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Assessment of Reuse Potential of Grey Water Using On-site Treatment Processes

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Abstract

Use of fresh water for purposes except for drinking can be minimized by the reuse of grey water produced regularly. Water coming from domestic equipment other than toilets (e.g., bathtubs, showers, washbasins, sinks, washing machines) is defined as grey water. The research is intended to assess the potential of reusing grey water from washbasins for gardening purposes. Samples of wash basin water were collected from a hall of BUET and a residential home. Hence, the samples had variation in sources including age and gender. Collected samples were then tested for 13 water quality parameters including pH, turbidity, TDS, EC, BOD, COD, fecal coliform etc. for understanding the quality of the grey water generated and its' variability and effect on reusability. Multiple parameters had concentration above the limit set by ECR'1997. Therefore, different treatment scenarios were adopted to meet the regulatory limit. The scenarios consist of sedimentation and filtration. All the methods reduced turbidity, BOD, COD and total solids to a significant amount and brought the concentration of these parameters within standards. However, the treatment schemes failed to reduce microorganisms to the required standard. The research outcome thus aims in achieving SDG-6 by increasing water use efficiency through reuse.

Keywords: *Grey Water; Sedimentation; Filtration; Reuse*

1 Introduction

About 41% of the population of Bangladesh does not have access to a safely managed source of water. According to Bangladesh National Building Code (BNBC 2020), water consumption for domestic purposes in residential buildings varies from 40 lpcd for slum dwellers up to 260 lpcd for single families. Water use in the domestic and industrial sectors is anticipated to increase by 100% and 440% by 2030 and 2050, respectively (Kirby et al., 2017). A statistical analysis showed significant decreasing trend (of 7.79 mm/year) in annual rainfall across Bangladesh (Rahman & Abd, 2022). So, water reuse and recycling are necessary for conservation of water resources, environmental protection, economic benefits, drought mitigation and climate change adaptation (Misra, 2014).
Wastewater can be divided into two groups: grey water and black water. Grey water is non-industrial wastewater produced by residential activities such as dishwashing, laundry, showering, and bathing (Eze et al., 2015). It typically contains fewer pathogens and pollutants and 90% less nitrogen than toilet water (Madungwe & Sakuringwa, 2007). This makes it a potential resource for water conservation and sustainability efforts. The volume of grey water produced in household accounts for 55% to 65% of total wastewater production (Halalsheh et al., 2008). It can be treated on site or off site for non-potable uses such as farming, gardening, compaction of soil, car washing, building and industrial activities like cooling boilers and other equipment (Funamizu et al. 2001). In residential structures, treated grey water reuse could reduce overall water use by 40 to 47% (Pidou et al., 2007). Grey water reuse systems may also be an important input to non-potable water supply when combined with other alternative water sources like rainwater harvesting due to their constant availability (Santos et al., 2012).

Very few studies are conducted on grey water reuse possibility in Bangladesh. The related studies either focused on specific treatment mechanisms or the methodology could not be regarded as cost effective. Also, most of the studies on grey water reuse did not provide relative comparison among different treatment schemes to figure out the best one. Our study focuses on analyzing the possibility of the implementation of various treatment options. Variation in characteristics of samples is ensured by production from variety of users. The methods are expected to require a minimum level of resources and expenditure. So it should be easy to operate and maintain within limited scopes. Thus, the outcome of the study would be much helpful in rendering a sustainable solution to the water scarcity problem while focusing the limited resources in underdeveloped or developing countries.

2 Methodology

The first set of samples was collected from the wash basin of Ahsan Ullah Hall and a residential home designated as AUH-1 and Home-1 respectively. The next batch was collected after 2 weeks designated as AUH-2 and Home-2. The wash basins were equipped with bendable magic pipes. It allowed the used water to flow directly into the 5-liter buckets placed under the sinks for sample collection. The concentration of 13 water quality parameters were tested including pH, color, turbidity, Dissolved Oxygen (DO), Total Solids (TS), Total Dissolved Solids (TDS), Electrical Conductivity (EC), alkalinity, hardness, BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand), Total Coliform (TC), Fecal Coliform (FC) and nutrients such as Phosphate (PO_4). Organic matters and nutrients are present in considerable amounts in grey water. These parameters provide information about the overall organic content and pollution load, helping assess treatment requirements. By analyzing these parameters, effective treatment systems can be designed and safe management of grey water can be ensured.

2.1 Sedimentation

19 liters of untreated grey water was kept in a bucket of 20-Liter capacity for sedimentation purposes. Turbidity was measured at 10 minutes interval to ensure settlement of sediments at the bottom of the bucket. After sedimentation, the top scum layer of the water was removed. The comparatively clear 13-liter water was separated. All the sediments settled at the bottom were discarded.

2.2 Filtration

Sylhet coarse sand passing No. 20 sieve and retaining on No. 40 sieve was selected as the filter material. A filter column with a diameter of 7 cm was prepared. The sand was poured into the column to a depth of 20 cm. Bacterial removal is not affected by the filtration rates. Higher filtration rates have a greater negative impact on turbidity and color removal efficiency. The grey water collected after sedimentation was pumped into the filter column at a steady rate to allow the water to percolate through the sand bed. The filtration rate was set at 4 m^3/m^2/day. The filtrated water was then collected at the outlet of the filter column.

Three sequential treatment schemes were followed.

- Scheme 1: Sedimentation for 1 hour (Sedi_1 Hr)
- Scheme 2: Sedimentation for 3 hours (Sedi_3 Hr)
- Scheme 3: Sedimentation + Filtration (Sedi_Fil)

This helped to determine removal efficiencies of different treatment approaches used. After performing treatment schemes, water quality parameters were tested for treated grey water. Parameter values before and after treatment were compared to ECR standards. Thus, further reuse potential was analyzed. The treated grey water is intended for gardening at the BUET campus.

3 Results and Discussions

3.1 Characteristics of Grey Water

Turbidity was in the range of 31.2 to 237 NTU. Suspended particles like clay, sediments and organic matter present in grey water can be indicated by high turbidity. The sample from Ahsan Ullah Hall had the highest BOD concentration of 200.2 mg/L. It also exceeded the limit set by ECR'97. This indicates that the water needs treatment to conform to the standards. BOD concentrations revealed that grey waters collected from both halls and home had similar biodegradable contents as they did not vary significantly. The variability in the non-biodegradable proportion was much larger as the COD values had more fluctuation from various sources. COD was 350 mg/L as the lowest in a raw sample from the hall, whereas it was 671 mg/L in the residential home. This indicates a range of concentrations equivalent to a low to medium grade wastewater (Jefferson et al., 2004). COD's dominance over BOD can be attributed to the presence of XOCs. These are synthetic organic compounds found in home chemicals such as bleaches, surfactants, softeners, and beauty products (Fatta-Kassinos et al., 2011). BOD_5/COD ratios lie in the range of 0.14 to 0.57, indicating that about half of the living organisms in grey water are biodegradable. One sample from home contained 211 mg/L of Total Suspended Solids. It exceeds the ECR standard as well, indicating the need for physical treatment. High value of EC and TSS can be caused by faulty or outdated plumbing and pipe systems (Boyjoo et al., 2013).

Table 1. Parameter Concentration of Samples

Parameters	**AUH-1**	**AUH-2**	**Home-1**	**Home-2**	**Bangladesh standard for discharge on land for irrigation (ECR'97)**	**Bangladesh standard for discharge of surface water for irrigation (ECR'23)**
pH	7.15	6.25	7.46	6.86	6-9	6.5-8.5
Color (PtCo)	41	55	174	79		
Turbidity (NTU)	237	71.2	217	31.2		
EC (µS/cm)	717	451	462	461	1200	
DO (mg/L)	4.90	0.24	2.6	0.25	4.5-8	
PO_4 (mg/L)	0.7	1.12	0.77	0.27		2
COD (mg/L)	350	374	671	469	400	100
Alkalinity (mg/L as CaCO3)	322	184	250	226		
Hardness (mg/L as CaCO3)	262	140	132	136		
TS (mg/L)	613	497	560	352		
TDS (mg/L)	467	330	349	325	2100	1000
TSS (mg/L)	146	167	211	27	200	
BOD (mg/L)	200.2	61.4	192.2	65.4	100	<=12

3.2 Treatment Outcomes

Three treatment schemes involving sedimentation and filtration processes were performed in the study. After each step in each of the schemes, specific parameters were tested. The outcomes of the schemes were analyzed for the purpose of comparison among them. The removal efficiencies of each of the schemes' parameters and extent of resources, expenditure, time and steps to reach those efficiencies were also focused on comparing them.

The main objective of the 1-hour sedimentation scheme is to compare with the results of 3-hour sedimentation and thus to decide about the sufficiency of brief time sedimentation to save time, resources and expenses as well. The scheme removed turbidity of the raw grey water significantly to the usual range according to the finding of (Khatun et al., 2011). Though the solids concentrations and BOD are found to have lower removal efficiency following this scheme, it is not of much concern as these parameters are well below the standards for irrigation. However, other treatment schemes might have higher removal efficiency. It simply overturns the idea of using this scheme as it may fail if sample grey water contains higher initial solids and organic loads. All the mentioned parameters were not removed to a higher extent even by 3-hour sedimentation. Besides, concentrations of total coliform and fecal coliform were much higher than the allowable standard values which indicate the necessity of further treatment process to be followed. Sedimentation alone could not lower these microbial contaminants. Next, filtration was performed to reduce these microbial pollutants up to acceptable levels and increase the removal efficiency of other parameters. Parameters like turbidity, COD, BOD and solids are highly removed by the filtration process. However, Total Coliform (TC) and Fecal Coliform (FC) concentration do not follow the guideline in any of the schemes. Therefore, further treatment is necessity after filtration to decrease TC and FC concentrations significantly.

To choose among these schemes for the purpose of treatment of raw grey water, removal efficiencies of the schemes were analyzed for comparison.

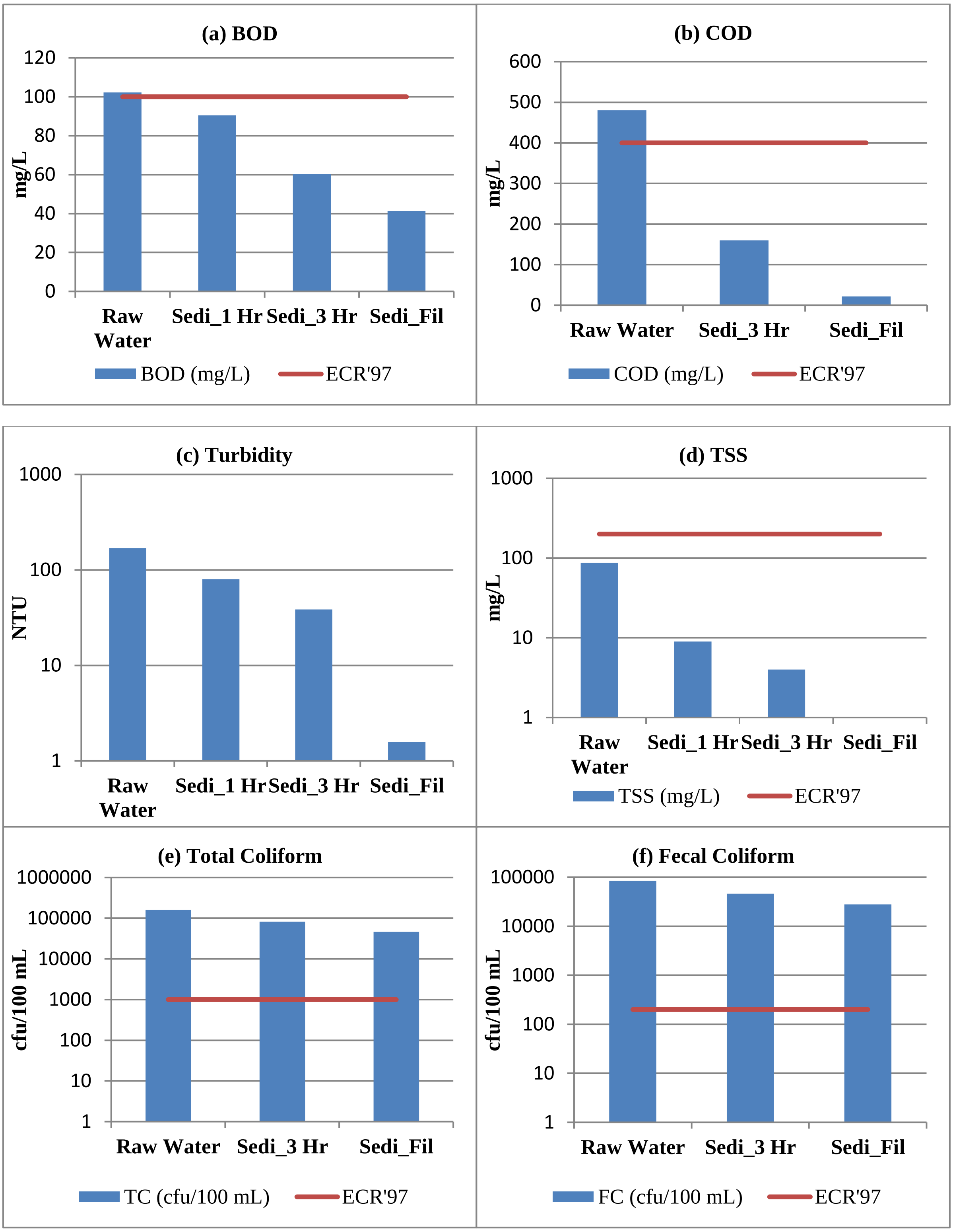

Figure 5 Variation of (a) BOD, (b) COD, (c) Turbidity, (d) TSS, (e) TC, (f) FC due to various treatment schemes

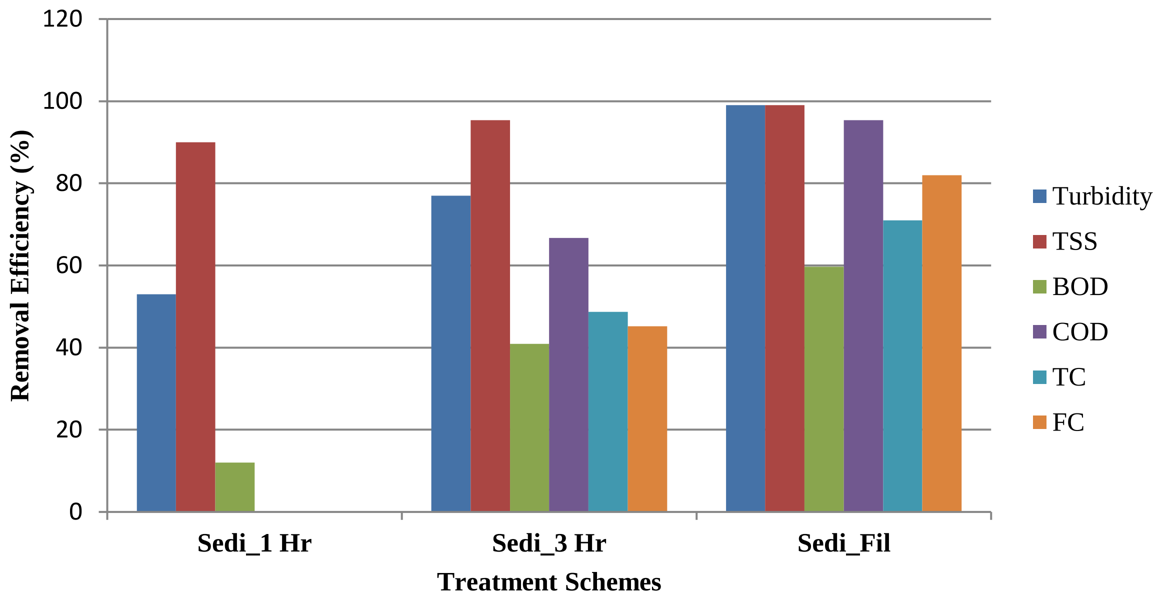

Figure 6 Removal Efficiencies of Treatment Schemes

While considering cost, sedimentation is a preferable method for treatment. But it fails in achieving higher removal efficiency of parameters than in combination with filtration. Resources utilized in all the treatment schemes were easily available. For sedimentation, only container of sufficient volume is required. For filtration, the special requirement was the coarse Sylhet sand. However, the processing of the sand to convert to required size by sieving required much labor work. The filter used in the filtration process was availed from the laboratory which might require production in abundance for vast application. Operation and maintenance of sedimentation is much easier. Some skill is required in filtration process, in operating variable flow rates, in cleaning filter media. However, in continuous operation on-site, this might not be an issue. Removal of contaminants to an acceptable level is the major concern in choosing the most suitable treatment option. This is because all the other criteria like cost, ease of operation and maintenance and availability of resources are mostly fulfilled by all the treatment schemes. Since in terms of achieving ECR’97 standards for irrigation for all the parameters, sedimentation + filtration was proved to be more successful than sedimentation alone, the scheme can be proposed for the purpose of treatment of our collected grey water sample when selected in between only these schemes. However, further treatment process to reduce TC and FC to acceptable levels is required after filtration process. In this case, solar disinfection can be a suitable option which is not only cost effective but also requires easily available resources as well as can be operated and maintained at ease (Disha et al., 2020)

4 Conclusions and Recommendations

Small variation of grey water characteristics is seen in terms of source. The water sample from a home showed higher concentration of color, COD and TSS compared to the halls. The quality of grey water originated from wash basins is like those observed in previous studies on grey water characteristics, reuse, and treatment. It indicates that it has high reuse potential. Multiple water quality parameters such as DO, BOD, COD, TC and FC of grey water from wash basins exceed the limit set the ECR’97 for discharge on irrigation land. So, it cannot be used directly for gardening purposes. It should be treated to some extent. Different water treatment methodologies were assessed. All three treatment schemes resulted in high removal efficiency of COD, BOD and TSS respectively. However, the method of sedimentation + filtration was a more feasible scheme in terms of removal efficiency than sedimentation. According to the outcome of the research, grey water collection and treatment of it to reuse can feasibly work as a solution to water scarcity problem in Bangladesh as well as worldwide.

However, there were some limitations of sample collection scope, manual processes, scarcity of workforce and resources to accurately determine grey water volume and flow rates, absence of practical model of the treatment schemes etc. There are no direct standards available for assessing the quality of grey water to be reused in Bangladesh. The latest update of ECR in 2023 was not followed in the study where there might be some discrepancies of ECR’97 with that of ECR’2023. It is recommended to increase the number of samples and duration of sampling, as it can represent the seasonal variation of grey water characteristics with much more clarity.

ECR'2023 should be followed in further studies for characterization and targeting for treatment. Most importantly, a more efficient treatment method should be applied to reduce important parameters like TC and FC to concentrations much below the standards which were not achieved in the study. Besides, pipe layouts should be installed in a household to separate grey water from black water. In addition, flow meter and electric sensors can be used to measure the quantity of grey water produced per day. Economic analysis can be conducted to determine actual amount of water that can be recycled and reused to eventually solve the issue of water crisis in Bangladesh. Further study on structural models for integrating these treatment schemes into every household for onsite treatment is recommended.

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