OPTIMIZING SUSTAINABLE WATER MANAGEMENT: STUDY ON IN-SITU RECYCLING OF GREYWATER

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ABSTRACT

The concept of utilizing wastewater as a water source was born out of the increasing water demand brought on by the exponential population expansion. Greywater is non-industrial wastewater free from fecal matter, generated from household activities such as using basins, bathrooms, kitchens, and washing clothes. The main aim of this study was to in-situ recycle greywater generated from houses for gardening, and rooftop fish farms. Three greywater samples per site were collected from three locations. Two samples were collected from two KUET student halls and the remaining one was collected from a residential building in Fullbari Gate, Khulna. A slow sand filter was developed in the laboratory for treatment purposes using kushtia sand, sylhet sand, charcoal, coconut husk, and stone chips. The effluent exhibited a pH range from 7.2 to 7.6, with the lowest dissolved oxygen (DO) value recorded at 5.8, surpassing the standard minimum requirement. The removal efficiencies for various parameters were as follows: BOD (Biochemical Oxygen Demand) - 75.86%, COD (Chemical Oxygen Demand) - 57.81%, TDS (Total Dissolved Solids) - 43.62%, conductivity - 54.65%, NO_3-N (Nitrate Nitrogen) - 36.63%, PO_4-P (Phosphate Phosphorus) - 52.98%, and SAR (Sodium Adsorption Ratio) - 51.87%.In terms of DO, BOD, conductivity, NO_3-N, and PO_4-P, the filter proved effective. However, additional treatment processes would be required to address COD, TDS, and SAR for optimal results. This practice can therefore reduce the disparity between water supply and demand by providing new water sources.

Keywords: *Greywater, wastewater, recycle, treatment, slow sand filter*

1. INTRODUCTION

The disparity between water supply and demand is growing as the world's population rises(Pangarkar et al., 2010). It affects global water security and may lead to a crisis in the coming years(Patil et al., 2022). Therefore, all sectors of consumption must minimize their usage of surface and groundwater(Uddin et al., 2019). And the need of the hour is to find a new water source to maintain the balance between freshwater supply and demand(Patil et al., 2022). A notable research goal in recent times has been to attain almost zero water requirements for buildings, in addition to nearly zero energy requirements(Bodnar et al., 2014). Reusing and recycling wastewater have been conducted all around the world using different approaches to address this issue(Patil et al., 2022). There are many types of wastewater, among those greywater is one. Greywater contributes 60-75% of the water volume to domestic wastewater(Ghunmi et al., 2011).

Greywater is non-industrial wastewater that is free from fecal matter generated from domestic processes(Ajit, n.d.). Therefore, wastewater from washbasins, kitchen sinks, laundry, and bathing, can all be called greywater(Patil et al., 2022). Low- or medium-grade wastewater is considered to be equivalent to greywater (Uddin et al., 2019). A variety of factors, including the number of occupants, their age distribution, how they live their lives and climate, influence the composition of greywater(Ghaitidak & Yadav, 2013; Oteng-Peprah et al., 2018). A lot of shampoos, soaps, body care items, etc. are produced in the greywater from bathrooms. Greywater from laundry contains a wide variety of detergents. soap, toothpaste, and other items contribute to sink greywater(Patil et al., 2022). So they have a more alkaline nature(Ajit, n.d.). Kitchen sink greywater contains a lot of fat, oil, and food residues(Patil et al., 2022). Hair, dust, and food fragments all contribute to suspended solids(Ajit, n.d.).

As a method of reducing water pollution, greywater treatment is environmentally beneficial(Pangarkar et al., 2010). Greywater can be treated and reused on-site instead of having to be transported to a central treatment plant, a process known as "in-situ recycling." This process is becoming increasingly significant these days(Ajit, n.d.). The goal of treatment is to fix aesthetic, health, and technical issues caused by organic matter, bacteria, and solids, as well as to fulfil using standards in certain field(Ghunmi et al., 2011). Generally, greywater is not excessively contaminated. So, in the house, it can be in-situ recycled for gardening and rooftop fish farms. Floor washing, car washing, and toilet flushing also can be included in this serial. Some contaminants in greywater are considered fertilizer for plants. When reusing greywater for gardening, phosphorus, nitrogen, and potassium are great sources of fertilizers(Pangarkar et al., 2010). So, it is crucial to employ a variety of strategies that may maintain water supplies by recovering nutrients and water from greywater and promoting recycling to help address these resource limitations(Magwaza et al., 2020).

Many countries across the globe have initiated the process of quantifying and characterizing greywater to execute the recycling of greywater effectively(Uddin et al., 2019). To purify greywater and lessen contamination before reuse or even before final disposal, they have used simple-to-advanced methods. Filtration has been the most commonly employed system.(Patil et al., 2022).Among available many technologies, the process known as slow sand filtering (SSF) is less expensive and uses less energy(Verma et al., 2017).

A slow sand filter is a type of water and wastewater purification system that employs both physical and biological methods to remove contaminants from water and wastewater(Desk, 2023). There can be many components of a slow sand filter (SSF). However, only the sand part of the filter mainly contributes directly to the purifying process(Ellis & Wood, 1985).

2. METHODOLOGY

In this study, sand was used as the main filter medium along with other media such as coconut husk, charcoal and stone chips. Two types of sand were used: kushtia sand and sylhet Sand. The entire procedure is depicted in the following diagram.

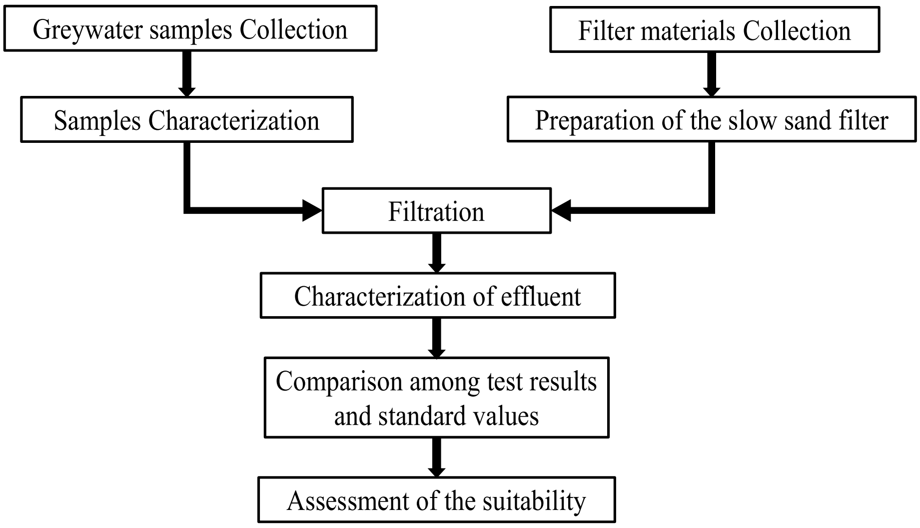


Figure 1: Flow diagram of the methodology

3. Collection of greywater samples

Three primary locations were chosen for the study: a residential building in Fullbarigate, Khulna, and the Amar Ekushey Hall and Rokeya Hall in Khulna University of Engineering & Technology (KUET). From each location, three samples of greywater were collected. Various sources of greywater, such as basins, bathrooms, kitchens, and water used for washing clothes, were identified by separating individual activities. Kitchen water was obtained from pipes and drains, while other sources were directly sampled.

The time gap between sample collection and filtration was consistently kept under three hours. In each case, five-litre water sample was collected, and one sample was filtered daily. Samples from a specific location underwent filtration for three consecutive days, followed by a four-day break before filtering the next location's samples.

3.1 Analysis of influent and effluent samples

Before and after filtration, samples were analysed to assess several greywater quality indicators (Patil et al., 2022). Following each sample collection, an analysis was conducted on the influent water, and after filtration, the effluent water underwent a similar assessment. This involved determining the values of specific parameters, such as pH, DO (Dissolved Oxygen), BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), TDS (Total Dissolved Solids), Conductivity, NO_3-N (Nitrate Nitrogen), PO_4-P (Phosphate Phosphorus), and SAR (Sodium Adsorption Ratio).

3.2 Filtration

In this study, a slow sand filter was constructed in a polyvinyl chloride (PVC) pipe using various filter media. The size of this container was 4” in diameter and 3’3” in height.

3.2.1 Filter media and their characteristics

Coconut husk, kushtia Sand, sylhet sand, charcoal, and stone chips were used as filter media. Coconut husk is a promising adsorbent that effectively extracts dye components (Patil et al., 2022). The sand bed is useful for eliminating phosphate (PO_4-P), chemical oxygen demand (COD), and biological oxygen demand (BOD)(Shaikh & Ahammed, 2021). When it comes to eliminating odor, volatile organic compounds (VOCs), and chlorine from water, charcoal works best *(Understand What*

*Activated Charcoal Is and How It Wor*ks, n.d.). Additionally, it can lessen the amount of oil, grease, and surfactants in water (Patil et al., 2022). Stone chips work as supporting media.

4. Filter installation

Table 1: Height of various filter layers used

Filter layer	Height
Free Space	4”
Coconut Husk	4”
Kushtia Sand	8”
Sylhet Sand	8”
Charcoal	5”
Stone Chips (passing 25 mm, retaining 19 mm)	3”
Stone Chips (passing 19 mm, retaining 4.75 mm)	7”

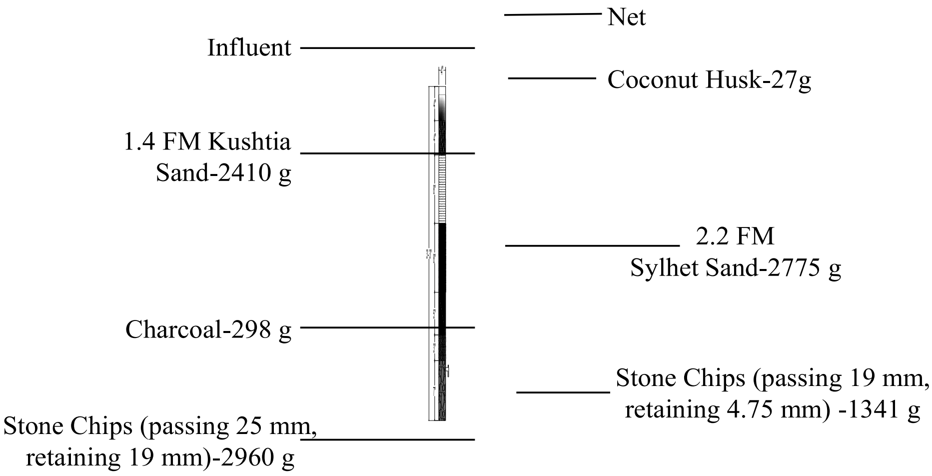


Figure 2: Schematic Diagram of Filter Media

Filter media were arranged one after the other in the PVC container from top to bottom according to the serial of Table 1 as shown in Figure 2. The filter height and width were decided based on many studies.

4.1.1 System functionality

After preparing filter beds PVC container was left open to the passage of water until each layer had stabilized. After that, the greywater was let to flow through the system.

5. RESULTS AND DISCUSSION

6. Characterization of influent and effluent greywater

Characterization of influent and effluent greywater was carried out for nine samples. An analysis was conducted on parameters such as pH, DO, BOD, COD, TDS, NO_3-N, PO_4-P, conductivity, and SAR. Table 2 delineates the characteristics of greywater samples both before and following the filtration procedure, while Table 3 outlines the standards for inland surface water. Reusing greywater in gardening and rooftop fish farms after the filtration process is justified by these criteria concerning irrigation water and water used in fisheries, respectively.

Table 2: Characteristics of greywater samples before and after the filtration process

Sample No	**1**		**2**		**3**		**4**		**5**		**6**	
Location	Rokeya Hall						Amar Ekushay Hall					
Type of Sample	Kitchen (washing Dishes)		Washing Clothes and Bathing		Kitchen (washing Vegetables and dishes) and using the basin		Kitchen (washing Vegetables and scaling fish)		Basin		Kitchen (scaling fish) and Bathing	
Before(B)/ After(A)	B	A	B	A	B	A	B	A	B	A	B	A
pH	6.45	7.51	7.9	7.6	6.3	7.2	7.8	7.5	6.9	7.2	8.3	7.3
DO(mg/L)	1.65	6.74	3.2	7.6	2.7	6.9	3.1	7	3.9	7.4	1.9	5.8
BOD(mg/L)	11.67	2.04	13.2	2.5	15.6	3	13.5	3.5	16.2	5.3	12.9	3.4
COD(mg/L)	820	280	1137	468	1213	327	800	295	632	258	922	517
TDS (mg/L)	4290	2200	4550	2140	4237	1998	5310	3002	4676	2722	4663	2781
NO_3-N (mg/L)	0.16	0.09	0.27	0.16	0.45	0.27	0.63	0.38	0.32	0.20	0.77	0.47
PO_4-P(mg/L)	0.07	0.02	0.16	0.06	0.20	0.06	0.09	0.03	0.06	0.02	0.15	0.09
Conductivity (mS/cm) at 25º C	3.45	1.44	3.92	1.68	3.75	1.71	4.28	2.04	3.97	1.93	4.04	1.87
SAR	68.76	29.71	70	31.33	45.06	23.64	65.58	37.38	52.13	25.91	79.06	33.81

Sample No	**7**		**8**		**9**	
Location	residential building					
Type of Sample	Kitchen(washing Vegetables and Dishes)		Washing Clothes and Bathing		Kitchen (washing) and bathing	
Before(B)/ After(A)	B	A	B	A	B	A
pH	6.6	7	7.5	7.36	7.6	7.2
DO(mg/L)	3.1	6.7	2.1	6.2	3.2	6.3
BOD(mg/L)	9.6	2.4	7.5	1.8	12.3	3.4
COD(mg/L)	956	441	1203	576	1191	590
TDS(mg/L)	4569	2314	4456	2912	5023	3595
NO_3-N(mg/L)	0.81	0.52	0.38	0.25	0.88	0.70
PO_4-P(mg/L)	0.11	0.07	0.24	0.16	0.14	0.09
Conductivity (mS/cm) at 25º C	4.30	1.81	4.20	1.78	4.60	2.34
SAR	55.13	28.65	57.89	26.20	75.56	34.83

Table 3: Inland Surface Water Standards

Pattern Type No	**Usage Patterns**	**pH**	**DO (mg/L)**	**BOD (mg/L)**	**COD (mg/L)**	**TDS (mg/L)**	**NO3-N(mg/L)**	**PO4-P(mg/L)**	**Conductivity mS/cm at 25º C**	**SAR**
P1	Irrigation Water	6.5-8.5	-	≤12	100	1000	5	2	2.25	<26
P2	Water used in fisheries	6-9	≥5	≤6	50	1000	7	0.5	-	-

(*Environmental Conservation Rules,* 2023, n.d.)

7. Efficiency of treatment system

Table 4 illustrates the effectiveness of the filter in eliminating specific parameters.

Table 4: Removing Efficiency of the filter

Parameters	% Removed
BOD	75.86
COD	57.81
TDS	43.62
NO_3-N	36.63
PO_4-P	52.98
Conductivity at 25° C	54.65
SAR	51.87

8. Comparison with standards

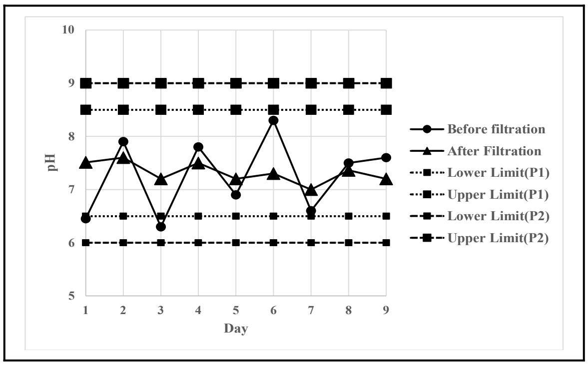


Figure 3: pH Level

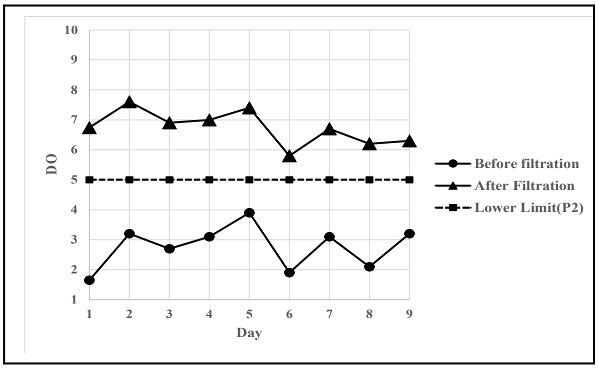


Figure 4: DO Level

Prior to the filtration process, certain samples exhibited pH levels beyond the acceptable range and all samples exhibited dissolved oxygen (DO) values below the expected threshold. Following filtration, however, all samples fell within the permissible limits for both pH and dissolved oxygen (DO) values.

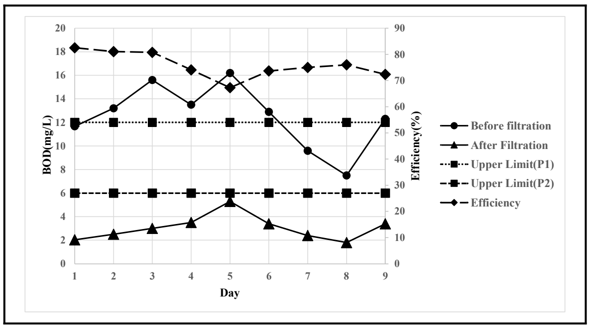


Figure 5: BOD Level

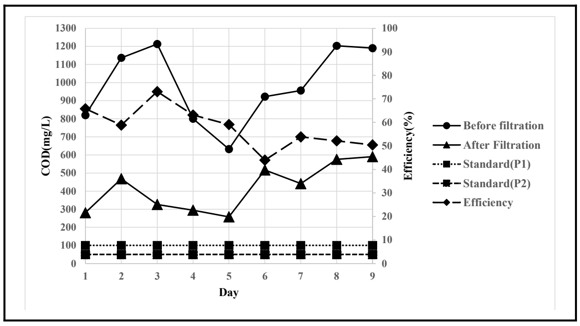


Figure 6: COD Level

The filter demonstrated sufficient efficacy in eliminating BOD from greywater samples. However, it did not exhibit adequate efficiency to attain the standard value for COD.

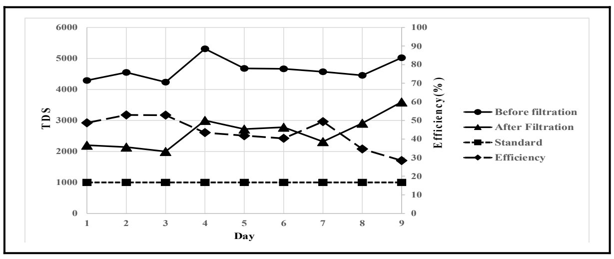


Figure 7: TDS Level

In terms of TDS removal, this filter did not show sufficient efficiency.

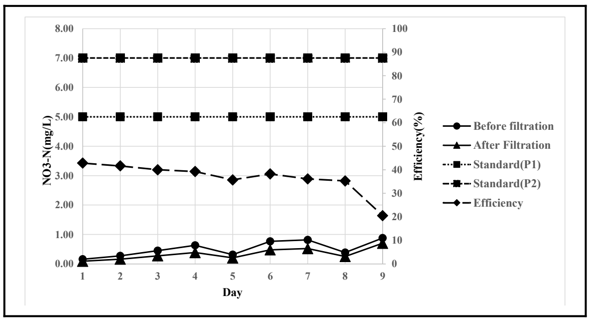


Figure 8: NO_3-N Level

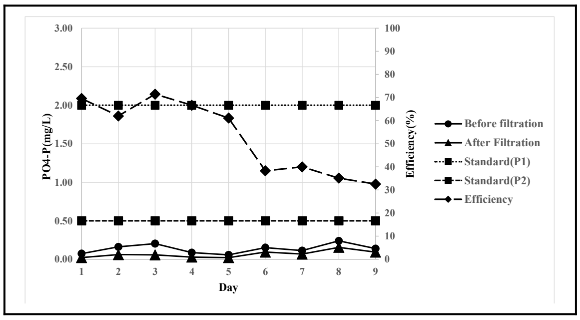
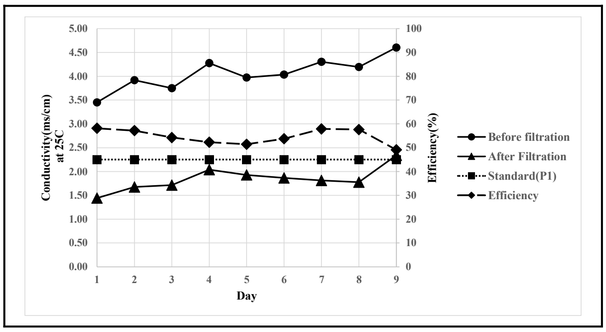


Figure 9: PO_4-P Level

The filter proved to be sufficiently effective in removing both NO_3-N and PO_4-P from the incoming influents. But here all collected greywater samples showed NO_3-N values below the standard value prior to the filtration process.



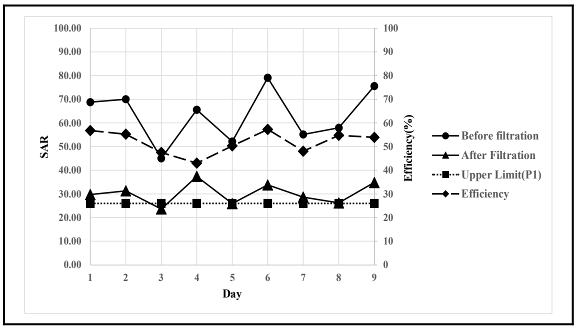


Figure 10: Conductivity Level

Figure 11: SAR Level

In the context of gardening, the significance of conductivity and SAR values is notable. While the filter demonstrated sufficient efficiency in reducing conductivity to meet the specified limit, it exhibited shortcomings in adequately lowering the SAR value.

9. CONCLUSIONS

This study clearly demonstrates the practicality of utilizing a slow sand filter unit for the treatment of domestically generated greywater. Moreover, it was found to be cost-effective. Regarding the reuse of treated greywater in gardening and rooftop fish farms, parameters such as pH, DO, BOD, NO_3-N, PO_4-P, and conductivity can be effectively managed using this type of slow sand filter. However, for reducing COD, TDS, and SAR to acceptable levels, additional treatment processes are required to ensure suitability for reusing purposes. Another potential solution in this context could involve diluting greywater by combining it with storm water.

However, in real-life scenarios, residents in a particular area might express interest in on-site greywater recycling through a slow sand filter. Subsequently, the consulted service provider would utilize this study as a pilot model, carrying out tests on a larger scale with increased samples and an extended time frame to determine efficiency on a broader scale and take subsequent actions.

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