TREATMENT OF GREYWATER GENERATED AT KUET CAMPUS IN BANGLADESH

Samonty Das*[1], Kazi ABM Mohiuddin[1] and Easin Arafat[2]

[1] *Departmentof Civil Engineering, Khulna University of Engineering & Technology (KUET), Khulna-9203, Bangladesh. email: samontydas@yahoo.com*
[2]*Department of Civil Engineering, North Western University, Khulna, Bangladesh*

ABSTRACT

Greywater treatment potentially reduces the pollutant in the environment, promotes the preservation of high quality freshwater and minimizes overall supply cost. The principle focus of the study is to create an understandings of greywater characteristics as a resource and to demonstrate a low cost reuse option which satisfies the normal water standards for secondary uses such as in toilet flushing, domestic use, construction, Cars-washing and irrigation in KUET campus. KUET, a model semi-urban area, is situated in the North- west part of Khulna city in Bangladesh. To realize this field survey, greywater sampling and analysis and a water treatment unit installation were undertaken. The greywater generated in this area exhibited high Chloride (850-1000 mg/L), Hardness (740-1020 mg/L), COD (40-290 mg/L) values necessitating treatment prior to disposal in the environment. Using treatment process the removal efficiency of Chloride, Hardness, COD are found 33%, 74% and 91% respectively. Other parameters BOD, Color, P^H, Total Coliform (TC) and Conductivity within standard limit are also improved satisfactorily. The treated water is very clear with Turbidity value roughly 1.59 NTU. Greywater reuse in agriculture after the appropriate treatment will be a highly advantageous technique as greywater are rich in organic matter and nutrients. Based on above findings, it can be concluded that, the recycling and reuse of treated greywater may prove to be a practice since its quantity and quality is sufficient to meet the demand for non-potable purposes without causing any hazard to human health and environment.

Keywords: *Greywater; BOD; COD; Effluent quality.*

1. INTRODUCTION

Greywater is all wastewater generated in households or office buildings from streams without fecal contamination, i.e. all streams except for the wastewater from toilets. Sources of greywater include sinks, showers, baths, clothes washing or dish washers (US EPA, 2015). As greywater contains fewer pathogens than domestic wastewater, it is generally safer to handle and easier to treat and reuse onsite for toilet flushing, landscape or crop irrigation and other non-potable uses. Due to the scarcity of fresh water, balancing the supply and demand for fresh water has always been a great challenge. Reuse of wastewater minimizes demand for freshwater. Greywater reuse in many parts of the world, including both industrial and developing countries, has gained significance recently. There are several advantages of greywater treatment: Reuse of greywater, Lower freshwater use, Groundwater recharge, Greater quality of surface and ground water, Reclamation of wasted nutrients, Less impact from septic tank and treatment plant infrastructure, Increased awareness and sensitivity to natural cycles. Bangladesh is the ninth most populous country and twelfth most densely populated countries in the world. With this vast population, there is an increasing problem of water management. During wet season water is available everywhere. But in dry season water is scarce in most of the areas in Bangladesh. Sometimes cultivation is hampered due to scarcity of water. Moreover, the groundwater table is undergoing day by day due to frequent use of groundwater. According to the World Health Organization (WHO), between 50 and 100 litres of water per person per day are needed to ensure that most basic needs are met and few health concerns arise. Bangladesh, having more than 150 million people, use a huge quantity of water everyday. From a survey in KUET campus it has been found that, none is using greywater even for agriculture, lawn, roof-top or gardening. Thus it proves that, no reuse of greywater is being done. The total used greywater is being misused everyday and draining out to the waste water bodies which is a great loss of the natural resource as well as deterioration of the environment. Greywater recycling system includes collection, storage, treatment and reuse. Limited human and financial resources, reliability of wastewater treatment, economic feasibility of the system, public perception and willingness, social and institutional acceptance, sufficient and consistence codes and guidelines are some barriers which may obstruct the development of greywater recycling and reuse in Bangladesh. In Bangladesh, guidelines and standards for greywater reuse does not exist (The Financial Express, vol 20). Regulations and guidelines for greywater reuse mainly focus on the healthy and environmental impacts and are often established by local authorities. The specific objectives of this study are

- To determine the characteristics of greywater as a resource.
- To develop a low cost treatment process for greywater recycling.
- To assess the treated greywater for potential reuse in domestic purposes.
- To propose an environment friendly greywater reclamation technique in the context of Bangladesh.

2. MATERIALS AND METHODS

2.1 Sample location

The study was undertaken in Khulna University of Engineering & Technology (KUET) is at Fulbarigate, the northwest part of Khulna City (22°54'02.6"N 89°30'04.6"E) which is found in 1969.The university has a 101-acre campus with academic buildings, auditorium complex, residence halls, teachers dormitory and residences, laboratories, engineering workshops, administrative building, cafeteria, gymnasium and other facilities. It is divided into three functional zones: residential zone for students; residential zone for faculty and staff and academic buildings. This is because the amount and quality of greywater is different in those three different zones. Water is used during 24 hours in a day in the 6 residential halls of the students and the quality of greywater is same in all the 6 residential halls but is different from the residential zone for faculty and staff where there are 19 residential buildings in this zone and water is used for 24 hours a day. Water is used about 9 hours in a day in the 16 academic buildings of the academic building zone and the water that comes out of these buildings is only basin water. The location of the study area is shown below in Figure 1.

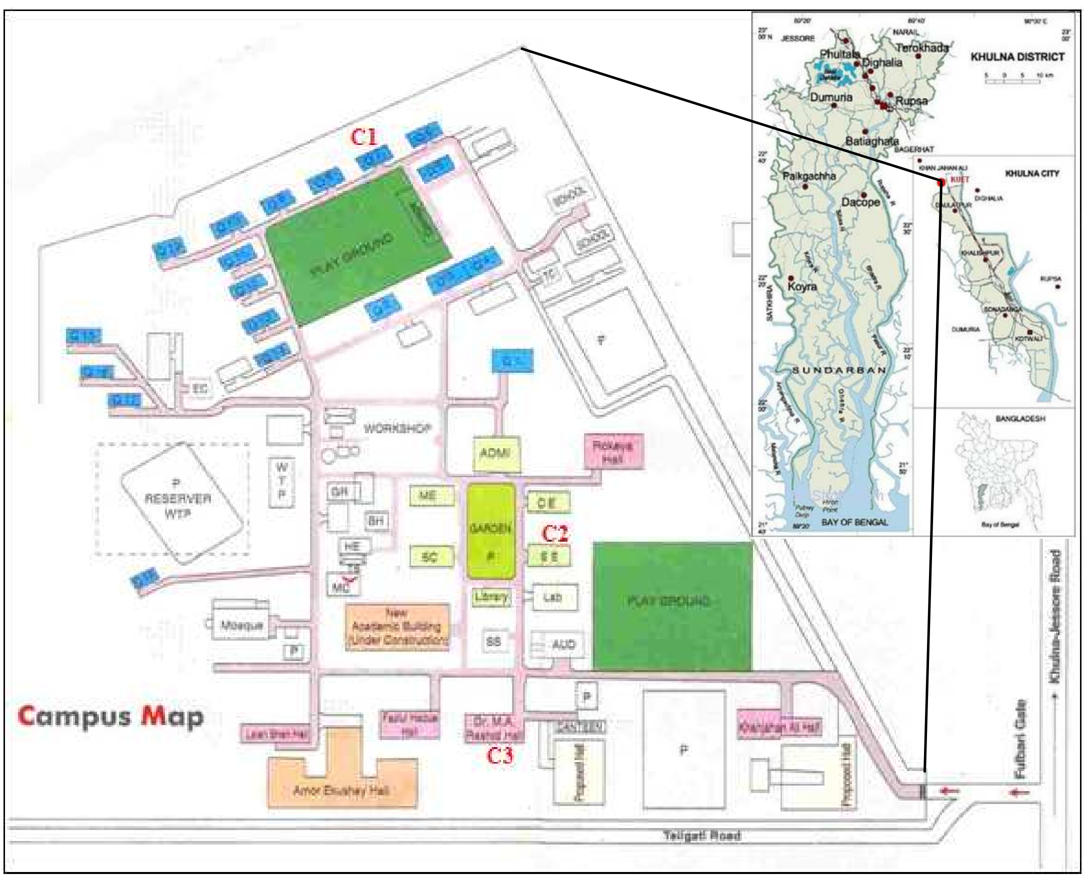


Figure 1: Location of the study area

This study is important because in KUET campus a huge amount of greywater is obtained daily from this area that can be utilized in the ongoing construction project, in irrigation purpose, in domestic use and so on which is a model of semi-urban area. This greywater can contribute to the local economy and can save a significant amount of underground water resource.

2.2 Greywater Characterization:

In order to characterize the total greywater in KUET campus greywater is collected in three point C1 (Drainage line of Quarter -5; Residential zone for faculty and staff), C2 (Drainage line of Civil Engineering; Academic building zone) and C3 (Drainage line of Rashid Hall; Residential zone for students). The collection points of greywater in KUET campus have shown in Figure 1. The parameter analysed (Table– 1) were chosen based on the existing law for irrigation, car washing, domestic use water quality. In each campaign 2 Liters of greywater which was well preserved and sent to laboratory for the analysis of these parameters. In each sample the following parameters were analyzed: DO, BOD_5, P^H, Chloride, Hardness, TDS, TSS, Color, Turbidity, COD, and Conductivity. Mixed water quality was found by mixing the greywater in ratio 2:2:1 (C1: C3: C2).

2.3 Development of Simple Water Treatment Unit:

The schematic diagram of the filtration unit is shown in Figure 2. The filtration unit consists of four major components. Filtration systems treat water by passing it through porous materials like brick chips to remove and retain contaminants. The sand filters coarse particles and imparts mechanical stability. The water then moves into a third bucket where is again is filtered through wood charcoal to remove organics, and finally through local sand to remove fine particles and stabilize water flow. Clean water then flows from the forth bucket into a water container as effluent. At the top of the filter 7 in. thick brick khoa layer of size 0.75 in. to 1.0 in. was placed. After that sylhet sand as a filter material was placed. The thickness of the sand layer was 6 in. Wood coal was used under sylhet sand filter. Thickness of wood coal was 7 in. At the bottom of the filter local sand was used. The thickness of sand filter was 6 in. The filters were connected by 0.5 in. diameter connecting pipe.

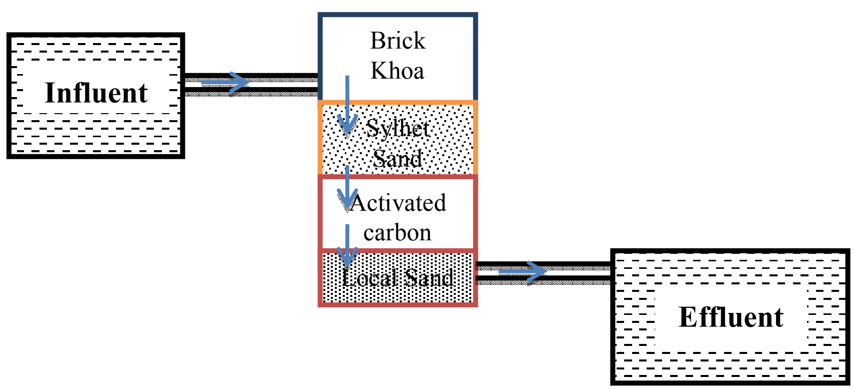


Figure 2: Schematic diagram of developed water treatment unit

2.4 Operation and Maintenance:

The greywater was collected from three locations with a small size water tank. Then it brought to laboratory for the analysis of water quality parameters. After separate analysis three samples were mixed in laboratory and analyzed. Then mixed water was flown through treatment filter. Treated water collected after filtration and the selected water quality parameters were tested.

3. RESULTS AND DISCUSSION

Collection of raw water and three samples was done and brought to laboratory. Three samples were tested separately and mixed sample water was also tested. Raw water and samples were tested to characterized the quality of greywater in KUET campus. The water quality parameters of raw water and mixed sample water were tested to study the performance of the treatment unit and to judge the suitability of the treated greywater for further reuse. Table 1 summarizes test results of the water quality parameters, pH, BOD5, Color, TDS, TSS, COD, EC, Turbidity, Chloride and Hardness of the greywater samples and Table 2 shows the test results of the water quality parameters, pH, BOD5, Color, TDS, TSS, COD, EC, Turbidity, Chloride and Hardness of the influent and effluent water samples. Figure 3 presents the test results for influent water and effluent water.

3.1 Greywater characterization:

From the analysis of P^H it is found that greywater is slightly basic due to presence of bicarbonate (HCO_3^-) or calcium carbonate ($CaCO_3$) from soap and detergent in kitchen, bathroom and basin water. BOD_5 of greywater for residential zone for faculty and staff is 5.16±2.87 mg/L, for residential zone for students is 4.63±1.2 mg/L, for academic zone is 2.91±.54 mg/L. The average of BOD_5 is 5.005±1.44 mg/L. The BOD_5 of raw water is 7.39 mg/L. The standard value of BOD_5 is 10 mg/L. It can be observed from our test that the value of BOD_5 is within the standard limit. The cause behind this phenomenon is having low organic load from food scraps, oil and grease which can result in a lower concentration of organic matter.

Testing for color can be a quick and easy test which often reflects the amount of organic material in the water, although certain inorganic components like iron or manganese can also impart color. Color of greywater for residential zone for faculty and staff is 67.75±13.2 Pt-Co, for residential zone for students is 426±32.54 Pt-Co, for academic zone is 2.5±.5 Pt-Co. The color of raw water is 0 Pt-Co. The highest color came from Residential zone for students (426±32.54 Pt-Co), as it contains much more organic matters from food, due to the dye of clothes and dissolved salts from detergent. Value of color of influent before treatment was 563.33±150.3 Pt-Co.

From the test result it can be observed that the TDS of greywater for residential zone for faculty and staff is 0.13± .01 mg/L, for residential zone for students is .21±.06 mg/L, for academic zone is .102± .026 mg/L. The average of TDS is .19±.02 mg/L. The TDS value of raw water is .133 mg/L. Value of TDS of influent water before treatment was .21±.02 mg/L. TSS of greywater for residential zone for faculty and staff is .0095±.02 mg/L, for residential zone for students is .01±.01 mg/L, for academic zone is .41±.72 mg/L. The average of TSS is .1975±.02 mg/L. The TSS value of raw water is 0.028 mg/L. This indicates that quality of greywater is quite saline.

From the analysis it can be observed that the COD of greywater for residential zone for faculty and staff is 160±94.2 mg/L, for residential zone for students is 38.75±4.5 mg/L, for academic zone is 38.75±4.5 mg/L. The average of COD is 226.25±126.23 mg/L. It can be observed that greywater from residential zone for faculty and staff demand more oxygen. The COD value of raw water is 0 mg/L. The result of a chemical oxygen demand test indicates the amount of water-dissolved oxygen consumed by the contaminants. This shows that greywater from residential zone for faculty and staff contains more contaminants.

Electrical conductivity is widely used to indicate the total ionized constituents of water. It is directly related to the sum of the cations (or anions), as determined chemically and is closely correlated, in general, with the total salt concentration. From the analysis we can see that the electrical conductivity of greywater for residential zone for faculty and staff is 1733±67.53 µmhoms/cm, for residential zone for students is 2822.5±209.34 µmhoms/cm, for academic zone is 1735.5±65.71 µmhoms/cm. The average of electrical conductivity is 1616.67±143.4 µmhoms/cm. The electrical conductivity value of raw water is 1782 µmhoms/cm.

Turbidity of greywater for residential zone for faculty and staff is 16.3±11.6 NTU, for residential zone for students is 85.125±122.8 NTU, for academic zone is 17.81±6.8 NTU. The average turbidity is 60.85±89.57 NTU. The turbidity of raw water is 1.31 NTU. Value of turbidity of influent water before treatment was 39.42±85.43 NTU which is larger than the standard value. The cause behind this phenomenon is the presence of lot of suspended particles (skin, particles, lint) resulting from washing activities. Beside this bacteria, hair, organic material, grease, soap and detergent residue usually result in high concentration of turbidity of greywater. So it should be treated before re-use.

From the test value of chloride of greywater for residential zone for faculty and staff is 812.5±175 mg/L, for residential zone for students is 900±40.82 mg/L, for academic zone is 762.5±110.86 mg/L. The value of chloride of raw water is 950 mg/L. Value of chloride of influent water before treatment was 1033.33±104.08 mg/L. It can be observed that presence of chloride ion is more or less same before and after use.

Hardness of greywater for residential zone for faculty and staff is 964.25 mg/L, for residential zone for students is 1639.5±161.67 mg/L, for academic zone is 711.75±48.42 mg/L. The average hardness is 835.5±139.24 mg/L. The value of hardness of raw water is 278 mg/L. The two main cations that cause water hardness are calcium (Ca2+) and magnesium (Mg2+) from soap and detergent from kitchen and bathroom water.

Table 1: Results of test of quality parameters for characterization

Parameter	Raw Water	Residential zone for faculty and staff (C1)	Residential zone for students (C3)	Academic zone (C2)	Influent water (Mixed water)
PH	7.68	7.12± .08	7.25±.23	7.18±.22	7.21±.01
BOD5 (mg/L)	7.39	5.16± 2.87	4.63±1.2	2.91±.54	5.005±1.44
Color (Pt-Co)	0	67.75±13.2	426±32.54	2.5±5	355±45.57
TDS (mg/L)	0.13	0.13± .01	.21±.06	.1± .026	.2±.02
TSS(mg/L)	0.028	.0095±.02	.01±.01	.00875±.005	.41±.72
COD(mg/L)	0	160±94.2	38.75±4.5	38.75±4.5	226.25±126.23
Conductivity (µmhoms/cm)	1782	1733±67.53	2822.5±209.34	1735.5±65.71	1616.67±143.4
Turbidity (NTU)	1.31	16.3±11.6	85.125±122.8	17.81± 6.8	60.85±89.57
Chloride (mg/L)	950	812.5± 175	900± 40.82	762.5±110.86	860±42.43
Hardness (mg/L)	278	964.25	1639.5±161.67	711.75±48.42	835.5±129.24

3.2 Greywater quality after treatment

Analyzing the results obtained with the purpose of water re-uses for irrigation, gardening, car washing, and construction works and in any other domestic works it could be said that:

P^H value of influent water before treatment was 7.9±97.2. It can be observed from our test that the value of P^H of effluent water after filtration is 7.68±.01 which is quite similar to influent water. The cause behind this phenomenon may be the filter contained some alkaline substance that dissolved in water and lead to slight increase in P^H value. The P^H value of raw water has found 7.68 which show same characteristics as effluent water . According to Bangladesh Environment Conservation Rule (1997) surface runoff water standard for P^H is 6.50-8.5. So this effluent water can be reused.

It can be observed from our test that the value of color of effluent water after filtration is 55±4.58 Pt-Co. The color is removed significantly by the developed treatment unit. The color removal efficiency is 92.03%. The causes behind this color removal are the absorption in brick chips, reduction of the organic matter, reduction of dissolved solid, mechanical staining that remove colloidal particles. Now this treated water is ready for use. The treated greywater could be efficiently used for irrigation, household gardening.

Value of TDS of effluent water after filtration is .149±.01 mg/L. Although TDS has decreased in treated water but the removal efficiency is very low (25.5%). The results indicated that there was not appreciably reduction in the total water salinity. Value of TSS of influent water before treatment was .009±.002 mg/L. It can be observed from our test that the value of TSS of effluent water after filtration is .0057±.001 mg/L. Although TSS has decreased in treated water but the removal efficiency is very low (36.67%).

Value of COD of influent water before treatment was 158.67±32.08 mg/L. It can be observed from our test that the value of COD of effluent water after filtration is 14.33±13.43 mg/L. The COD removal efficiency is 91% . COD has removed significantly because the large chain of organic matter could not pass through the small pore of brick chips and also adsorbed in sand. COD has also removed for the lessening of the amount of bacteria. This treatment method is very efficient for removing COD. So, this treated water can be reused.

Value of electrical conductivity of influent water before treatment was 3140±1177.84 µmhoms/cm. It can be observed from our test that the value of electrical conductivity of effluent water after filtration is 2226.67±1497.53 µmhoms/cm. According to Bangladesh Environment Conservation Rule (1997) surface runoff water standard for electrical conductivity is 2250 µmhoms/cm. Our tested value within the standard value. So this filtration method is efficient for greywater treatment.

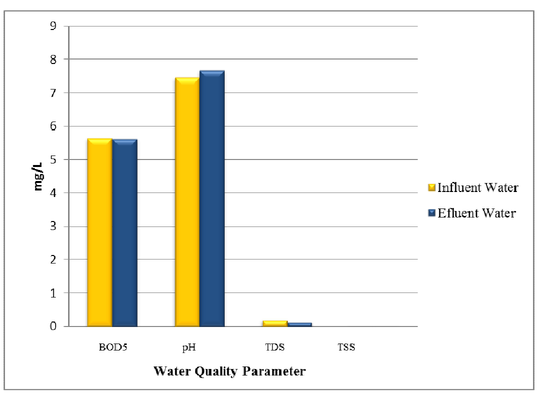
It can be observed from our test that the value of turbidity of effluent water after filtration is 1.59±.36 mg/L indicates that treated water is quite clear and can be reused. Thus, the reclaimed greywater could be used for car washing and construction works.

From our test the value of chloride of effluent water after filtration is 616.67±28.86 mg/L. Although chloride has decreased in treated water but the removal efficiency is very low (40.3%). As KUET campus is in salty region presence of chloride ion in water is quite natural. In salt affected highlands like Khulna, in the saline soils rice, jute, sugarcane, pulses, oilseeds, spices, vegetables and fruits are grown. Based on the tolerance to soil salinity, the crops were ranked as sunflower> sugar beet> barley> linseed>chili>sweet potato>cowpea>groundnut. So, this treated water can be used for agricultural purposes.

Value of hardness of influent water before treatment was 1145.13±613.58 mg/L which is larger than the standard value. It can be observed from our test that the value of hardness of effluent water after filtration is 303.67±61.79 mg/L. So the value of hardness has decreased much in treated water and the removal efficiency is quite higher (73.5%). This method is efficient for removing hardness from water.

Table 2: Results of test of quality parameters before and after treatment

Parameter	**Influent Water (Before treatment)**	**Effluent (After treatment)**	**Parameter**	**Influent Water (Before treatment)**	**Effluent (After treatment)**
PH	7.46±.46	7.68±.01	COD(mg/L)	158.67±32.08	14.33±13.43
BOD5 (mg/L)	5.65±9.55	5.63±.26	Conductivity (µmhoms/cm)	3140±1177.84	2226.67±1497.53
Color (Pt-Co)	563.33±150.3	55±4.58	Turbidity (NTU)	39.42±85.43	1.59±.36
TDS (mg/L)	.21±.02	.15±.01	Chloride (mg/L)	1033.33±104.08	616.67±28.86
TSS (mg/L)	.009±.002	.0057±.001	Hardness (mg/L)	1145.13±613.58	303.67±61.79



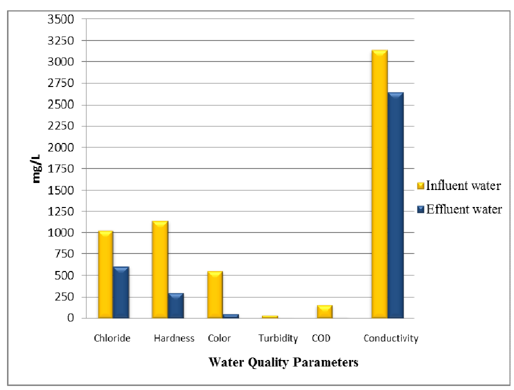


Figure 3: Test results of influent water and effluent water

4. CONCLUSIONS

Characteristics of greywater in KUET campus and water quality in terms of different parameters were studied. From the tested value, it can be said that greywater quality is quite basic. The value of the tested seven parameters (Color, TDS, TSS, COD, Turbidity, Chloride, and Hardness) of the generated greywater exceeded the standard permissible values of water quality. Treated water quality was found to be satisfying the permissible limit. Thus the treated greywater could be efficiently used for irrigation, household gardening. The treated greywater was very clear with turbidity value 1.59 NTU and hardness removal efficiency was about

73.5% which was satisfactory. Thus, the reclaimed greywater could be used for car washing and construction works.

In treated water low removal efficiency of TDS, TSS and presence of chloride indicated that quality of water was saline. In salt affected highlands like Khulna, in the saline soils rice, jute, sugarcane, pulses, oilseeds, spices, vegetables and fruits are grown. Based on the tolerance to soil salinity, the crops were ranked as sunflower > sugar beet > barley > linseed > chili > sweet potato > cowpea > groundnut. So, this treated water can be used for agricultural purposes. Quality analysis after treatment may be a significant extension of the work which might later lead to the selection of suitable treatments required for reusing greywater. Survey can be done to find out the possible level of public acceptance of greywater reuse. The greywater pass through the filter and the treated water can be stored in the storage tank. And the reclaimed water will be pumped from storage tank.

REFERENCES

U.S. Environmental Protection Agency (EPA) (2004), Guidelines for Water Reuse, Washington, DC, USA.