Greywater Reuse and Treatment Methods for Quality Improvement: A Review

Deepak Narayan Paithankar(✉) and Shashi Ranjan Kumar

Department of Civil Engineering, Oriental University, Indore, India
deepakpaithankar@msn.com

1 Introduction

Water plays an important and varied role for human activity, industries and irrigation. It works as a reagent, solvent, cleaning and washing agent [1]. Life without water is scary. But, this natural source is continuously reducing due to rising population and human activities, and the water available per capita/year has already reduced indicating the condition of severe water shortage [2]. Drinking water is emerging as one of the most valuable needs worldwide [3] and its shortage has already forced the Australian water industry and its population to search for alternate source of water [4]. The shortage in natural water resources and a rising population have become an alarming situation [5].

It is estimated that 50–75% of domestic water consumption is related to wastewater due to human activities such as washing, cleaning, bathing, gardening, etc. [1]. The actual requirement of tap water for cooking and drinking is low. Population growth and their activities have led to an increase in the amount of domestic wastewater load discharged into water bodies, thereby, affecting the aquatic life and the environment [2]. To overcome the problem of water shortage and pollution, some countries have already adopted the practice of desalination of sea and brackish water and reuse wastewater [3].

In the recent years, smart practices of saving water due to the use of a greywater treatment system are gaining popularity [6]. In literatures, greywater is defined as domestic wastewater except the water from toilet flushes [7]. Greywater originating from bath and laundry contains remains of soaps, detergents, hairs, lints, etc. while the greywater emerging from kitchen contains oils, fats, salts and food particles. The pathogenic microorganisms like bacteria, protozoa, viruses and parasites are also found in greywater. Concentrations of these pathogens may be high in untreated greywater, therefore, it is necessary to take precautions in greywater reuse. Some countries have strict guidelines for handling greywater, and direct human contact is forbidden [8]. Treated greywater should be safe, hygienic, eco-friendly, economical and esthetic [9].

Treatment and reuse of greywater can be a useful non-potable source of water for toilet flushing, gardening, washing of cars and floors, etc., [10, 11]. There are many psychological issues related to use of greywater which sometimes presents a barrier in its recycling. Areas of rural India facing drought/short supply have already started recycling greywater. Wastewater from food processing is reused in cattle rearing [12].

Methods used for greywater treatment may include physical systems such as sedimentation filters, screening and ultra-filtration (UF) membranes; chemical processes

R. M. Singari et al. (eds.), *Advances in Manufacturing Technology and Management*,
Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-981-16-9523-0_37

such as ion exchange resins, coagulation/flocculation for removal of effluents and biological processes such as constructed wetlands, RBC, MBR and SBR to reduce pathogenic concentration. Physical treatment systems cannot reduce the desired microbial concentration, they are used along with some disinfection steps like chlorination or addition of activated charcoal or in combination with chemical or biological process [13]. Bark and charcoal are gaining attention as filter media in addition to soil and sand because of their high porosity and high carbon content [14, 15]. The aim of this paper is to review the works carried out in different parts of the world for greywater treatment.

2 Literature Review

Barzegar et al. [1] collected greywater samples from a dormitory in Iran. The sample water was kept at 4 °C to avoid biological reactions. 750 mL of greywater sample was inserted into an electrocoagulation reactor consisting of 2 electrodes, and the system was powered with a D.C supply of 20 V. The sample water was subjected to electrolysis and magnetically stirred. The researchers added the pH of the sample by adding sulfuric acid and Sodium Peroxide. An ozone generator and UV lamp were also used for treatment. The researchers measured the COD and TOC removal rate with samples of different pH values and concluded that the removal rate reached a maximum of 85% and 70% with pH = 7.0 and was related to the current density and ozone dosage. The removal efficiency of the system is not very good and also practical implementation of the project on site would be unfeasible due to cost and complexity requirements.

Liberman et al. [3] constructed a pilot system in Ben-Gurion university sports center. Two tanks were used for filtration of greywater. The shower water of the sports center was pumped from the sewage into the feed tank which served as a sedimentation filter. For removal of hair and other impurities, three filters with reducing pore size were connected at the outlet of the feed tank. The water was inlet to an MBR which contained a submerged ultra-filtration module. To start the system, the researchers obtained 160 L of activated sludge from a local wastewater treatment plant as a starting biomass which had a mixed liquor suspended solid (MLSS) concentration of 500 mg/L. The MLSS concentration increased to a value of 5000 mg/L over a period of 9 months and no sludge was wasted during the process. High MLSS concentration and no sludge wastage indicated the development of biomass needed for biological reaction. The system produced very low levels of COD, TSS, BOD_5 and TOC levels. The authors have reported that the cost of effluent production by the system is less than the cost of domestic water in Israel.

Al-Ismaili et al. [6] performed the treatment on wastewater collected from a house in Oman. The treatment system involved a storage tank to preserve raw greywater which was later pumped into a polyethylene tank consisting of layers of natural filters i.e., dune sand followed by fine gravel and medium and large stones. The water was subjected to Chlorination to purify the water. The treated water met the required standards for irrigation of trees and garden crops. The system automatically pumps water from storage tank to the filter tank as soon as the water level in the storage tank reaches 0.4 m^3/d. The system requires cleaning and replacement maintenance only in case of upper layer of dune sand in order to clean debris every 6–8 weeks. The system needs a maintenance cost of nearly 60 US $ every 3 years where the sand dunes have to be completed replaced whereas other materials of the filter can be thoroughly washed and reused.

Bani et al. [16] evaluated the performance of an SMBR system in terms of effluent quality and membrane fouling. The team operated the SMBR for a period of 42 days with constant pressure of 13 kPa in six consecutive stages. The system produced the following values for COD, NH3-N, turbidity and color: 45 mg/L, 0.26 mg/L, 3 FTU and 18 PtCo in the effluent, respectively. Furthermore, TSS was completely eliminated and fecal coliform count was below the required value. The researchers concluded that the treated greywater could be used for most of the non-potable applications—in arid areas.

Ramprasad et al. [17] describe the operation of a GROW (Green Roof Top Water) Recycling system which was installed and monitored in a student hostel at IIT Madras for a period of 2 years. The system consists of 12 trapezoidal shaped troughs placed in 4 rows one above the other over a steel scaffolding frame which gives the appearance of a staircase. Each trough had the capacity to hold 125 L of water. Troughs in a row were serially connected whereas rows one above the other were laterally interconnected. The GROW treatment system is a novel approach with a shallow horizontal subsurface flow with 8 varieties of local plants, and the treatment was carried out in two different phases by replacing the filter media and the species of plants. The greywater was inlet to trough 1 through an overhead tank which moved from trough 1–12 and finally appeared at the output of trough 12. The system produced a high removal efficiency for BOD, COD, TSS, Fecal coliform as 90.8%, 92.5%, 91.6% and 91.4% respectively. The removal rate was found to increase during the summer and also with high loading rate.

Couto et al. [18] constructed a greywater treatment unit in a Brazilian airport. The unit consisted of two 500 L of polyethylene tanks, one for controlling the flow rate of the greywater to the filter bed and second to store treated greywater. The unit included two hydraulic pumps to operate the inlet and outlet flows of the tank. An anaerobic filter and UV disinfectant device working at 36 W was placed between the two tanks. pH average was 7.7 with BOD_5, COD, Turbidity and TSS efficiencies as 73%, 71%, 88% and 77% respectively. The *E. coli* removal rate was 80%. The reuse of treated greywater did not pose any health threats. However, the installation and maintenance cost of the cost ran into thousands of US$.

Cui et al. [19] constructed a pool to study the removal efficiency of constructed wetlands. The researchers divided the pool into 4 cells, with each cell measuring 2 m × 1 m. All 4 cells were constructed to work as independent constructed wetlands. The first 3 cells were further divided to hold 5 compartments each. The first cell was designed to work as a horizontal baffle flow constructed wetland where the water horizontally moved from one compartment to the other. The second cell was a vertical baffle flow constructed wetland where holes were made in the compartment to enable vertical flow from one compartment to other. The third cell was a hybrid baffle flow constructed wetland where water flow among the compartment was vertical as well as horizontal. The 4th cell was a subsurface horizontal baffle flow constructed wetland. All the cells were filled with limestones and gravel. The first compartment of all the first 3 cells was filled with cinder, rubble and blast furnace slag, whereas the remaining 4 compartments were filled with blast furnace slag. The 4th cell was only filled with blast furnace slag above the gravel layer. Finally a layer of fine sand was spread over all the 4 cells. Finally yellow flower canna was planted in all the 4 cells. The vertical baffle flow constructed wetland showed higher nitrogen and phosphorous removal efficiency among the 4 methods. The removal efficiency of TP, COD, BOD_5, pollutants was highest in the hybrid baffle flow constructed wetland.

Ghaitidak et al. [20] carried out a treatment study on the greywater originating from students hostel located at (SVNIT), Surat. The researchers examined four treatment options on site, namely a two-stage sand filtration and three coagulation/flocculation options with alum, polyaluminium chloride (PAC) and ferric chloride (FeCl3) treatment. Treated GW from all four options was found to be safe for restricted access area irrigation, construction and industrial cooling as per USEPA [21], WHO [22] and CPCB [23] standards. Treated greywater from all 4 options was compared on the basis of (i) effluent quality and (ii) removal of parameters. The researchers found that results with two-stage sand filtration technique outperformed the other methods of treatment but the major limitation in the implementation of a two-stage sand filtration system is that it needs close monitoring, addition of coagulant, cleaning of screening mesh and mini coarse sand filter on a daily basis. Also the filters have to be regenerated after 30–40 days.

Masi et al. [24] demonstrated a pilot installation of green wall located at the main entrance of an office building in Pune. The experiment was carried out in two phases. In the first phase, the green wall was filled with LECA (lightweight expanded clay aggregate) and the treated greywater was analyzed for the removal rate. Chemical oxygen demand, COD removal rate varied between 16% and 20% in the first phase. In the second phase, the green wall was filled with two different mixtures (i) LECA and sand (ii) LECA and coconut fibers as both are porous in nature and can increase the treatment time. The removal rate observed in the second phase was 7–80% and 14–86% with LECA-sand and LECA-coconut fiber respectively. Researchers found that the treated greywater was suitable for irrigational use as per Indian regional and National regulation. In one sample they found that treated greywater could even be used for toilet flushing after UV treatment.

Kariuki et al. [25] made a 5 barrel greywater system using recycled polyethylene plastic barrels. First tank was used to collect greywater. The other 3 tanks were used to perform flocculation, sedimentation and disinfection and the last tank was used as the storage tank. A case study was performed by collecting sample water from Kenyatta University. The low-cost technology was found to be effective in reducing pollutants and turbidity and it reduced the *E. coli* and total coliform concentration. Researchers found that the treated greywater met the required standards for surface irrigation.

Gorky [26] studied the vertical subsurface flow constructed wetland system for treatment of greywater. Two miniature size tanks were separately constructed in a lab with volume less than 5 m^3. Both tanks were used as independent filters. The first tank consisted of graded stone filters. The second tank was filled with coarse aggregate gravel followed by layers of fine sand and coarse aggregate. Colocasia esculenta was planted in this bed and allowed to grow for some days. The greywater was then inlet into the bed through the graded stone filter. The treated greywater was collected through the down flow filter and tested. The average pH, BOD, COD, TDS, TSS values obtained were 7.28 mg/L, 142 mg/L, 0.3 mg/L and 16 mg/L respectively. The root zone treatment improved the quality of greywater either for reuse or safe disposal into water bodies. The results achieved in the first stage of the research were not satisfactory owing to the small size of the plants, but improvement in efficiency was observed later with their growth.

Katuliza et al. [27] performed a case study in slum area of Kampala city (Uganda). The researchers made a two step filter unit mounted on a hollow steel frame to treat greywater. Both filtration tanks were made of plastic and first filled with gravel which was followed by a layer of crushed lava rock. The size of crushed lava rocks differed in both the tanks and it was smaller in the second tank. Both tanks were fitted with an outlet valve in addition to the exit value, so that 200 mL of sample could be collected from either of them at any time without disturbing the filtration process. The sedimentation process was carried out by first collecting the greywater originating from kitchen, laundry and bathing in a 20 L bucket and the water was allowed to settle for an hour. Oil and grease floating over the water were manually removed while other impurities settled at the bottom of the bucket were carefully discharged. The sediment water was then poured into the first tank for filtration. The filter achieved an efficiency of 85–88% for COD and TSS while *E. coli* was almost eliminated. As lava rocks are easily found in the Kampala city (Uganda) therefore maintenance of the system was not a cost issue.

Fountoulakis et al. [28] performed a study to evaluate the efficiency of a compact Submerged Membrane Bioreactor (SMBR) system. The SMBR system was supplied with greywater generated from bathtub, shower and washing machine through a single house in Greece. The system achieved a mean removal rate of more than 80% for both COD and anionic surfactants. TSS before and after treatment was found to be 95 mg/L and 8 mg/L respectively. Total coliform and *E. coli* removal was almost 100%. The system was also analyzed for the level of nitrogen as it is beneficial for plant growth. The researchers found that in case of nitrogen, removal rate of SMBR fluctuated from 19% in winter to 45% during other seasons of the year. The treated greywater quality was compared with the defined standards for its reuse and the researchers found that it was suitable for indoor use i.e., toilet flushing.

Poyyamoli et al. [29] performed a case study on the greywater originating from a single house in Puducherry. The greywater treatment unit was designed to filter 350 L of water daily. The greywater produced in kitchen, bath and laundry was fed to a filtration and sedimentation tank where most of the dissolved solids were filtered and settled. Then the filtered water was supplied to a vertical subsurface flow constructed wetland in which Arundo donax was planted. Two 500 L tanks were used to manage the treated water. After filtration through the constructed wetland, treated water was first collected in the collection tank and then pumped to the storage tank from where it was utilized for toilet flushing and gardening. The system helped to reduce the municipal water intake by 47%. The removal efficiency for BOD_5, COD, alkalinity, coliform bacteria was 95.2%, 81.1%, 74% and 99.1% respectively.

Singh et al. [30] used an inexpensive laboratory treatment method to purify 5 L of greywater collected as a sample from kitchen, bathroom and laundry by using primary, secondary and tertiary treatment. The greywater was first treated using filter bed made up of natural materials such as coconut shell, wood, sand, etc. In the secondary stage, the greywater was further treated by microbial cultures of Aspergillus niger, Pseudomonas sp. and Penicillium sp. In the tertiary stage, activated charcoal was used to remove the dissolved solids. They used the treated greywater to find if could be helpful in irrigation. The researchers performed two independent trials, where the seeds of V. radiata and V. mungo were fed with treated and untreated greywater for 30 days. The seeds fed with treated greywater showed 100% germination and they attained a higher length then the other pair which was supplied with untreated greywater. The researchers concluded that there are many rural settlements which lack an access to water and the greywater treated by such inexpensive methods can be used by these settlements for the purpose of irrigation and cultivation of crops.

Tee et al. [31] created experimental set-up to compare the performance of conventional horizontal subsurface flow (HSF) constructed wetland with an up-down flow baffled constructed wetland. Two tanks were independently designed and divided into 6 compartments such that in the conventional HSF the greywater horizontally moves between the compartments and in the second tank the greywater movement from one compartment to another was in an up-down manner. First 4 compartments of both the tanks were filled with Rice husk followed by gravel in the other two outermost compartments. Both tanks were planted with cattails. Better removal efficiency was observed with the up-down flow constructed wetland as the greywater traveled through the filter media for a longer time.

The study undertaken by Vakil et al. [32] made use of the electrocoagulation technology for treatment of greywater by collecting greywater generated from a single Indian household. Results reveal that nearly 70% of the total COD and more than 99.9% pathogens were removed in the experiment by using energy of 0.3 kW h/m^3 of wastewater. Removal of COD could not exceed 70% despite repeated attempts due to discharge of aluminum anode in greywater during the process of treatment. The system used in this research required 12 V source for its operation which according to the researchers can be made available by using a 12 V battery that can be charged using a solar cell.

In addition to the above review, case studies carried out by different researchers and their findings are shown in Table 1. The use of Living walls and green roofs has been found in some of the literatures. Greywater treatment through green walls is gaining popularity in urban areas. Green walls not only help to recycle wastewater, they also help to provide a cooler air circulation and act as filters to reduce noise levels. The concept of green walls is being used in many offices and hospitals as its effect on health has also shown good results. However, proper plant and media selection are important in green wall design [33, 34].

2.1 Research Gap

Techniques involved in literatures indicate that there is wide scope to work on cost effectiveness of greywater treatment which gives a scope to develop a low-cost greywater filter which may include use of different low-cost materials as a filter media along with other cost effective accessories.

The potential use of greywater can be studied for regenerative purposes, say irrigating the agricultural lands, toilet flushing's, home garden watering, etc.

Proper management and utilization of treated greywater for a locality can be taken up for the study to extend the results for probable use of treated greywater on a mass scale.

Nawatech Project [40] is an Indian-European based research and development project to treat and reuse greywater in urban parts of India. Various projects undertaken by this joint venture in Maharashtra are shown in Table 2.

Table 1 Few case studies around the world

Location	GWT system	Pollutant removed	Advantage	References
Nigeria (Residential quarters)	Gravity system by sedimentation unit. Filtration unit	BOD (85.68%) COD (57.09%) TSS (70.74%) FC (100%)	Handling of graywater. Possesses no risk of health	Nnaji et al. [35]
Malaysia (Kitchen water)	Filtration system using sand, peat, charcoal and gravel	BOD_5 40%, COD 37%, SS 72%, $NH^+{}_4$ N 87% pH 6.6–6.7	Peat is an effective and inexpensive filter media. Low cost system	Mohamed et al. [36, 37]
Jordan (Village Houses)	Filter system using volcanic ash and white gravel	BOD (73%) COD (65%) TSS (84%) FC (15.67%)	No effect on soil and plants. Local water is saved	Mohamed et al. [36–38]
Cairo, Egypt (Mosque)	Physical and chemical treatment system	BOD (71%) COD (67%) SS (87%) Turbidity (90%) TC (100%)	Applicable for multiple occupancy building	Mohamed and Ali [39]

Source Wurochekke et al. [2]

3 Greywater Reuse Standards

Globally, there are no specific rules and regulations for treatment and reuse standards of greywater. WHO [41], published the safety manual for reuse and disposal of greywater. In addition to WHO guidelines, each country has defined its own standards for reuse of greywater in different applications. In India, central Pollution control board has set some standards to reuse greywater for certain applications. However direct contact with treated greywater is restricted in many countries concerning health risk. The quality standards of treated waste water by CPCB and US EPA are given in Table 3 [10].

4 Conclusion

Greywater reuse can help us to reduce our dependencies on freshwater supplies for non-potable uses such as toilet flushing, irrigation, watering of lawns, backyards kitchen gardens, floor washing, etc. Many countries have adopted the practice of recycling grey-water. The importance to reutilize wastewater can be understood by looking at the scenario in drought prone areas. This paper reviewed the reuse applications of greywater and the treatment process adopted by various researchers. It was found that in addition to the filter media, design process also played an important role in the removal efficiency of greywater treatment system. Many researchers have designed their systems by making use of locally available filter media, and they achieved good results which meet

Table 2 Nawah Tech case studies in Maharashtra

Location	GWT system	Volume Treated	Parameters of treated greywater
Amanora Park, Pune	SBR and MBR	40 m^3/d	BOD: 25 COD: 125
MJP, Pune	Green Wall	0.24 m^3/d	BOD: 6.7 ± 2.7 COD: 21.0.4 ± 15.3
COEP, Pune	Anaerobic treatment with constructed wetlands	180 m^3/d	pH: 6.93 BOD: 65 COD: 175 TSS: 66
Indradhanush Environ. Education & Citizenship center, Pune	Filter beds	40 m^3/d	BOD: <30 COD: <80 TSS: <30
Ordnancefactory, Nagpur	Constructed wetlands with reed beds	100 m^3/d	pH:6.8–7.0 BOD: <5 COD: <10 TSS: Nil
Dayanand Park, Nagpur	Constructed wetlands with different configurations	100 m^3/d	pH: 6.8–7.2 BOD: <30 COD: 50–60 TSS: 20–30

Source Nawah Tech Project, Issue 25, 2016 [40]

Table 3 Quality standards of treated greywater

Stds	Use	pH	BOD	Turbidity	TSS	FC	RC	References
CPCB (India)	Irrigation	5.5–9	100	–	200	–	–	CPCB (2008)
	Inland surface water	5.5–9	30	–	100	–	1	
	Public sewer	5.5–9	350	–	600	-	–	
USEPA	Toilet flushing, Irrigation of lawns, home gardens	6–9	10	2	–	–	1	USEPA (2012)
	Agriculture use, Industrial cooling, Construction	6–9	30	–	30	200	1	

Source Sonali [10]

the required standards for reuse in certain applications. Greywater treatment systems should be eco-friendly, economical and low maintenance systems. Low-cost treatment system opens the opportunity for large scale implementation of such systems in urban and drought prone areas to utilize greywater.

Acknowledgements. Authors express their sincere thanks to Dean, Oriental University, Indore, India and Management of Sanjivani Group of Institutes, Kopargaon, Maharashtra, India for availability of resources all the time.

Author Contributions. Deepak Paithankar (Research Scholar) done writing of the manuscript. Dr. Shashi Ranjan Kumar (Professor) participated in editing and done corrections in the manuscript.

References

1. Barzegar G, Wu J, Ghanbari F (2019) Enhanced treatment of greywater using electrocoagulation/ozonation: investigation of process parameters. Process Saf Environ Prot 12:125–132
2. Wurochekke A, Mohamed R, Al-Gheethi A et al (2016) Household greywater treatment methods using natural materials and their hybrid system. J Water Health 427–434
3. Liberman N, Shandalov S, Forgacs C et al (2016) Use of MBR to sustain active biomass for treatment of low organic grey water. Clean Technol Environ Policy 1219–1224
4. Toole J, Sinclair J, Malawaraarachchi M et al (2012) Microbial quality assessment of household greywater. Water Res 46:4301–4313
5. Blanky M, Rodríguez MS, Halpern M et al (2015) Legionella pneumophila: from potable water to treated greywater; quantification and removal during treatment. Sci Total Envron 533:557–565
6. Al-Ismaili M et al (2017) Extended use of grey water for irrigating home gardens in an arid environment. Environ Sci Pollut Res 24:13650–13658
7. Boano F, Caruso A, Costamagn E et al (2020) A review of nature-based solutions for greywater treatment: applications, hydraulic design, and environmental benefits. Sci Total Environ 711:134–141
8. Oron G, Adel M, Agmon V et al (2014) Greywater use in Israel and worldwide: standards and prospects. Water Res 58:92–101
9. Comino E, Riggio V, Rosso M (2013) Grey water treated by an hybrid constructed wetland pilot plant under several stress conditions. Ecol Eng 53:120–125
10. Manna S (2018) Treatment of gray water for reusing in non-potable purpose to conserve water in India. Int J Environ Sci 13(8):703–716
11. Sushmitha M, Chanakya H, Khuntia H (2019) Efficient grey water treatment and reuse options for india—a review. Springer, pp 225–232
12. Chanakya H, Khuntia H (2014) Treatment of gray water using anaerobic biofilms created on synthetic and natural fibers. Process Saf Environ Prot 92(2):186–192
13. Barıs S, Turkay O (2016) Domestic greywater treatment by electrocoagulation using hybrid electrode combinations. J Water Process Eng 10:56–66
14. Dalahmeh S, Pell M, Hylander L et al (2014) Effects of changing hydraulic and organic loading rates on pollutant reduction in bark, charcoal and sand filters treating greywater. J Environ Manage 132:338–345

15. Dalahmeh S, Pell M, Vinnerås B et al (2013) Efficiency of bark, activated charcoal, foam and sand filters in reducing pollutants from greywater. Water Air Soil Pollut 223(7):3657–3671
16. Bani M, Al-Qodah Z, Al-Shannag M et al (2015) On the performance of real grey water treatment using a submerged membrane bioreactor system. J Membr Sci 476:40–49
17. Ramprasad C, Smith C, Fayyaz M, Philip L (2017) Removal of chemical and microbial contaminants from greywaterusing a novel constructed wetland: GROW. Ecol Eng 106:55–65(2017)
18. Couto E, Calijuri M, Assemany P et al (2015) Greywater treatment in airports using anaerobic filter followed by UV disinfection: an efficient and low cost alternative. J Clean Prod 106:372–379
19. Cui L, Ouyang Y, Yang W et al (2015) Removal of nutrients from septic tank effluent with baffle subsurface-flow constructed wetlands. J Environ Manage 153:33–39
20. Ghaitidak D, Yadav K (2016) Greywater treatment for reuse: comparison of reuse options using analytic hierarchy process. J Water Health 873–881
21. USEPA (2012) Water reuse guidance manual factsheet. Report EPA/600/R-12/618, USEPA, Washington
22. WHO-guidelines (2006) Guidelines for safe use of waste water, excreta and graywater – Excreta and graywater use in agriculture. World Health Organization
23. CPCB (2008) Performance of sewage treatment plants – coliform reduction. Central Pollution Control Board, Ministry of Environment and Forests, New Delhi, India
24. Masi F, Bresciani R, Rizzo A et al (2014) Short communication green walls for greywater treatment and recycling in dense urban areas: a case-study in Pune. J Water Sanit Dev 153–163
25. Kariuki F, Kotut K, Ngángá V (2011) The potential of a low cost technology for the greywater treatment. Open Environ Eng J 4:32–39
26. Gorky S (2015) Treatment of gray water using constructed wetlands. Int Res J Eng Tech 2:62–68
27. Katukiza Y, Ronteltap M, Niwagaba C et al (2014) A two-step crushed lava rock filter unit for grey water treatment at household level in an urban slum. J Environ Manage 133:258–267
28. Fountoulakis M, Markakis N, Petousi I et al (2016) Single house on-site grey water treatment using a submerged membrane bioreactor for toilet flushing. Sci Total Environ 551–552:706–711
29. Poyyamoli G, Golda A, Nandhivarman M (2013) Constructed wetlands for the treatment of domestic gray water: an instrument of the green economy to realize the millennium development goals. The Economy of Green Cities. Springer, Netherlands, pp 313–321
30. Singh S, Pradhan N, Ojha N et al (2016) Grey water treatment and its application in cultivation of plants. Asian J Microbiol Biotechnol Environ Sci 18(4):1043–1053
31. Tee H, Lim P, Seng C et al (2012) Newly developed baffled subsurface-flow constructed wetland for the enhancement of nitrogen removal. Bioresour Technol 104:235–242
32. Vakil K, Sharma M, Bhatia A et al (2014) Characterization of greywater in an Indian middle-class household and investigation of physicochemical treatment using electrocoagulation. Sep Purif Technol 130:160–166
33. Prodanovic V, Hatt B, McCarthy D et al (2017) Green walls for greywater reuse: understanding the role of media on pollutant removal. Ecol Eng 102:625–635
34. Snigdhendubala P, Al-Ghamdi S, Mackey H (2019) Greywater recycling in buildings using living walls and green roofs: a review of the applicability and challenges. Sci Total Environ 652:330–344
35. Nnaji CC, Mama CN, Ekwueme A, Utsev T (2013) Feasibility of a filtrationadsorption grey water treatment system for developing countries. Hydrol Curr Res S1:006
36. Mohamed B, Abeer A, Theib O (2013a) Assessing the efficiency of grey-water reuse at household level and its suitability for sustainable rural and human development. J Appl Sci Technol 3(4):962–972

37. Mohamed RM, Amir HMK, Martin A, Stewart D (2013b) A monitoring of environmental effects from household greywater reuse for garden irrigation. Environ Monit Assess 185:8473–8488
38. Mohamed RM, Martin A, Stewart D (2013c) A monitoring of environmental effects from kitchen greywater reuse for garden irrigation. Environ Monit Assess 185:8473–8488
39. Mohamed NM, Ali SS (2012) Economical study for greywater reuse to achieve the sustainability in Egypt. Aus J Basic Appl Sci 6(3):655–665
40. Meinhold K et al (2016) Sustainable sanitization practice. Nawah Tech (2016)
41. Sanitation safety planning (2015) manual for safe use and disposal of waste water, gray water and excreta. World Health Organization, WHO