A MINI-REVIEW ON GREYWATER TREATMENT AND ITS REUSE POTENTIAL FOR SUSTAINABLE WATER MANAGEMENT

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ABSTRACT

Properly treated greywater reuse is increasingly in demand to promote environmental sustainability and mitigate water scarcity, particularly in developing nations. A massive amount of ablution water, a promising source of greywater, is being generated in different mosques from a person's washing rituals before his prayer, and it is being directly disposed down to the drain in most cases. Against this backdrop, the reuse potential of ablution water and other light greywater treatment processes have been explored in this review. Various treatment technologies such as sand filters, bioreactors, carbon and chlorine filters, etc., implemented in many countries such as Malaysia, Oman, Jordan, etc., have proven effective and efficient in producing safe greywater for reuse. Several studies show that the quantity of greywater generated from ablution varies widely (1.5L-7L/person/each time) depending upon regions and people's awareness. In addition, the ablution water is reasonably clean, with no soap or solid pollutants, making it suitable for non-potable water applications such as irrigation, toilet flushing, gardening, and car washing. Research findings suggest that conventional processes such as sedimentation, filtration, disinfection, and cost-effective sand filters in treating ablution water demonstrate notable efficacy in improving water quality parameters. However, further considerations for applicability in countries like Bangladesh may favour low-cost and easily applicable solutions, making technologies like sand filters and constructed wetlands particularly promising for sustainable greywater treatment practices. The paper also highlighted the social aspect of greywater reuse for its acceptability and for raising awareness among the intended community. This review study may, therefore, help identify appropriate and low-cost treatment technology for this greywater and suitable reuse options for the sustainable water management of developing countries like Bangladesh.

Keywords: *Ablution water, greywater, water treatment process, reuse of greywater.*

1. INTRODUCTION

Ensuring clean water resources for all and their safe reuse is an important target to attain sustainable development goals by 2030. Therefore, the reuse of different types of wastewater following proper treatment has become a global concern for the sustainable management of wastewater and the saving of the earth's freshwater resources. It has been predicted that one-third of the world's population may lack reliable access to safe drinking water (Ghaitidak & Yadav, 2013). The situation may be worsened by factors such as rapid population growth, unregulated and massive water use in agriculture and industry, changes in living standards, etc. Moreover, climate change is anticipated to significantly affect global water demand, especially in arid and semi-arid countries, where renewable groundwater and surface water resources are already scarce (Hellegers et al., 2013). In this context, the reuse of wastewater, especially less polluted greywater, has become a viable option to overcome the water scarcity issue and minimize environmental pollution.

In this context, ablution water can be considered a significant greywater source. Ablution, or "wudu," is a spiritual cleansing process central to the daily lives of millions of Muslims worldwide. Ghernaout (2017) explored the teachings of the Holy Koran and the Prophet Muhammad (peace be upon Him) regarding environmental protection and sustainability. Astonishingly, Prophet Mohammed (peace be upon Him) himself utilized a mere 0.6 liters of water for ablution, as prescribed by the Sunnah, which addresses ancient customs and practices of the Islamic community. However, it is complicated to note that contemporary practices in some regions, including Bangladesh, have seen ablution water consumption rise to as much as 2.5-7 liters per ritual(Al Mamun et al., 2014; Al-Alawi, 2019; Abid & Ansari, 2020)highlighting the need for more efficient water use in this context. The southwest region of Bangladesh, like many other regions grappling with water scarcity, faces an acute challenge in ensuring sustainable water resource management (Abedin et al., 2019). As population growth and economic development continue to strain freshwater supplies, there is an urgent need to explore innovative solutions to address this impending crisis. One such answer lies in the potential of greywater reuse, particularly from ablution rituals, to turn what was once considered wastewater into a valuable resource(Penn et al., 2012). People are not fully aware of the water crisis and the importance of recycling (Pinto & Maheshwari, 2010). Research suggests that ablution greywater (AGW) possesses qualities that make it a viable candidate for reuse, particularly in non-potable applications such as landscaping, toilet flushing, vehicle washing, and irrigation (S. Alharbi et al., 2019; Jamrah et al., 2006; March et al., 2004; Suratkon et al., 2014; Tabidi et al., 2022). Unlike domestic greywater sources, AGW is relatively clean, containing no soap or solid pollutants, though it may have minor quantities of bacteria(Suratkon et al., 2014). Implementing low-cost and straightforward treatment procedures can contribute to sustainable development and water resource conservation without compromising human health or the environment. However, planning for the full use of treated effluent is still in the early stages, and accessible treated wastewater is still not utilized to its full potential(Jasim et al., 2016). For greywater treatment, many treatment technologies have been proposed and tested, including physical (March et al., 2004), chemical (Lin et al., 2005; Pidou et al., 2007), and biological(Atanasova et al., 2017; Fountoulakis et al., 2016). Few studies have been published on physical-chemical approaches utilizing sand filters for AGW treatment (Al-Mughalles et al.; Al-Wabel & Al-Wabel, 2011; Prathapar et al., 2006; Wurochekke et al., 2014, 2015). Nature-based solutions can help reduce the demand for freshwater resources and the number of pollutants discharged into the environment(Boano et al., 2020). Shafiquzzaman et al. (2018) and (2020) researched to develop five more straightforward approaches for treating AGW, employing a low-cost ceramic filter, alum coagulation, and activated carbon adsorption, either separately or in combination. So, a thorough and deep study is necessary to implement low-cost, easy maintenance, and straightforward processes to reuse the ablution and other light greywater in Bangladesh.

This paper aims to bridge this gap by reviewing existing literature and summarizing critical findings related to the reuse of ablution water in Bangladesh. In doing so, it seeks to shed light on the potential benefits, challenges, and opportunities associated with this practice in the context of the country's water scarcity challenges. By exploring the religious, cultural, technological, and environmental dimensions of ablution water reuse and light greywater treatment process, this review paper aims to provide insights that inform policymakers, communities, and future research endeavors.

2. METHODOLOGY

This article provides a thorough assessment of several important pieces of research that address different greywater treatment techniques all over the world. Therefore, a variety of electronic resources, including Google Scholar, ScienceDirect, and specifically renowned publishers like Elsevier and Springer, have been used in the study. Keywords and phrases like "greywater treatment," "greywater recycling," "greywater reuse," and "ablution water" were combined to perform the search. This study has over 100 research articles on light greywater reuse technologies (physical, chemical, biological, and physiochemical). Only a few research publications from the 1990s have been used to contrast traditional technologies with the current ones(Deboch & Faris, 1999. Cooper, 1999).

3. CHARACTERIZATION OF ABLUTION WATER

3.1 Quantity of ablution water

Several studies have reported varying amounts of water used for ablution, a significant greywater source. The Prophet Muhammad (peace be upon Him) prescribed a small amount of water, using just 0.6 liters for ablution. Al-Alawi surveyed GCC countries and discovered that up to 7 liters of water were utilized for each wudu. According to the Sunnah, which covers the norms and traditions of the Islamic community, the Prophet Mohammed (peace be upon Him) only needed 0.6 liters of water for his perfect ablution (Abid and Ansari, 2020). In Delhi, the ablution ritual uses an average of 3.10 m^3 of water per person per day in a mosque, but residential indoor usage is only 0.26 m^3, according to Abid and Ansari (2020). Prathapar et al. (2006) discovered that daily ablution water produced at the Al Hail South mosque, Oman, ranged from 0.77 m^3 to 1.94 m^3. While in Egypt, the average volume of water from ablution was about 5.37 L per person(Al-Mughalles et al., 2008; Eriksson et al., 2003). A study in Yemen showed that the water quantity used by one worshipper during ablution was about 2.7 L per person for each mosque, and the maximum value of water used was during the Friday prayer (Al-Mughalles et al., 2012). At the International Islamic University Malaysia (IIUM) Masjid at Gombak Campus, Al Mamun et al., 2014 calculated that about 7 L per person of water is used for ablution. Jamrah et al., 2006 studied greywater generation in Amman City, Jordan, finding a daily per capita ablution water demand ranging from 0.6 to 2.03 L per person, with a weighted average of 1.14 L per person. Zaied (2017) investigated ablution water consumption in the Arab region, discovering that 30-47% is wasted when taps release water continuously. Using a naturalistic method, Utaberta et al. 2014 found an average ablution water consumption of 1.5-2 L per person.

3.2 Physiochemical Quality of Ablution Water (Greywater)

Suratkon et al. (2014) found that greywater from the ablution is reasonably clean since it includes no soap or solid pollutants. However, it does contain minor quantities of bacteria, primarily from gargling. As a result, collecting this moderately polluted water and putting it through little treatment may be recycled and utilized in non-potable water applications._Table 1 shows that the physical and chemical parameters of used water in the ablution process do not degrade much, and it can be used for irrigation purposes, according to the ECR,2023. According to Albalawneh & Chang (2015), greywater, with a BOD5/COD ratio of 0.31 to 0.71, is highly biodegradable and suitable for agricultural irrigation. Unlike residential wastewater, it is less contaminated, has fewer suspended particles, has lower turbidity, and can be efficiently processed for reuse, as Parsons et al. (2000). According to the Environmental Conservation Rules 2023, if the pH ranges from 6.5-8.5, BOD lies at 10 or less, DO value 5 or less, and total coliform number/100 stays at 1000 or less, then the water is applicable for irrigation(The Environment Conservation Rules, 2023) Ablution water typically has a pH range of 6.92 to 7.10, a COD range of 50 to 70 mg/L, a BOD range of 20 to 40 mg/L, a TSS range of 5 to 146 mg/L, a turbidity range of 10 to 30 NTU, and an E. coil range of 100 to 1000 CFU/100 mL (Al-Wabel & Al -Wabel, 2011; Radin Mohamed et al., 2016).

4. PROCESSES ADOPTED FOR TREATING GREYWATER

Greywater can be a valuable resource for non-potable uses such as irrigation, but appropriate treatment technologies are necessary to mitigate potential risks (Vuppaladadiyam et al., 2019). Sophisticated mathematical modeling software like Simulink was also employed to understand better how different paths interact in greywater treatment units (Kuriqi et al., 2019). Awasthi et al. (2023) looked into a few of the cutting-edge greywater treatment systems that have garnered interest recently, including membrane-based technology, improved electro-coagulation, nature-based solutions (constructed wetlands), and solar-based approaches.

Table 1: Physico-chemical quality of ablution water found in different countries

Parameters	Concentration present in Raw water (% removal of treatment option)					
	Malaysia	Jordan	Oman	KSA	Indonesia	Malaysia
pH	N/A	6.85	7.20(2.64%)	7.4 (9.5%)	8.4	7.14(8.26%
TDS (mg/l)	24.7(1.62%)	6.6-65.2	121(33.83%)	329 (19.76%)	602	N/A
TSS (mg/l)	31(35.81%)	303-960	9.39(60.7%)	10.8(88.24%)	-	9(33.3%)
Turbidity (NTU)	16.4(78.66%)	N/A	12.6(52.14%)	13.7(94.3%)	-	N/A
EC(μS cm−1)	N/A	320-2520	221(33.03%)	N/A	-	N/A
BOD_5 (mg/l)	N/A	3.3-5.9	N/A	30.6(69.61%)	-	31(10.7%)
COD (mg/l)	31.3	410-600	51.47(32.9%)	52.58(82.3%)	-	3.66(14.8%
DO (mg/l)	N/A	420-588	1.32(189.4%)	N/A	-	6.92(1.6%)
E.Coli (CFU/100ml)	N/A	1.06-1.58	>200(100%)	N/A	TNTC	N/A
Alkalinity (mg/l)	N/A	N/A	N/A	69.6 (28.3%)	-	N/A
Total Coliform (CFU/100ml)	N/A	N/A	N/A	1035(3.67%)	-	N/A
Treatment Option adopted	Sand Filter	Bioreactor*	Sand with Disinfection**	Ceramic Unit***	Coagulation with Chlorine	Sand and Gravel Filter
Reference	Al Mamun et al. (2014)	Al-Zu'bi et al.(2015)	Prathapar et al. (2006)	S. Alharbi et al. (2019)	Mudofir et al. (2023)	Radin et al. (2016)

*Modified re-circulated vertical flow bioreactor; **Sand trap, collection tank, filtration unit with chlorination unit; **
***Ceramic unit, carbon adsorption column with chlorine dispenser

4.1 Physical Process

4.1.1 Conventional Process

Al Mamun et al. (2014) and Prathapar et al. (2006) described a greywater treatment process involving sedimentation, filtration, and disinfection. Tabidi et al.(2022) proposed an approach that includes screening, sand removal, pH monitoring, aeration, filtration, chlorination, and storage. Mandal et al. (2011) designed a greywater treatment system with primary screening, sedimentation, filtration, and disinfection processes, successfully reducing COD, BOD, and Escherichia coli.

4.1.2 Sand Filter and Biosand

Sand filters, for example, are a low-cost greywater treatment approach limited by poor BOD, COD, and TOC removal effectiveness and frequent clogging difficulties(Li et al., 2009; Zipf et al., 2016). Sand filters are easy to operate, require low maintenance, and can remove various chemical contaminants from light greywater. Radin Mohamed et al. (2016) discussed the potential reuse of ablution water in mosques through sand and gravel filtration and explored the effectiveness of this. Al-Wabel & Al-Wabel (2011) introduced a similar system of sand filters with activated charcoal and a UV unit to achieve tertiary-quality effluent. The system can save 30-40% of fresh water for toilets and irrigate the landscape area. Patil et al. (2020) developed a Greywater treatment using a Sand Gravel Filter (SGF), a Laterite Soil Vegetated Vermifilter (LSVVF), and a Laterite Soil Vegetated Filter (LSVF) on a laboratory scale. Sand filters are useful and can be used for treating light greywater in Bangladesh, as they are effective in removing various contaminants and are easy to operate. Deboch & Faris (1999) evaluated the efficiency of rapid sand filter treatment plants in removing fecal coliform bacteria, color, and turbidity. A study found that light greywater reuse can reduce the daily household wastewater flows by 25-40%(Penn et al., 2012). Vara Lakshmi et al. (2012) assessed a locally designed sand filter's effectiveness in removing various chemical contaminants from environmental water sources, reducing turbidity, chlorides, total solids, total dissolved solids, and suspended solids in the water samples. Babaei et al. (2019) investigated the effectiveness of a new hybrid system for treating greywater using a multi-layer slow sand filter (MSSF), a microfilter (MF), and an ultrafilter (UF) in a laboratory scale over 157 days. Another study by Dalahmeh et al. (2014) found that using foam, bark, activated charcoal, and sand in multi-filters removed linear alkyl benzene sulfonate (LAS) from greywater up to 70%, more than 99%, and 96%, respectively. The bio-sand filter is an adaptation of the slow sand filter technology. It involves a sand column coated with biofilm and a mix of biological and physical processes(Halwani et al., 2016). A study compared the performance of two low-cost household water filters, the filtration ceramic filter, and the biosand intermittent slow sand filter, in improving water quality by reducing turbidity, total organic Carbon (TOC), dissolved organic Carbon (DOC), E. coli, and total coliform counts from pond water for 30 days(Duke et al., 2006). Keeping the ablution water quality in consideration, sand and bio-sand filters can be a potential option for Bangladesh as they can gain a high removal efficiency.

4.2 Chemical Treatment

Chemical processes most effectively reduce suspended solids, organic materials, and surfactants in low-strength grey water (He et al., 2022; Li et al., 2009). Chemical water treatment is a method to improve water quality by eliminating contaminants, and it generally includes chemicals, ozonation coagulation, flocculation, etc. (Gupta et al., 2012).

4.2.1 Coagulation

S. K. Alharbi et al. (2019) proposed a promising treatment process of ablution water with alum coagulation and activated carbon. Mudofir et al. (2023) described the treatment of ablution wastewater using an electro-coagulation (EC) process. The EC process effectively reduced total suspended solids, turbidity, and chemical oxygen demand levels in the treated wastewater. However, total dissolved solids, electrical conductivity, and coliforms were still relatively high in the treated wastewater. Lin et al. (2005) also developed a small-scale, low-cost electro-coagulation technology with a 28 m^3 per day recovery rate for home greywater for non-contact human use.

4.2.2 Activated Carbon

Berger (2012) found that biochar and activated carbon effectively reduced COD, MBAS, Tot-N, and Tot-P in greywater. Biochar was more effective in lowering total nitrogen, but further research is needed to evaluate its potential for full greywater treatment. Another pilot plant study by Thiel et al. (2006) found that granular activated carbon (GAC) filters outperformed anthracite filters in reducing organics, lowering chlorine demand, and reducing total trihalomethane formation potential (TTHMFP).

4.2.3 Physiochemical

S. Alharbi et al. (2019); Shafiquzzaman et al. (2020) others researched to develop five more straightforward approaches for treating AGW, employing a low-cost ceramic filter, alum coagulation, and activated carbon adsorption, either separately or in combination. Utaberta and Handryant (2014) also described a greywater treatment process for the UKM Mosque that involves physical, chemical, and biological processes. The physical process includes screening, flotation, and filtration, while the chemical process involves flocculation-coagulation to remove colloidal particles, heavy metals, phosphorus compounds, and toxic organic substances. Parsons et al. (2000) compare the effectiveness of chemical and biological processes in treating grey water. The study found that physical-chemical processes can be a suitable alternative to biological treatment, especially in systems that serve small populations.

Table 3: Recent findings on light greywater treatment in different parts of the world

Treatment Process	Type/source	Key findings	Ref.
Modified re-circulated vertical flow bioreactor	Low-quality greywater	• The content of Ca, Mg^{2+} and DO significantly increased up to 79%, 75% and 98%, respectively • The removal efficiency of NO_3^-, Cl^-, and SO_4^{2-} was satisfactory, ranging from 19 to 100% with no significant changes in case of pH or EC.	Al-Zu'bi et al. (2015)
Constructed wetland	Kitchen greywater	• High percentage of removal of BOD(81.42%), COD(84.57%), AN(39.83 %), 54.70 % SS(4.70 %), and 45.01 % turbidity(45.01 %).	Wurochekke et al. (2015)
Electrocoagulation	Household grey water	• With 0.3 kW h/m^3 of sewage, over 70% of the total COD and more than 99.9% of pathogens were removed.	Vakil et al. (2014)
Aerobic digestion and hydrogen peroxide disinfection	Showers and drains of bathroom sinks	• About 88% and 68% of TSS and COD, respectively were removed with a hydraulic retention time of 5 hours and an organic loading rate of 2.16 gCOD/L/day. • Bacteria were eliminated by disinfection with 1 mL/L hydrogen peroxide, and after a day of storage, they were entirely removed.	Teh et al. (2015)
Slow sand and slate waste filtration, followed by granular activated carbon filter	Toilet wastewater	• In comparison to the slate waste filter, the average removal efficiencies for turbidity, apparent color, COD, and BOD were 66, 61, 60, and 51% for the sand filter and 54, 56, and 56% for the latter five. For the sand and slate waste filters, the average removal efficiencies of the total and thermotolerant coliforms were 61 and 90%, respectively.	Zipf et al. (2016)
Horizontal flow wetland	Tourist spot	• The removal effectiveness was relatively high: more than 90% for COD, BOD_5, TSS, VSS, and turbidity, and for TOC it is greater than 80%	Zraunig et al. (2019)
Bioremediation using Chlorella variabilis	Bathroom and wash basin	• After being grown for 19 days in 30% diluted samples and raw greywater, the microalgae are extracted from the medium by centrifugation, which removes over 90% of the substance.Almost 90% removal for COD, BOD_5, TN, and TP	Oktor & Çelik (2019)
Vermifilter	Synthetic	• Using LSVF(Laterite Soil Vegetated filter), removal efficiencies for BOD_5, TKN, and P were found to be 50–60%, 30–50%, and 30–50%, respectively.	Patil et al. (2020)
Container-based vertical-flow constructed wetland	Hand basin and shower	• The modular/elevated lava sand VFCW had mean effluent values of 6.3 mg/L COD and 0.05 mg/L P_{tot}, and at very low water temperatures, it demonstrated significant nitrification.	Morandi et al. (2021)
Vertical flow constructed wetlands	Light Greywater	• The removal rates for turbidity and COD increased dramatically in the second year of operation • Pollutant removal from sand-based systems, both planted and unplanted, was more successful, with a 5-log reduction in total coliforms and a 4-log reduction in Escherichia coli.	Stefanatou et al. (2024)

4.3 Biological Treatment

4.3.1 Constructed Wetland

Engineered wetlands, known as constructed wetlands, are built to resemble natural wetland systems for treating wastewater. These systems, mainly composed of plants, substrates, soils, microorganisms, and water, use intricate physical, chemical, and biological processes to remove pollutants or enhance water quality(Saeed & Sun, 2012, 2013; Vymazal, 2007, 2013). As the main natural component of CWs, plants act as intermediaries for purification reactions by enhancing various removal processes and directly utilizing nitrogen, phosphorus, and other nutrients. They can also accumulate toxic elements in wastewater, such as heavy metals and antibiotics (Rai et al., 2013; Yan & Xu, 2014). In order to treat kitchen greywater, Wurochekke et al. (2015) built a wetland and exposed it to hard abiotic conditions like pH, temperature, and oxygen. Other treatments included sedimentation, mechanical filtration, adsorption, die-off, predation, antibiotic production, and excretion by plants and bacteria. Boano et al. (2020) found that nature-based solutions for greywater treatment use natural processes to treat greywater, such as filtration through soil, plants, or other materials. Some examples of nature-based solutions for greywater treatment include green roofs, green walls, constructed wetlands, and soil infiltration systems. These solutions can be more cost-effective and energy-efficient than traditional treatment methods, as they rely on natural processes and do not require as much energy or chemicals. However, the effectiveness of these solutions can depend on factors such as climate, soil type, and the specific design of the system. Treating greywater shows that the water's turbidity, TSS, COD, and BOD quality have improved. Constructed wetlands with plants also increase the efficiency of removing pollutants (Dan et al., 2011; Sandoval et al., 2019). Manjate et al. (2015) performed two types of FVF-constructed wetland systems and showed different feeding strategies and the use of planted and unplanted units to treat raw sewage using the first stage of the French vertical flow constructed wetland system.

4.3.2 Other Processes

Vertical-flow (VF) systems have a much greater oxygen transfer capacity and are cheap and considerably smaller than horizontal-flow (HF) systems (Cooper, 1999). The advantage of HF systems is that they are simple and have low construction and operational costs. Combining the advantages of the HF and VF systems results in an effluent with a low BOD that is partially denitrified and entirely nitrified, meaning that its Total N concentration is significantly lower (Vymazal, 2005). Nolde (2000) has prescribed a rotary biological contactor (RBC) and a fluidized bed reactor for treating grey water that can be used for toilet flushing. Merz et al. (2007) performed a membrane bioreactor technology to reuse the greywater and revealed that greywater with low COD and low absolute nutrient content may be treated using MBR technology.

5. SOCIAL AWARENESS AND ACCEPTANCE OF USING TREATED GREYWATER

It is crucial that users are aware of whether wastewater reuse systems are effective or not. Greywater usage and understanding are still developing (Amaris et al., 2020). Carrosio et al. (2020) put together a report on survey participants' knowledge of contemporary garbage treatment technologies. The results of the survey indicate that respondents and some water specialists support significant water reuse. Given that most respondents believe water is scarce and support the reuse of greywater, the research shows a strong correlation between the acceptability of greywater reuse and levels of water stress. However, the municipalities were Communities in need of water and those who opposed multiple wastewater initiatives for recycling (Carrosio, 2020). This might be viewed as having insufficient community involvement and public education before implementation. According to Smith and Hyde (2015), people mostly reuse greywater for non-drinking water requirements. The justifications offered for not using recycled greywater were negative. According to a poll on public opinion, 21.6 to 67.6% of respondents favored using recycled greywater for household laundry, car washing, watering fruit trees, and vegetable growth. Additionally, due to costs, health risks, groundwater pollution, or environmental effects, 2.0 to 91.8% of the populace opposed reusing greywater (Jamrah et al., 2006). 0Sustainable measures may arise from the public's increased awareness of greywater and its benefits for augmenting the water supply (Ntibrey et al., 2021). It is necessary to take into account all relevant economic, technological, social, and environmental issues when examining water reuse and conservation sustainability (Sgroi et al., 2018).

6. CONCLUSION

This comprehensive review delves into aspects of treating greywater, focusing on ablution water and other sources. It provides insights into physical, chemical, and biological treatment processes. The paper emphasizes the benefits of reusing greywater in water-stressed regions like Bangladesh. The review covers a range of physical treatment methods, including approaches, sand filters, and biosand systems. These methods effectively reduce parameters such as COD, BOD, and turbidity. However, it is crucial to evaluate their application due to challenges like clogging and limited removal efficiencies in some cases. Chemical treatment techniques such as coagulation and activated carbon effectively address suspended solids matter and surfactants in low-strength greywater. Biological treatment methods show promise for greywater treatment through constructed wetlands that mimic natural systems. These engineered wetlands utilize plants, substrates, and microorganisms to remove pollutants. Their applications demonstrate the versatility of constructed wetlands for treating kitchen greywater and greywater. Based on the literature reviewed in this study, it is clear that more research specific to the context of Bangladesh is needed to address identified research gaps. This review serves as a reference for researchers, policymakers, and professionals interested in the sustainable handling of greywater. It offers perspectives on existing practices and the challenges and prospects that lie ahead.

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