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DEVELOPMENT OF A SUITABLE TREATMENT OPTION FOR POTENTIAL REUSE OF DOMESTIC GREY WATER

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ABSTRACT

With increasing pressures on water resources, the concept of beneficial use of grey water has rapidly become an imperative for water agencies around the world. The principal focus of this study was to investigate the characteristics of domestic grey water and to develop a simple treatment unit for potential reuse of domestic grey water. For this purpose four types of samples, namely- basin water, bathroom water, kitchen water and mixed grey water, collected from Rokeya Hall, KUET in Khulna of Bangladesh, were analyzed for different water quality parameters. The water quality parameters of considered four types of grey water exceeded the standard value of wastewater. A filter was constructed for treatment purpose which involves low-cost filtration process. Using the simple treatment process, the removal efficiency of Color, Turbidity, BOD_5, COD, TDS and TSS were upto 86.78, 95.67, 83.21, 80.26, 19 and 76.67% respectively for considered four types of grey water. The concentration of $SO4^{2-}$ slightly increased after filtration but within the standard value. This increment may be occurred due to supply water was used for cleaning of filter material which contains a high concentration of Sulphate instead of distilled water. By improving the efficiency of domestic grey water treatment unit, the scope of reuse of grey water can be increased.

Keywords: *Grey water, Characteristics, Treatment, Reuse*

1. INTRODUCTION

Water is a vital resource but severely limited in most countries. The population growth has not only increased the fresh water demand but also the volume of wastewater generated. Bangladesh is a South Asian Country having more than 150 million people. During wet season water is available in almost everywhere. But during the dry season water is scarce in most of the area in Bangladesh. Sometimes cultivation is hampered due to scarcity of water. Moreover the groundwater table is undergoing day by day due to very frequent use of groundwater. With increasing pressures on water resources, the concept of beneficial use of treated wastewater has rapidly become an imperative for water agencies around the world. Water reclamation, recycling and reuse are now recognized as key components of water and wastewater management. As long as the problem is about the scarcity of water and no new sources can be developed in Bangladesh without the traditional underground water, surface water and some other sources of potable water, the only choice remain is to reuse the household water, which in environmental science is named as 'Grey water'. Grey water is all wastewater that is discharged from a house, excluding black water or toilet water. Grey water gets its name from its cloudy appearance and from its status as being neither fresh (white water from ground water or potable water) nor heavily polluted (black water). It includes the water from bathtubs, showers, hand basins, laundry, floor wastes, kitchen sinks, dishwashers and washing machines (Ahmed et al., 2001). It commonly contains soap, shampoo, and toothpaste, food scraps, cooking oils, detergents and hair. Grey water makes up the largest proportion of the total wastewater flow from households in terms of volume. Typically, 50-80% of the household wastewater is grey water. If a composting toilet is used, then 100% of the household wastewater is grey water.

Grey water has a relatively low nutrient and pathogenic content and it is less polluted than other types of wastewater. Therefore, it can be easily treated to high-quality water using simple technologies such as sand/gravel filters. With grey water recycling, it is possible to reduce the amounts of fresh water consumption as well as wastewater production, in addition to reducing the water bills. If grey water is regarded as an additional water source, an increased supply for irrigation water can be ensured which will in turn lead to an increase in agricultural productivity. Non-potable reuse applications include industrial, irrigation, toilet flushing and laundry washing dependent on the technologies utilized in the treatment process.

Grey water can be used untreated, or it can be treated to varying degree to reduce nutrients and disease-causing microorganisms. The appropriate uses of grey water depend on both the source of grey water and the level of treatment (Ahmed et al., 2001). So grey water is considered to be the largest potential source of water reuse option at point source and it can satisfy most water demands as long as it is adequately treated to ensure water quality appropriate for the use.

The main objectives of this study are:

- To investigate the characteristics of domestic grey water.
- To develop an approach for treatment of domestic grey water.
- To evaluate the treated domestic grey water for potential reuse.

2. METHODOLOGY

The methodology of the study is showing below as a flow chart in Figure 1.

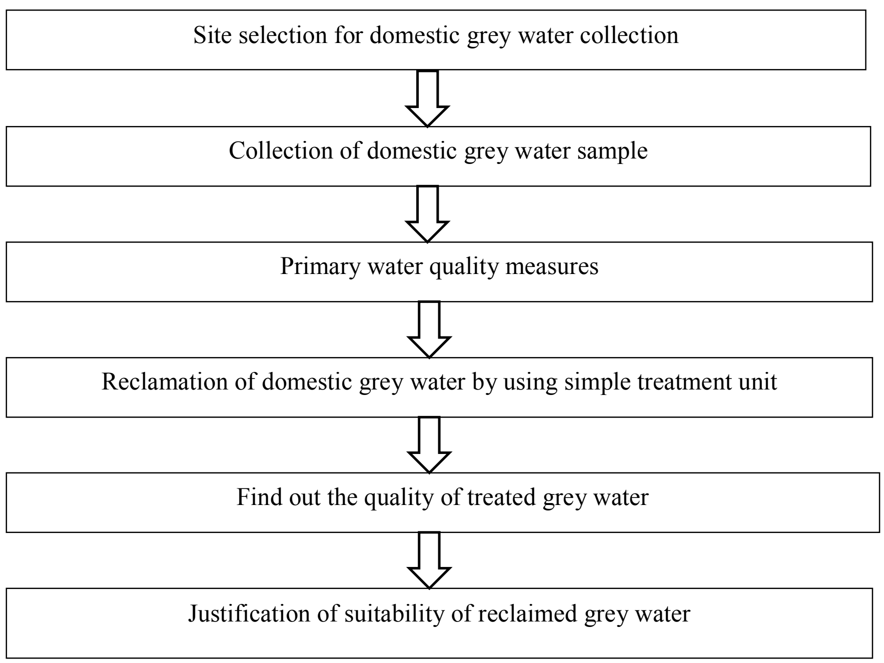

Figure 1: Functional steps of the study

2.1 Sample Collection

Inlet water or supply water and outlet water or grey water samples were collected in plastic bottles from Rokeya Hall, KUET, Khulna. Four types of grey water samples such as basin, bathroom, kitchen and mixed grey water samples were collected.

2.2 Laboratory Testing

After collecting the samples, they were brought to the Environmental Engineering laboratory in the Khulna University of Engineering and Technology. Different Laboratory tests were performed to determine the water quality parameters present in the domestic grey water.

2.2 Development of Simple and Suitable Grey Water Treatment Unit

In this study the filter was constructed with three major components such as roughing filter, wood coal and sand filter. The turbidity of the collected grey water samples was very high. So roughing filter was used as pre-treatment of grey water.

Roughing filter consists of brick khoa in two different layers of two different sizes. Sieving was done to find out the required sizes of brick khoa. At the top of the roughing filter 4 inch thick brick khoa layer of size 0. 5 to 0.75 inch was placed and then 3 inch thick brick khoa layer of size 3/8 inch to 0.5 inch was placed. So the total thickness of the filter material in the roughing filter was 7 inches. The sand filter consists of sylhet sand and local sand as filter material. The thickness of the sylhet sand was 5 inch and the thickness of the local sand was 8 inch. So the total thickness of the sand layer was 13 inch. Wood coal was used over sand filter and the thickness of the wood coal was 3 inch. The thickness of the filter material in the filter is shown in table 1.

Table 1: Thickness of aggregate layers

Aggregates	Aggregate size	Thickness of the layer
Brick khoa	0.75 inch to 0.5 inch	4 inch
	0.5 inch to 3/8 inch	3 inch
Wood coal	-	3 inch
Sand (sylhet)	-	5 inch
Sand (local)	-	8 inch

The filter materials such as brick khoa, wood coal, sylhet sand and local sand were cleaned properly by supply water and then the materials were dried in the oven. Then the materials were placed in the filter. Collected grey water samples were passed through the filter. Down flow water collection system was applied. At the bottom of the filter 0.5 inch hole was drilled for outgoing filtered water and thin clean cloth was used below the hole. No power was used for the flow generation. Gravity flow pattern was used in this system. Caution was taken to avoid clogging of the filter material. The practical view of the developed domestic grey water treatment unit is shown in figure 2.

Figure 2: Practical view of the developed domestic grey water treatment unit.

3. ILLUSTRATIONS

3.1 Water Quality Analysis of the Sample Grey Water and Treated Grey Water

The collection of raw grey water was done and brought to laboratory. The raw grey water was treated by developed the simple wastewater treatment unit. The water quality parameters of the raw grey water and the treated water were tested to study the performance of the treatment unit and to judge the suitability of the treated wastewater for further reuse. The samples were not reserved but tested as soon as possible to get better results.

The performance of the developed grey water treatment unit was studied in the laboratory with regard to different physical (p^H, color, turbidity, TDS), chemical (sulphate) and biological (BOD_5, COD) water quality parameters.

3.2 Discussion on Test Results

The results obtained from different tests performed to find out different parameters of grey water collected from different sources of grey water in the Rokeya Hall, KUET; to evaluate characteristics of grey water is described in Table 2 and Table 3.

Table 2: Different water quality parameters of domestic grey water before and after treatment (Basin water and Bath water).

Parameters	Grey Water					
	Basin			Bath		
	Waste water	Treated water	Removal Efficiency	Waste water	Treated water	Removal Efficiency
p^H	7.81	7.30	6.53%	8.1	7.64	5.68%
Color (Pt.Co)	288	92	68.06%	287	86	70.03%
Turbidity (NTU)	48.3	15	68.94%	52	12.3	76.35%
BOD_5 (mg/l)	93	36.6	60.65%	125	21	83.21%
COD Test (mg/l)	320	188	41.25%	640	316	50.63%
Total Dissolved Solids (mg/l)	3220	2650	17.70%	3830	3260	14.88%
Total Suspended Solids (mg/l)	210	117	44.29%	210	106	49.52%
$SO4^{2-}$ Test (mg/l)	65	94	-	63	89	-

Table 3: Different water quality parameters of domestic grey water before and after treatment (Kitchen water and Mixed grey water).

Parameters	Grey Water					
	Kitchen			Mixed		
	Waste water	Treated water	Removal Efficiency	Waste water	Treated water	Removal Efficiency
pH	6.3	7.29	-	7.13	7.40	-
Color (Pt.Co)	2450	324	86.78%	410	112	72.68%
Turbidity (NTU)	393	17	95.67%	64	8.44	86.81%
BOD_5 (mg/l)	370.2	272.2	26.47%	206.4	54.6	73.55%
COD Test (mg/l)	2046	448	78.10%	1135	224	80.26%
Total Dissolved Solids (mg/l)	3590	2990	16.71%	3750	3037	19%
Total Suspended Solids (mg/l)	1200	280	76.67%	240	115	52.08%
$SO4^{2-}$ Test (mg/l)	76	105	-	60	78	-

3.3 Guideline Values

For the purpose of successful implementation of grey water recycling different countries of the world have already started the quantification and characterization of grey water. In most countries guidelines and standards either do not exist or are being revised or expanded. The following are the guideline values of water in the agricultural sector and potable water:

Table 4: Guideline values of grey water parameters in the agricultural sector and potable water.

Parameters	**Agricultural Sector**	**Potable Water**	
	Maximum Permitted Values	**Bangladesh Standard (ECR,1997)**	**WHO Guideline Values,2004**
p^H	6.5-8.5	6.5-8.5	6.5-8.5
BOD_5(mg/l)	120	0.2	-
COD(mg/l)	200	4	-
TSS(mg/l)	120	10	-
TDS(mg/l)	13400	1000	1000
Color (Pt.Co)	-	15	15
Turbidity (NTU)	-	10	5

(Source: M.Platzer et al 2004)

3.4 Graphical Representation of Results

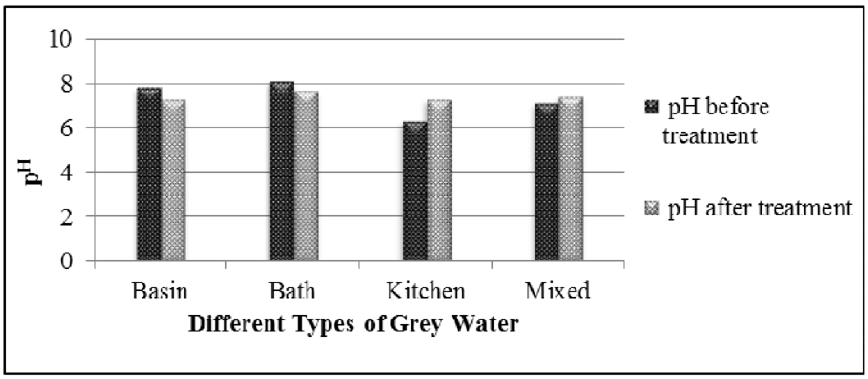

Figure 3: p^H values of grey water before and after treatment.

Figure 3 shows the variation of p^H of grey water before and after treatment. After Analyzing it has been seen that p^H of different types of grey water has the range of 6.3 to 8.1. The value of p^H of kitchen water was 6.3 which was the most acidic, as organic acids are produced from food. The highest p^H value of 8.1 obtained from bathroom water which was slightly basic due to the presence of soaps and detergents. The value of p^H of different types of grey water were slightly changed after filtration. The p^H of basin and bath water slightly decreased and the p^H of kitchen and mixed grey water slightly increased after filtering in the sand filter. The cause behind this phenomenon may be the sand filter contained some alkaline substance that dissolved in the water and lead to slight increase in p^H value. After treatment the p^H value of kitchen grey water becomes 7.29. The ideal p^H level of potable water and standard for irrigation water is 6.5-8.5 (Bangladesh ECR, 1997; WHO, 2004). So the value of p^H of treated grey water samples were within the limit.

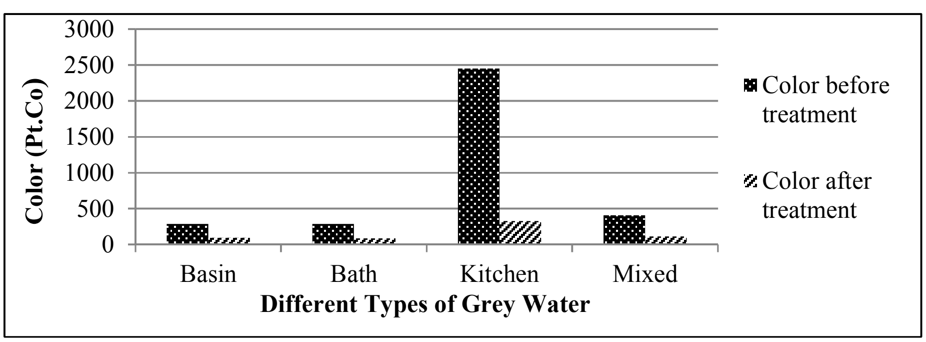

Figure 4: Color values of grey water before and after treatment.

Figure 4 shows the variation of color of grey water before and after treatment. After analyzing it has been seen that the highest color reading came from kitchen water as it contains organic matter derived from food. The lowest color was obtained from bathroom water which was due to the presence of dye, soap, detergent, shampoo etc. The color removal efficiency of basin, bathroom, kitchen and mixed grey water in the developed treatment unit were 68.06%, 70.03%, 86.78% and 72.68% respectively. The color was removed mostly in the roughing filter. There were several causes behind the color removal. These were the adsorption in the brick chips, reduction of the organic matter, reduction of dissolved solids and mechanical staining that remove colloidal particles and removed color. The standard value of color for potable water is 15 Pt.Co. The value of color of treated grey water samples were beyond this limit. So this water cannot be used for domestic purpose but it can be used for irrigation purpose.

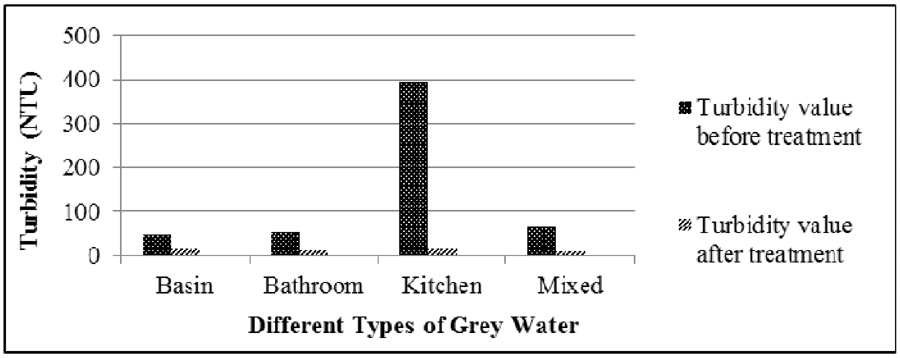

Figure 5: Turbidity of grey water before and after treatment.

Figure 5 shows the variation of turbidity of grey water before and after treatment. Grey water was highly turbid as it contained lots of suspended particles resulting from washing activities. After Analyzing it has been seen that turbidity was highest for kitchen water and lowest for basin water. After treatment, the turbidity removal efficiency of basin, bath, kitchen and mixed grey water were 68.94%, 76.35%, 95.67%, and 86.81% respectively. The guideline value of turbidity for potable water is 10 NTU (Bangladesh ECR, 1997) and 5 NTU (WHO, 2004) and the waste water standard of turbidity for irrigation is 50 NTU. The turbidity of the treated grey water samples were within irrigation standard but beyond the potable water standard. So this water can be used for irrigation purpose.

The roughing filter was intended as pretreatment for the reduction in turbidity and total suspended solid in the raw water because the turbidity of the grey water samples were very high. So it was necessary for the grey water samples to pass through the roughing filter before sand filtration. When the raw water pass through the pore of the filter, particles caused turbidity stacked and results significant reduction in turbidity. Also the reduction of the colloidal particles by the adsorption and electrostatic attraction also result in reduction of the turbidity.

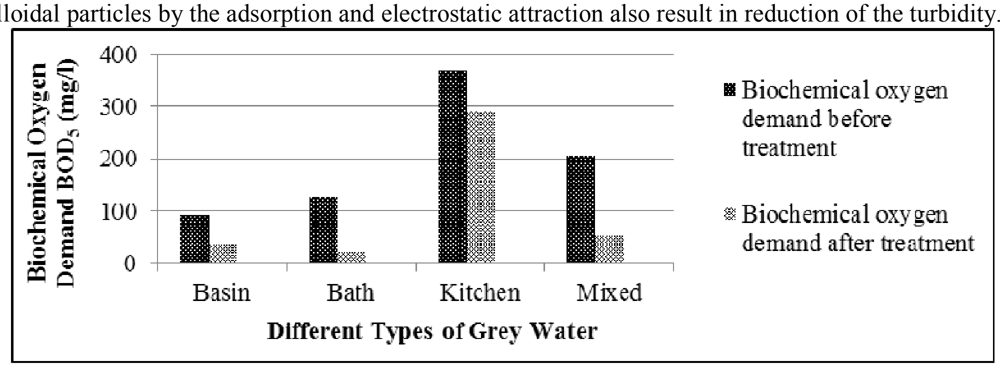

Figure 6: BOD_5 of grey water before and after treatment.

Figure 6 shows the variation of BOD_5 of grey water before and after treatment. After analyzing it has been seen that kitchen water has the highest value of BOD_5 of 370.2 mg/l than other sources of grey water as it consists organic matter from food. The BOD_5 removal efficiency in the developed treatment unit were 60.65%, 83.21%, 26.47% and 73.55% for basin, bath, kitchen and mixed grey water respectively. BOD_5 was removed significantly in roughing filtration layers as large chain of organic matter cannot pass through the small pores of aggregate and also adsorbed in the filter media. The curved flow path around grain brings the organic matter in contact with sand surfaces, where they adhere because of physical attraction and presence of gelatinous coating. The BOD_5 also reduced for lessening the amount of bacteria. The standard value of BOD_5 for potable water is 0.2 mg/l (Bangladesh ECR, 1997). BOD_5 guideline for wastewater discharged to irrigation land is 100mg/l (Bangladesh ECR, 1997, schedule-10). Again the maximum permitted value of BOD_5 of grey water for agricultural sector is 120 mg/l (Referred to Table 4). Eliminating the kitchen water other treated grey water can be reused for irrigation which were within the irrigation standard.

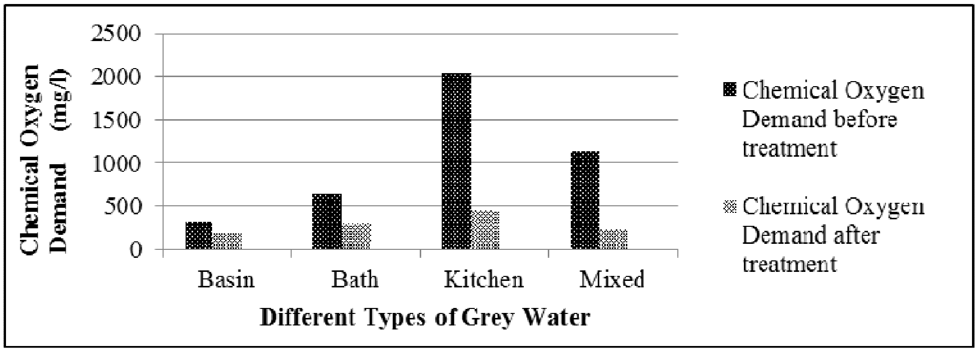

Figure 7: COD of grey water before and after treatment.

Figure 7 shows the variation of COD of grey water before and after treatment. After analyzing the raw grey water it has been seen that grey water has a high range of COD value. Kitchen water has the highest COD value (2046 mg/l) whereas basin water has the lowest (320mg/l). So reusing kitchen water would not be a good practice because of its high COD value and the grey water should be treated before reuse. Again COD values found are greater than BOD_5 values which concludes that biologically resistant organic matters are also present here. The COD removal efficiency of basin, bath, kitchen and mixed grey water in the developed treatment unit were 41.25%, 50.63%, 78.10% and 80.26% respectively. COD was removed significantly in roughing filtration layers as large chain of organic matter cannot pass through the pores of aggregate and also adsorbed in the filter media. The curved flow paths around grain bring the organic matter in contact with sand surfaces, where they adhere because of physical attraction and presence of gelatinous coating. The COD also reduced for lessening the amount of bacteria. Standard COD value for potable water is 4mg/l and wastewater standard of COD for irrigation land is 400mg/l (Bangladesh ECR, 1997). The maximum permitted value of COD of grey water for agricultural sector is 200 mg/l (Referred to Table 4). Except kitchen water others can be used for gardening, agriculture etc.

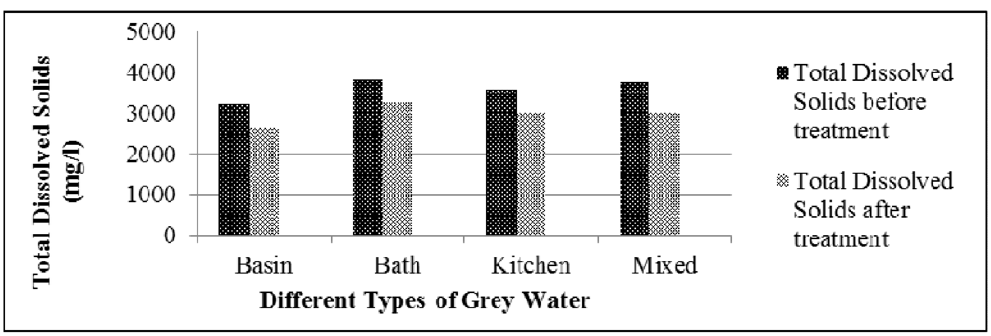

Figure 8: Total Dissolved Solids of grey water before and after treatment.

Figure 8 shows the variation of TDS of grey water before and after treatment. Analysis shows that water from bathroom has the highest TDS as it contains dissolved detergents and the lowest TDS value obtained from basin water. The TDS removal of basin, bath, kitchen and mixed grey water in the developed treatment unit were 17.70%, 14.88%, 16.71% and 19% respectively. The TDS value decreases slightly after treatment before decrease in concentration of chlorides and decreased electric conductivity .TDS was mostly removed by the sand filter media. The main cause behind this was the smaller grain size of the sand particle which creates larger surface area and smaller pore. The pores in the sand bed act as a minute sedimentation basin and curved flow paths around grains bring the fine particles and bacteria in contact with sand surfaces, where they adhere because of physical attraction and presence of gelatinous coating. The sticky gelatinous coating are formed on the sand grains by the previously deposited bacteria and colloidal materials. The standard value of TDS for potable water is 1000 mg/l and the guideline value of TDS for agricultural sector is 13400 mg/l. The TDS of the treated grey water samples are well below this irrigation guideline value.

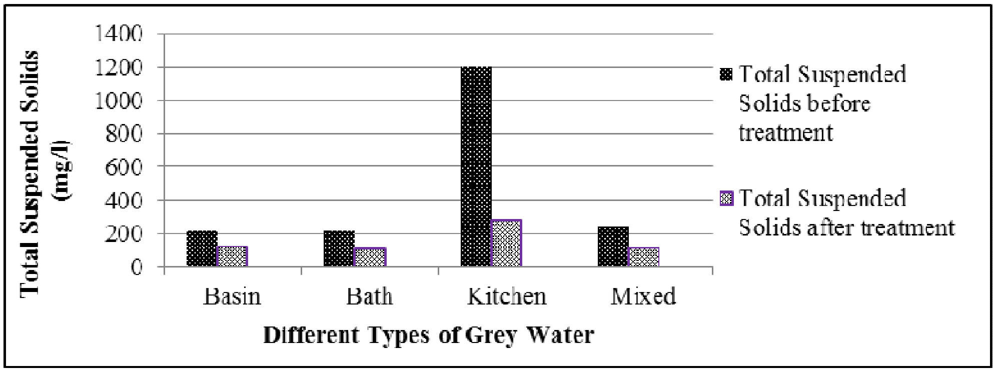

Figure 9: Total Suspended Solids of grey water before and after treatment

Figure 9 shows the variation of TSS of grey water before and after treatment. After analyzing the raw grey water it has been seen that Total suspended solid was higher in kitchen water as waste from food, vegetables, fishes etc was present there. The TSS removal of basin, bath, kitchen and mixed grey water in the developed treatment unit were 44.29%, 49.52%, 76.67% and 52.08% respectively. The TSS removal can be explained on the basis of mechanical straining action. The particles too large to pass through the interstices between the sand grains are retained by mechanical straining. It takes place exclusively in the top layer of the filter media. The accumulated material in the tip layer of the bed increases the straining efficiency but it also increases the resistance against the downward flow of water. The standard value of TSS for potable water is 10 mg/l and for irrigation purpose is 120 mg/l. The reclaimed water was almost within the permissible limit of irrigation except for kitchen water.

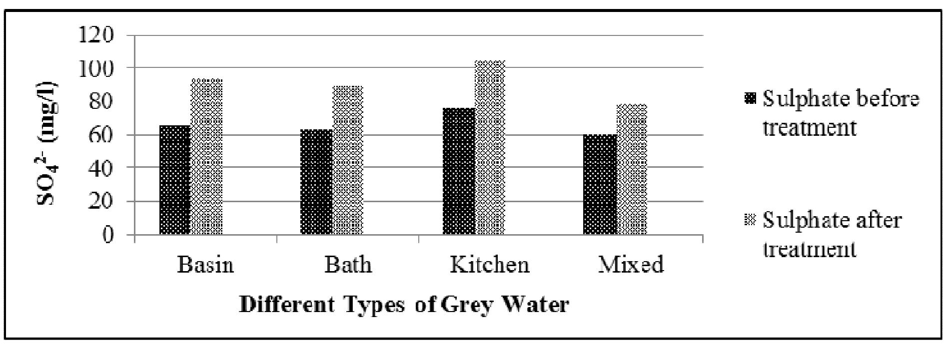

Figure 10: $SO_4^{2-}$of grey water before and after treatment

Figure 10 shows the variation of TSS of grey water before and after treatment**.** From the experimental results, the removal of sulphate by the developed treatment unit is not remarkable. The concentration of sulphate increased after treatment. It may be happened due to various reasons; i) The calibration of the spectrophotometer may not be done properly ii) instead of distilled water, supply water was used for cleaning of filter material which contain high concentration of sulphate. The standard value of sulphate for potable water is 400 mg/l . so the value of sulphate of treated grey water were within the limit.

4. CONCLUSIONS

In this study the water quality parameters of considered four types of grey water (basin, bath, kitchen and mixed) were analyzed. The quality of grey water varies from sample to sample and kitchen water was found to be very much polluted from the quality analysis. Using the simple filtration treatment process, the removal efficiency of Color, Turbidity, BOD5, COD, TDS and TSS were upto 86.78, 95.67, 83.21, 80.26, 19 and 76.67% respectively for considered four types of grey water. The efficiency of the filter could be improved by varying the sizes, ranges and proportions of the materials of the media and also, depth of the media. Comparing the quality of treated grey water samples with available standards of wastewater and grey water, the treated grey water samples were found to be satisfactory to reuse in irrigation except kitchen water. So reusing kitchen water would not be a good practice. Based on the above findings, it can be concluded that the recycling and reuse of treated domestic grey water would have promising application in the household gardening and agricultural uses after simple treatment without any hazard to human health and environment.

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