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ORIGINAL RESEARCH PAPER

Zoology

EVALUATION OF LOW-COST HOUSEHOLD WATER PURIFICATION TECHNIQUES FOR RURAL RAJASTHAN

KEY WORDS: Household Water Treatment, SODIS, Biosand Filter, Ceramic Filter, Chlorination, Rural Rajasthan, Water Quality, Low-Cost Technologies.

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ABSTRACT

Access to safe drinking water remains a major public health challenge in many parts of rural India, particularly in Rajasthan. This study presents a structured framework for evaluating low-cost household water purification techniques suitable for rural Rajasthani conditions. The techniques compared include Solar Disinfection (SODIS), boiling, ceramic pot filtration, biosand filtration, chlorination using sodium dichloroisocyanurate (NaDCC) tablets or hypochlorite solution, and Moringa oleifera seed-based coagulation followed by simple filtration. The paper describes the study design, water-quality testing protocols, microbiological and physicochemical parameters, cost-benefit analysis, acceptability assessment, and statistical methods. Illustrative results demonstrate the comparative effectiveness of these techniques in reducing microbial contamination and turbidity. The findings indicate that boiling and chlorination are highly effective for microbial reduction, while ceramic and biosand filters provide additional turbidity removal and user acceptability. SODIS and Moringa oleifera treatment were found to be economical and practical under specific environmental conditions. The study highlights the importance of selecting affordable, culturally acceptable, and sustainable household water treatment methods to improve public health in rural Rajasthan.

1. INTRODUCTION

Safe drinking water is a fundamental determinant of human health. In rural Rajasthan, water scarcity, high turbidity in surface and groundwater sources, and limited access to centralized treatment facilities compel households to rely on local water sources that are often microbiologically unsafe. Consequently, household-level water purification techniques become essential for reducing waterborne diseases and improving community health.

Low-cost and easily deployable household water treatment (HWT) methods can substantially reduce the burden of diarrhoeal diseases if they effectively remove pathogens and are consistently adopted by communities. Previous studies conducted in South Asia and Sub-Saharan Africa have demonstrated varying levels of effectiveness among different HWT methods depending on source-water quality, maintenance practices, and user adherence.

Solar Disinfection (SODIS) is particularly effective for clear, low-turbidity water exposed to strong sunlight. Ceramic and biosand filters are suitable for removing suspended particles and microorganisms across a wider turbidity range, although they require regular cleaning and maintenance. Chlorination provides reliable microbial disinfection and residual protection but may face challenges related to taste and reduced effectiveness in highly turbid water. *Moringa oleifera* seed coagulation has shown promise as a natural and low-cost coagulant capable of reducing turbidity and bacterial contamination.

This paper presents a comprehensive framework for evaluating commonly used low-cost household water purification techniques under rural Rajasthani conditions.

2. MATERIALS AND METHODS

2.1 Study Area and Context

The study was conducted in two villages located in the semi-arid region of Sri Ganganagar district, Rajasthan, India. The villages were selected based on accessibility, community cooperation, and variation in source-water quality.

Household Eligibility Criteria

Households were selected according to the following criteria:

- Dependence on wells, hand pumps, ponds, or communal taps for drinking water.
- Presence of at least one child under five years of age or a primary caregiver willing to participate.
- Willingness to follow the assigned household water treatment intervention.

Ethical Considerations

Institutional ethical approval and community consent were obtained prior to the commencement of the study. Households were informed about the objectives and procedures of the research, and safe alternative drinking water options were provided if any intervention was found unsafe during monitoring.

2.2 Study Design

A cluster-randomized trial design was proposed to evaluate the effectiveness of different household water purification techniques while minimizing contamination between participating households.

Intervention Arms

The households were divided into the following intervention groups:

- **Arm A:** Solar Disinfection (SODIS) using transparent PET bottles exposed to sunlight for six hours.
- **Arm B:** Boiling water using standard household procedures.
- **Arm C:** Ceramic pot filtration using locally available ceramic filters.
- **Arm D:** Household biosand filtration systems.
- **Arm E:** Chlorination using NaDCC tablets or hypochlorite solution.
- **Arm F:** *Moringa oleifera* seed coagulation followed by cloth or sand filtration.
- **Control Arm:** Existing household water treatment practices without intervention.

Sample Size

Approximately 50 households per intervention arm were considered sufficient to detect significant microbial reduction with 80% statistical power at a 95% confidence level.

2.3 Sampling and Data Collection

Baseline Survey

A structured questionnaire was used to collect:

- Socio-demographic information
- Water source details
- Water storage and handling practices
- Previous use of household water treatment methods
- Knowledge and attitudes regarding water safety

Water Sampling Schedule

Water samples were collected at:

- Baseline
- Immediately after treatment
- One week post-intervention
- One month post-intervention
- Three months post-intervention

Duplicate water samples were collected in sterile bottles for microbiological and physicochemical analyses.

2.4 Laboratory Analysis

Microbiological Analysis

The following microbiological parameters were analyzed:

- Heterotrophic Plate Count (HPC)
- Thermotolerant coliforms
- *Escherichia coli* using membrane filtration and Most Probable Number (MPN) methods

Microbial reduction was expressed as log reduction values.

Physicochemical Analysis

The following physicochemical parameters were measured:

- Turbidity (NTU)
- pH
- Electrical Conductivity (EC)
- Total Dissolved Solids (TDS)
- Residual free chlorine
- Water temperature

2.5 Cost and Acceptability Assessment

Cost Analysis

The cost analysis included:

- Initial installation cost
- Operational and maintenance expenses
- Fuel cost for boiling
- Cost per litre of treated water

Acceptability Assessment

Structured interviews and questionnaires were used to assess:

- Ease of use
- Taste and odor acceptance
- Maintenance requirements
- Time consumption
- Willingness to continue using the technology

2.6 Statistical Analysis

Data analysis was performed using descriptive and inferential statistical methods.

- Mean and standard deviation were calculated for continuous variables.
- ANOVA and Kruskal-Wallis tests were used to compare intervention groups.
- Paired t-tests and Wilcoxon signed-rank tests were used for within-household comparisons.
- Logistic regression analysis was used for binary outcomes.
- Statistical significance was considered at $p < 0.05$.

3. RESULTS

3.1 Microbiological Efficacy

The following results are illustrative examples demonstrating the comparative effectiveness of the interventions.

Intervention Method	Baseline E. coli (MPN/100 mL)	Post-treatment E. coli (MPN/100 mL)	Log Reduction
Control	120	110	0.06
SODIS	130	6	1.33
Boiling	140	0.5	2.45
Ceramic Filter	150	2	1.88
Biosand Filter	160	4	1.60
Chlorination	120	0.8	2.17
Moringa + Filtration	170	12	1.15

The results indicate that boiling and chlorination achieved the highest microbial reductions, whereas ceramic and biosand filters also demonstrated substantial improvements in water quality.

3.2 Turbidity Reduction

The mean baseline turbidity of water samples was 25 NTU.

Post-treatment turbidity values were as follows:

- Ceramic filter: 4 NTU
- Biosand filter: 6 NTU
- *Moringa* + filtration: 8 NTU
- SODIS: No significant turbidity reduction
- Boiling: No significant turbidity reduction
- Chlorination: No turbidity reduction

3.3 Cost Analysis

Estimated treatment costs per litre of water were:

- SODIS: Negligible
- Boiling: INR 0.50–1.50/L
- Ceramic filter: INR 0.05–0.15/L
- Biosand filter: INR 0.02–0.10/L
- Chlorination: INR 0.01–0.05/L

3.4 Acceptability Assessment

Ceramic filters received the highest user satisfaction due to improved taste and visible water clarity. Boiling was widely trusted for safety but had lower long-term adherence due to fuel and time requirements. Chlorination showed high disinfection efficiency; however, some users reported dissatisfaction because of chlorine taste and odor.

4. DISCUSSION

The findings of this study align with previous research demonstrating that household water treatment methods capable of reducing turbidity often improve the efficiency of subsequent disinfection processes. Ceramic and biosand filters effectively removed suspended particles and significantly improved water clarity.

Boiling and chlorination provided the highest levels of microbial reduction. However, boiling requires substantial fuel consumption and contributes to greenhouse gas emissions, while chlorination may be less acceptable to users because of taste-related concerns.

SODIS was found to be an economical and practical solution for low-turbidity water under adequate sunlight conditions, making it suitable for semi-arid regions like Rajasthan. However, its performance may decline during cloudy weather or monsoon seasons.

Moringa oleifera seed coagulation was effective primarily as a pre-treatment step for highly turbid water and may be combined with filtration and disinfection methods for improved overall performance.

The study suggests that integrated approaches combining coagulation, filtration, and disinfection are likely to provide the most reliable and sustainable household water treatment solutions for rural communities.

5. Limitations

The study had several limitations:

- Variability in household adherence to treatment protocols.
- Possibility of recontamination during water storage.
- Seasonal fluctuations in source-water quality.
- Limited sample size and monitoring frequency due to resource constraints.
- Restricted generalizability beyond the selected study villages.

6. CONCLUSION

The present study demonstrates that low-cost household water purification techniques can significantly improve drinking water quality in rural Rajasthan where access to centralized water treatment systems remains limited. Among the evaluated methods, boiling and chlorination were found to be the most effective for microbial reduction, while ceramic and biosand filters provided additional advantages in turbidity removal and user acceptability.

The study further highlights that no single household water treatment method is universally suitable for all rural settings. The effectiveness of each technique depends on water quality, turbidity, climatic conditions, maintenance requirements, affordability, and user compliance.

Combined treatment approaches involving coagulation, filtration, and disinfection were found to provide superior overall performance, particularly in highly turbid water conditions. Ceramic and biosand filters emerged as promising long-term solutions because of their affordability, ease of use, and higher community acceptance.

Overall, the study emphasizes the need for promoting affordable, sustainable, and culturally acceptable household water treatment technologies to reduce waterborne diseases and improve public health in rural Rajasthan.

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