial loads. Prototype three's performance highlights the importance of material preparation—particularly charcoal activation and sand-grain uniformity—in achieving high filtration efficiency. Nevertheless, limitations remain. The absence of complete microbial sterilization means the filtered water should undergo an additional disinfection step such as boiling or solar exposure. Seasonal variations in water contamination may also influence performance, indicating the need for community-level monitoring. Despite these constraints, the system offers strong potential for rural households, emergency relief operations, and low-income settlements

5. Conclusion

This study demonstrates that a low-cost water filtration system constructed from locally available natural materials can significantly improve the quality of contaminated surface water. The combination of sand, gravel, activated charcoal, and Moringa oleifera provides aneffective, sustainable, and environmentally friendly purification mechanism suitable for resource-limited communities. The filtration prototypes showed substantial reductions in turbidity, microbial contamination, color, and odor, with prototype three delivering the highest performance. Although additional disinfection steps are recommended, the system's accessibility, affordability, and minimal environmental impact make it a viable solution for increasing safe water access in underserved regions. Further research may explore long-term durability, scaling strategies, and community-based implementation models

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