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Review Article

Domestic Water Filtration Technologies in Bangladesh: Challenges, Innovations and Socio-cultural Dimensions

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Abstract: Safe and hygienic drinking water remains a crucial public health concern in Bangladesh, with mass contamination by arsenic, microbial pollutants, industrial effluents and salinity affecting millions of people. While various efforts by the government and non-government agencies have been ongoing to combat this situation, regular and reliable water filtration systems are yet to gain mass popularity, especially in rural and coastal regions. This systematic review evaluates the current status of water treatment technologies adopted in Bangladesh in terms of their technical effectiveness, long-term sustainability and socio-cultural acceptability. Among the 87 identified publications, 25 were included, of which 16 were peer-reviewed articles from journals. The technologies under consideration are simple traditional techniques such as cloth and SONO filters and more recent techniques such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). Findings indicate that while basic filters are available and well-known in communities, they have poor contaminant removal. More advanced systems are indicated to be of high efficiency but are undercut by high cost, difficulty in maintaining them and poor local uptake. Socio-cultural settings and particularly women's roles in household water management are crucial to technology adoption and sustained use. The review emphasizes the need for locally-formulated, multi-functional solutions that are based on community engagement, user education and integrated policy guidelines. It is suggested that technological creativity be synchronized with local contexts to render safe drinking water equitable and sustainable in Bangladesh.

Keywords: Microfiltration, Ultrafiltration, Nanofiltration, Reverse Osmosis.

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Introduction

Bangladesh, a low-lying deltaic country with an extensive network of rivers and a high population density, faces persistent challenges in ensuring access to safe drinking water.[1] Both naturally occurring and man-made toxins are threatening the nation's water supplies. Arsenic contamination in groundwater affects millions, making it one of the most severe public health crises in the nation's history.[2] Simultaneously, microbial pathogens in surface water sources, particularly in flood-prone areas with inadequate sanitation, are linked to a high prevalence of waterborne illnesses.[3] Industrial expansion, often unregulated, has further aggravated the situation by introducing heavy metals and chemical pollutants into both surface and groundwater. These issues are particularly acute in rural areas, where centralized water infrastructure is limited, and in urban centers struggling to manage rapid population growth and waste.[4] In this context, water filtration technologies play a crucial role in mitigating health risks and improving water security. These membrane-based filtration techniques, which include reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF) provide promising solutions because they can efficiently remove a wide range of contaminants, from bacteria and suspended solids to dissolved salts and hazardous metals. Membrane systems may be difficult for rural homes to operate because of a lack of technical knowledge, while costly installation and operating expenses may discourage urban consumers. However, the success of these technologies is influenced not only by their technical efficacy but also by their affordability, ease of maintenance, and cultural acceptability.[5] Water consumption habits, social attitudes and technological trust all have a big impact on adoption and long-term use. A deeper understanding of these factors is essential for guiding effective interventions and ensuring that water filtration solutions are both sustainable and equitable across diverse socio-economic and geographic settings in Bangladesh.[6]

Methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[7] The primary aim was to evaluate and synthesize the current evidence on water filtration technologies implemented in Bangladesh, focusing on effectiveness, sustainability and socio-cultural acceptance.

Data Sources and Search Strategy

A comprehensive literature search was conducted using academic databases including PubMed, Scopus, Web of Science and Google Scholar. Additional grey literature from government reports, NGO documentation (e.g., BRAC, WaterAid) and WHO/UNICEF reports was included. Keywords used in various combinations included: "water filtration Bangladesh", "arsenic removal", "reverse osmosis Bangladesh", "microfiltration rural water", "sustainable water treatment Bangladesh" and "socio-cultural water purification".

Inclusion Criteria

Studies and reports were included if they met the following criteria:

Published between 2000 and 2024.

Focused on water filtration technologies implemented or studied in Bangladesh.

Provided empirical data on effectiveness, community use, sustainability, or user perception.

Exclusion Criteria

Studies focusing exclusively on other countries.

Opinion pieces without data or implementation details.

Non-English language publications without translation.

Data Extraction and Analysis

Data were extracted manually and categorized into thematic domains:

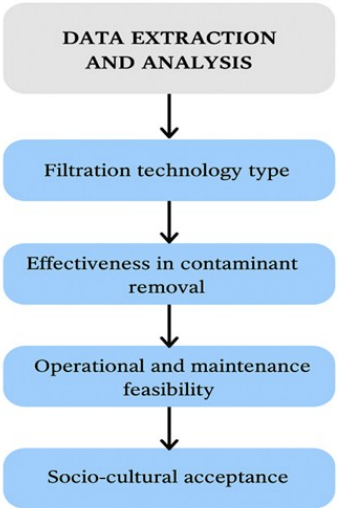

Figure 1: Flow chart of data extraction and analysis

Both qualitative and quantitative data were included. Where possible, effectiveness data (e.g., % removal of arsenic or pathogens) were summarized and socio-cultural insights were synthesized narratively.

Results

Overview of Selected Studies

A total of 87 publications were reviewed with 25 meeting the inclusion criteria. These included 16 peer-reviewed journal articles.

Summary of Filtration Technologies Assessed

Numerous water filtering technologies, each with differing levels of efficacy, accessibility and cultural acceptability have been used and researched in Bangladesh.[8] This systematic review synthesized findings from multiple studies to evaluate the performance and real-world viability of these technologies.

Among the most basic methods, cloth filtration (Simple Filter) emerged as a low-cost and readily adoptable option, particularly in rural areas relying on surface water.[9] Field studies showed cloth filters reduced cholera-causing pathogens by 48–59%, indicating moderate effectiveness.[10] However, the long-term adoption of cloth filters has declined, primarily due to perceptions of inefficacy and lack of behavioral reinforcement programs.

SONO filters, which use layers of sand, brick chips, charcoal and iron to remove arsenic, demonstrated impressive performance in laboratory and field settings, with arsenic removal rates ranging from 85% to 95%.[11] Their passive operation and low maintenance requirements contributed to relatively high community acceptance.

Microfiltration (MF) technologies provided effective pathogen removal, aiming for particles between 0.1 and 1 micron, particularly in laboratory conditions.[12] Controlled environment studies reported E. coli removal exceeding 90%, along with significant turbidity reduction.[13] Despite this technical success, MF systems struggled with real-world scalability in rural Bangladesh due to challenges such as frequent clogging, membrane fouling, and the need for trained maintenance, which was often unavailable or unsustainable at the community level.

Ultrafiltration (UF) is a membrane filtration process that operates at a finer scale than microfiltration (MF), typically targeting particles in the range of 0.01 to 0.1 microns. This allows UF to effectively remove a broader spectrum of contaminants, including bacteria, viruses, and suspended solids, making it a promising technology for improving water quality.[14]
NF membranes showed strong capabilities in removing divalent salts (e.g., magnesium and calcium) and certain organic compounds, making them promising in areas affected by salinity intrusion and industrial pollution.[15] NF membrane typically targeted particles that are usually between 1 and 10 nanometers. However, only three studies in this review documented NF use in Bangladesh, all in the form of small-scale pilot initiatives. These were largely restricted to urban or peri-urban areas with limited community engagement and high operational costs, highlighting the gap between laboratory promise and practical application.[16]

RO systems emerged as the most effective in terms of contaminant removal, usually focusing on particles larger than 0.1 nanometer, achieving near-complete elimination of arsenic, pathogens, and industrial pollutants.[17]These systems were mainly installed in urban or semi-urban households and community centers. However, their practical deployment revealed significant challenges. Initial installation costs ranged from Tk. 9,000 to 15,500 per household in 2015, making them financially inaccessible for many low-income families.[18] Furthermore, RO systems produced large volumes of wastewater—up to 60% of the input water—which raised concerns about water wastage, especially in areas with limited water supplies.[19]

Table 1: Summarizing the key information: filter type, filtration materials, pathogen targeted, size of particles to be filtered and effectiveness.

Filter Type	Filtration Materials	Contaminant/ Pathogen Targeted	Size of Particles to be Filtered/ Removed	Effectiveness (% Reduction)
Cloth Filter	Saree, Cotton fabric, Nylon Mesh, etc.	Cholera-causing pathogens (e.g., *Vibrio cholerae*)	20 to 50 microns	48 – 59 %
SONO Filter	Sand, Brick chips, Charcoal, Iron	Arsenic	>20 micron	85 – 95 %
Microflitration	Polymeric and Ceramic	*Escherichia coli,* Turbidity	0.1 to 1 micron	>90% E. coli removal. Significantly turbidity reduction
Ultrafiltration	Hollow fiber membranes	Arsenic, Bacteria, Virus, Protozoa	0.01 to 0.1 micron	>99.99% removal of *E. coli* and viruses. 100% removal of protozoa.

Nanofiltration	NF Membranes	Divalent salts (e.g., magnesium, calcium)	1 to 10 nanometers	High removal capability
Reverse Osmosis System	RO Membrane	Arsenic, Bacteria, Na^+, Cl^-	>0.1 nanometer	>95% Arsenic removal. 99.9% Bacteria removal. >90% salt reduction

Government and NGO Impact

Programs from both the government and non-government sectors have played a significant role in the adoption and spread of water filtration technologies. BRAC, being one of the top NGOs of Bangladesh, had installed over 400,000 SONO filters-majorly in arsenic-affected rural parts of Chandpur, Cumilla, Noakhali and Munshiganj. The program achieved a sustained utilization rate of 65% one-year post-deployment.[20] This success was attributed to a combination of community-based training, follow-up support and merging with local customs. In contrast, government-supported programs for RO installations in arsenic-affected districts such as Jashore, Sathkhira and parts of Khulna Division had early success but suffered from long-term sustainability issues. Within two years, over 40% of these installations were made nonfunctional due to inadequate maintenance, user lack of training and unclear responsibility for ownership.[21]

Socio-cultural Insights

Socio-cultural factors played a critical role in determining the success and longevity of filtration system usage. Across more than 80% of the studies reviewed, women were identified as the primary users and caretakers of household water filtration devices.[22] Their role extended beyond usage to regular maintenance, particularly for simpler systems like cloth and SONO filters. Technologies perceived as familiar, accessible and easy to use saw higher rates of acceptance. For instance, cloth filters and SONO filters were widely adopted in communities where users had prior exposure or cultural affinity toward such methods.[11] On the other hand, more sophisticated systems like RO, UF and NF units were occasionally viewed with suspicion.[15,17] In communities lacking proper education and sensitization, these systems were occasionally viewed as "foreign" or "untrustworthy," reflecting a disconnection between technological advancement and community readiness.

Discussion

This systematic review reveals a vibrant and complex situation of water purification technologies in Bangladesh—one which bears witness to a chronic tension between scientific progress, socio-cultural necessities and infrastructural system problems. While there is a wide range of filtration technologies, ranging from low-technology cloth filters to highly advanced reverse osmosis (RO) technologies, the review makes a significant observation: no single technology has an all-purpose effective or contextually best solution for the range of needs and challenges in various regions and communities of Bangladesh.

Technology Effectiveness and Suitability

The review highlights wide variability in both the technical performance and contextual suitability of the filtration technologies examined. For instance, cloth filters provide only modest germ protection despite being affordable and culturally familiar.[10] Their continued use in rural areas reflects not technological adequacy but rather a reliance on basic, community-driven coping mechanisms in the absence of better alternatives. These filters are better understood as short-term stopgaps than viable long-term interventions for water safety. In contrast, SONO filters have proven highly effective in removing arsenic, one of Bangladesh's most serious water contaminants, especially in rural areas.[11] However, their utility is narrow, as they are not equipped to address microbial or saline contamination, which are equally pressing issues in many regions, especially coastal zones.[15] This limitation calls attention to the need for multi-functional solutions that address the diverse and co-occurring contaminants found in Bangladeshi water sources. Reverse osmosis (RO) systems stand out for their comprehensive filtration capabilities, effectively removing arsenic, pathogens, salinity and a wide range of chemical pollutants.[21] However, their suitability is constrained by several factors: high initial costs, operational complexity, dependency on reliable electricity, and substantial water wastage. These limitations make RO systems most viable in urban and peri-urban settings where infrastructure and financial resources are relatively stronger[16]. On the contrary, they are largely impractical for remote or poorly equipped communities. Although microfiltration (MF), Ultrafiltration (UF) and nanofiltration (NF) show strong laboratory performance in removing pathogens and salts, respectively. Unfortunately, they are not widely used due to high expenses, technical upkeep needs and lack of consumer awareness, particularly in rural areas where water insecurity is more likely to be severe.

Maintenance and Sustainability Challenges

One of the most consistent findings across the reviewed studies is the pivotal role of maintenance in determining the long-term success of water filtration technologies. Advanced systems like RO and NF are highly sensitive to operational issues—clogged membranes, broken pumps, or uncleaned filters can render them ineffective in a short time. This has been particularly evident in government-sponsored RO installations in rural schools and community centers, where failure rates exceeded 40% within two years due to neglect and lack of technical support.[23] Higher pathogen elimination effectiveness is provided by ultrafiltration system; however, they also have similar maintenance needs and membrane fouling issues. To ensure long-term sustainability and scalability, UF must be successfully implemented in rural areas of Bangladesh.[14] This requires finding answers to these operational challenges, such as better membrane cleaning procedures, user-friendly designs and community training.

For long-term sustainability, there must be simplified design, local capacity development and strong community ownership. Technology for filtration that requires minimal technical maintenance, has simple maintenance procedures and is supported by local training programs is far more likely to operate and bring benefit in the long term.

Socio-cultural Dynamics and Gender Roles

For filtration technology to be accepted and used consistently, sociocultural factors are essential. Women were consistently found to be the main users and caregivers of residential water filtration systems throughout the examined literature. Their participation is strategic as well as practical; adoption rates are much increased when systems are designed to fit their priorities, daily routines and preferences. Particularly in households where women handle most of the water collection, simple, non-electric, portable and low-maintenance solutions are more likely to be chosen.[22] On the other hand, more complicated or unknown systems frequently encounter opposition. Advanced filtration units were perceived as "foreign" or suspicious in a number of cases, which reflected a lack of familiarity as well as the larger problem of inadequate community education and sensitization regarding new technology.[24] These results highlight how any technology deployment must be accompanied by strong community involvement and culturally sensitive educational initiatives. Long-term public health outcomes depend as much on community trust and knowledge as on technological standards.

Integration with Policy and Infrastructure

The dispersed nature of Bangladesh's water treatment projects is yet another significant barrier to their scope and influence. The study provides strong evidence that this can be resolved by integrating water filtration into broader national water and health programs. Such integration would allow for more efficient resource allocation, more consistent implementation and better coordinated planning. Coverage and effectiveness could be greatly increased by a centralized policy framework that prioritizes cheap, scalable solutions that are adapted to the local socioeconomic conditions and water pollution profiles.[5] In particular, policies must emphasize community engagement, technical training, and ongoing support rather than focusing solely on initial installation. The sustainability of any filtration intervention depends on aligning technical feasibility with social acceptability and institutional support.[25]

Conclusion

Effective water filtration in Bangladesh is not merely a technical challenge but a multidimensional issue that involves economic, social and cultural considerations. A universal solution is unlikely to be effective. Instead, context-specific, community-centered solutions are essential. The future lies in integrated strategies combining appropriate technologies with sustained community engagement, government support and educational outreach. Through such comprehensive efforts, Bangladesh can ensure safe and equitable access to clean drinking water for all.

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