INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 5)
Available online at: www.ijariit.com

Design and development of grey water reuse system

Parameshwaramurthy P. M.
param_enviro@yahoo.co.in
Sri Jayachamarajendra College of Engineering, JSS TI Campus, Manasagangothri, Mysuru, Karnataka

Sadashiva Murthy B. M.
bmsada@gmail.com
Sri Jayachamarajendra College of Engineering, JSS TI Campus, Manasagangothri, Mysuru, Karnataka

Krupa Kadekoppa
krupaskadekoppa@gmail.com
Param Enviro Engineers, Bengaluru, Karnataka

ABSTRACT

Grey water is an alternative source of water which can potentially save a significant quantity of precious drinking water. The present study emphasizes primarily on the treatment of greywater to make it fit for serving various purposes. This paper provides an insight into the design of laboratory scale grey water treatment system, comprises of oxidative mineralization, disinfection, and filtration of grey water. Laboratory scale treatability trails were performed by the means of synthetic grey water and real grey water. Grey water treatment system demonstrated satisfactory removal of contaminants which was evident from the COD removal efficiency of 85% and 90%, TSS removal efficiency of 98% and 86%, and faecal coliform with removal efficiencies of 99% and 96% respectively. It could be inferred from the study finding that the treated water possed low turbidity value (< 1 NTU) and was free of suspended solids. Thus this study explored the capability of the grey water treatment system to carry electrochemical oxidation of grey water contaminants and making treated water fits for reuse. This implies that this treatment technology possesses the potential to be considered as a viable alternative to conventional grey water treatment systems.

Keywords— *Grey water, Oxidative mineralization, EAOP, Disinfection, Ultrafiltration*

1. INTRODUCTION

In the view of incessant pressure building up on freshwater resources across the globe accompanied with increasing scarcity of new sources of supply and the high cost involved in the procurement of freshwater, various initiatives are underway for exploring innovative methods in order to adequately meet the ever-increasing water demand. In comparison to wastewater generated by industries or municipal treatment plants, greywater has been found to be more optimum for reuse applications, such as groundwater recharge, vehicle wash, fire extinguisher, toilet flushing etc., (Rana, 2016). Grey water recycling has been recognized widely as a sustainable solution to the rampant increment in the freshwater demand, water shortages and for environmental protection.

Grey water discharge leaves both short-term and long-term impact on the environment and human health. High concentrations level of Boron, Sodium or surfactants, some of which may not be biodegradable can be detrimental for crops as they pollute soil and groundwater (Gross et al., 2005). In addition, nutrients present in grey water may lead to eutrophication that is principally the self-purification capacity of the site of disposal (Harremos 1998; Morel and Diener 2006). In particular, sodium tripolyphosphate, one of the common ingredient of several detergents, has been associated with the process of eutrophication (Ko¨hler 2006). Furthermore, the accumulation of heavy metals and micropollutants in the environment may disseminate toxicity throughout the food chain, and consequently, distort the ecological balance (Taghipour et al. 2013). This may adversely affect humans and animals when they are exposed for a prolonged time duration or after bioaccumulation and biomagnification (Gonza´lez-Naranjo and Boltes, 2013). Also, pathogenic microorganisms present in grey water are potent to cause diseases that result in either morbidity or mortality depending on the severity and duration of the exposure (Birks and Hills, 2007).

Grey water has emerged as a preferable option for water reuse in contrast to black water due to its low contamination level. Utilization of grey water is reused either onsite or nearby, can possibly diminish the requirement of new water supply, bring down the energy and carbon footprint of water services, and meet a wide range of social and economic needs. In particular, the reutilization of grey water can aid to diminishing the demand for expensive high-quality consumable water. By appropriately matching water quality as per the requirement, the reuse of grey water can be put to use in lieu of potable water in non-potable applications that can be met with non-potable water, such as toilet flushing and landscaping. Recent studies by Newcomer, Boyd, Nyirenda, Opong, Marquez & Holm (2017), assessed the viability of reusable domestic grey water in rural areas of northern Malawi and concluded that low-cost solutions of reusing grey water supply were most beneficial to the people due to their low-income standard of living. To limit the bacterial regrowth after UV disinfection chlorine is usually added to the water distribution systems (Shoults & Ashbolt, 2017; Crook et al., 2015). The disinfection treatment techniques require low labour skills and the process is highly effective in killing pathogenic microbes when designed and utilized properly (Li et al., 2010).

In past few years, Electrochemical Advanced Oxidation Process (EAOP) has gained lots of significance in treatment of wastewater as it leverages electricity for generating free radicals that are highly reactive in nature and also prevents generation of secondary waste material. Researchers are striving hard and working relentlessly to improvise the electrochemical advanced oxidation process. To accomplish this motive, they are paying majorly concentrating on redesigning the existing electrodes by incorporating few modifications and on improving the removal process by the means of materials possessing high adsorption potential or altering the amount of current applied. The conventional processes involved utilization of electrodes made from Pt, IrO2 or PbO2. EAOP is preferred as it involves simultaneous disinfection of the grey water, along with organic mineralization (Butkovskyi et al., 2014).

Due to the presence of less number of contaminating pathogens and low nitrogen level, reuse and recycling of grey water are gaining more recognition and prevalence (Li et al., 2003). Various investigations have been carried underpinning the treatment of grey water leveraging range of technologies that differ from each other both in terms of intricacies involved and outcomes (Fangyue Li-2009). The primary objective of this work is to critically examine the treatment process of grey water and reusing the treated grey water as a substitute of the precious potable water in applications which can be accomplished with water below par the drinking quality. Non-potable reuse applications include industrial, irrigation, toilet flushing and laundry washing relies significantly on the technologies utilised in the treatment process.

2. MATERIALS AND METHODOLOGY

2.1 Synthetic grey water

The chemical composition of synthetic grey water has been stated in Table 1 (Nazeem and Meera, 2013). The formulated grey water sample was used for treatment studies.

Table 1: Chemical constituents of synthetic grey water

S. no	Chemical	Concentration (g/L)
1.	Glucose	0.3
2.	Sodium acetate trihydrate	0.4
3.	Ammonium chloride	0.22
4.	Potassium dihydrogen phosphate	0.075
5.	Di-Sodium hydrogen phosphate	0.15
6.	Magnesium Sulphate	0.05
7.	Cow dung	0.25

The synthetic grey water was prepared by weighing all the ingredients and subsequently mixed with 500 mL water in a blender at low speed for one minute. The feed tank was filled with 20 liters of tap water followed by addition of concentrated ingredient mixture. The grey water was then kept at rest. To ensure complete mixing of the chemical ingredients, the grey water should be kept at rest for at least nine hours or overnight, then the homogenized sample was drawn from the mixture and analyzed for determining basic physicochemical and microbiological parameters.

2.2. Real grey water

Real grey water was prepared by mixing water derived from the bathroom, washing clothes and kitchen in different proportion (J S Lambe et al.,) The domestic source of water comprised of effluent generated from hand washing, bathing and washing clothes. Kitchen water was collected from a nearby canteen. All these formulations were mixed to simulate organic and inorganic pollution of grey water. Simulated grey water was analyzed for the basic parameters prior to treatment studies.

2.3. Treatment method

The pilot treatment plant had been designed for effective treatment and reuse of grey water. Treatment scheme includes Pre-filtration, Electrochemical Advanced Oxidation Process (EAOP) followed by Ultrafiltration. The ceramic membrane was used as an ultrafiltration unit, for addressing the problems associated with high concentration of organic and inorganic constituents, nutrients, oil, and grease. The treatment method influences the oxidative mineralization of organics for making it suitable for recycling. The units of the pilot plant include SS mesh filter, EAOP flow cell, AC to DC power supply, ultrafiltration membrane, membrane housing (SS) with flanges and fitting, magnetic chemical resistance feed pump, rotameters, pressure gauge electrical control panel and sensors.

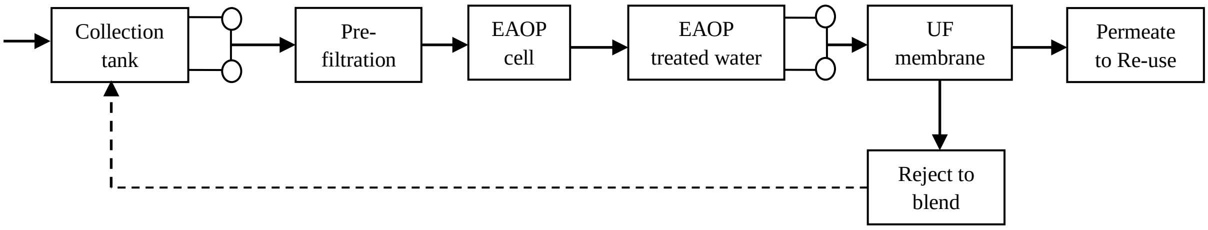

Fig. 1: Schematic of grey water treatment

2.4. Pilot treatment plant

The pilot treatment plant was designed for effective treatment and reuse of grey water. The major components of the pilot plant include an EAOP flow cell, AC to DC power supply, ultrafiltration membrane, membrane housing (SS) with flanges and fitting, magnetic chemical resistance feed pump, rotameters, pressure gauge, electrical control panel, and sensors. As per the design, a compact modular mobile skid was erected using stainless steel 304-grade material, treatment units were mounted inside the skid and pipelines were installed.

2.5. Experimental Method

The dimensionally stable anodes are leveraged extensively in lieu of conventional electrodes. These electrodes possess high current efficiency, but the active radicals generated cause only partial degradation of waste materials (Oliveira et al., 2007). Presently, boron-doped diamond electrode has also gained great attention of researchers and is utilized on a large scale for EAOP due to certain properties which distinguish it from other conventional electrodes, such as high resistance towards corrosion, high capacity to generate HO radicals and inert nature (García-Espinoza et al., 2018; Svorc et al., 2017). Investigators have tried to alter the amount of electricity applied by increasing it by few amperes and observe its impact on the degradation of waste materials. It was observed that with increment in the applied electricity the degradation rate of waste materials also got enhanced. Also, extending the duration of applied electricity further improved the degradation rate (García-Espinoza et al., 2018).

Grey water was treated in the lab-scale electrochemical cell under batch mode. The electrochemical cell consisted of a powerful, non-selective anode was incorporated in the electrochemical cell to support the generation of hydroxyl radical. The total cell area is 42 cm^2. Treated liquid was constantly pumped through the oxidation chamber during the treatment process. Connecting the electrolytic cells to regulated DC power source instigated electrolytic reaction with the advent of the applied current. Treated samples were taken at time 0, 0.25, 0.5, 1, 2, 3 and 4 h, for various qualitative analysis.

A known volume of (20 L) grey water sample was taken in a container and the sample was pumped to flow through electrolytic cell. As electrodes connect to a regulated DC power source, the electrolytic reaction occurs. The experiment was conducted within the stipulated electrolysis time period (3 hours). A scientific investigation conducted in similar lines was referred to gain an idea about the appropriate voltage required specifically for each experiment. During the electrolysis, samples were drawn at 30 minutes interval and the parameters of treated water were determined to leverage standard methods. The pre-treated sample was made to pass through the ceramic membrane in batch mode at specific operational conditions. Final treated water was analysed on the basis of physicochemical and microbiological parameters.

Fig. 2: Pilot treatment plant

2.6. Analytical Methods

Standard methods were followed for the analysis of water samples. The qualitative characterization of grey water samples was accomplished with the amalgamation of several physicals, chemical, and biological techniques pH were analysed using the standard potentiometric method. TDS was measured by determining electrical conductivity and TSS was measured by the gravimetric method. BOD_5 was evaluated by the means of Winkler’s method and COD by open Reflux method. Nitrates were analysed using the PDA method and phosphates by Stannous Chloride method.

3. RESULT AND DISCUSSIONS

3.1. Characteristics of grey water

Physico-chemical and microbiological parameters of simulated real grey water and synthetic grey water were analysed. The physicochemical parameters considered for analysis were pH, BOD5, COD, TSS, TDS, nitrates, and phosphates. Table 2 shows the physicochemical and microbiological parameters of the grey water analysed during the study.

Table 2: Characteristics of grey water

Parameters	Units	Synthetic grey water	Real grey water
pH	-	6.8-7.3	6-8
TDS	mg/L	520	580
TSS	mg/L	50-300	
COD	mg/L	430-619	780-900
BOD	mg/L	150-200	180-280
ORP	mV	87-245	130-350
Electronic Conductivity	µs/cm	800	890
Nitrate	mg/L	4-14	4
Phosphate	mg/L	10-20	4-15
Coliform	CFU/100 ml	10^3-10^6	10^3-10^6
Turbidity	NTU	NA	<10

The two simulations of grey water taken into consideration for this study were found to be characteristically different due to the difference in the composition and concentration. Results stated in the above-mentioned tables indicate that grey water parameters are highly variable, as expected from a simulation of real and synthetic grey water. Real grey water was found to be loaded high organic content in contrast to synthetic grey water as it comprised primarily kitchen water and laundry water. pH of the samples varied between 6.8 and to 7.3 for synthetic grey water and 6 to 8 for real grey water. The main reason for pH fluctuation of real grey water can be attributed to the addition of kitchen water collected from the nearby canteen. High organic content in the grey water fixed the pH within the acidic range. The parameters were optimized based on the outcomes of initial treatment studies and accordingly subsequent plans were developed to accomplish further investigations and attain desired outcomes. It could be inferred from the comparison of synthetic and real grey water that COD is higher in RGW than in SGW while, on the contrary, conductivity and BOD5 are lower in SGW than in RGW. The differences marked in BOD5 can be justified by the absence of certain chemical pollutants in SGW, sebum, which is produced by humans and thus infeasible to imitate. The concentration of surfactants is higher in RGW than in SGW, which instigates higher COD value for RGW as surfactants are organic in nature. Microbiological loads of SGW and RGW are disparate, however, the addition of cow dung to SGW can beneficial as it can serve as a source of micro-organisms. This will ensure the presence of same indicators of faecal contamination as observed in SGW and RGW. This supports the higher coliform concentration in SGW in contrast to RGW.

3.2. Treatability studies

3.2.1. COD degradation as a function of applied current: Figure 3 through graphically the depict COD degradation values of SGW and RGW that were measured as a function of applied current density at 100, 120, 150, 180 and 200 mA/cm^2 at 3 hours taking into account both synthetic and real grey water. At a current density of 180 mA/ cm2, maximum COD reduction was observed in both SGW and RGW. Therefore 180 mA/cm^2 was considered as optimum current density value for COD removal.

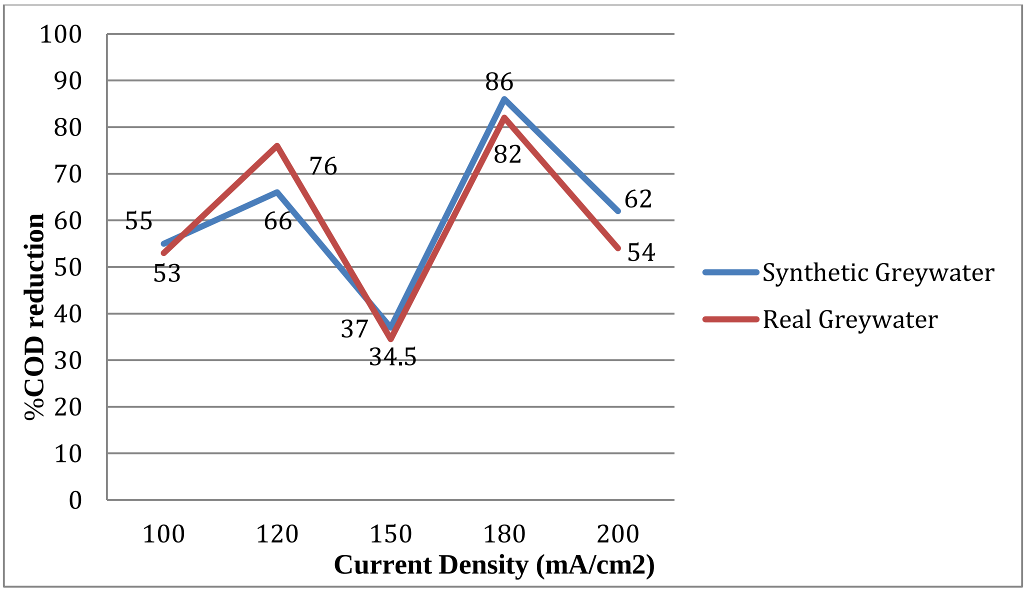

Fig. 3: COD reduction as a function of applied current

3.2.2. COD reduction as a function of electrolysis time (treatment time): Figure 4 graphically represents COD degradation measured as a function of applied current density at 100, 120, 150, 180 and 200 mA/cm^2 at 6hours treatment time. It can be observed from the graph that, till 3h of electrolysis time, COD degradation gradually increased after a slight increase in COD. Between 3 and 5 hour, the COD removal process becomes very slow due to slow oxidation, which can be attributed to the mass transfer of pollutants. Hence 3 h can be taken as optimum treatment time for COD removal.

3.3. Treatment performance

This grey water treatment system aims at treating and reusing the treated water. The system comprises of, oxidative mineralization, disinfection, and filtration. The system demonstrated satisfactory removal of contaminants as given in table 3. Total suspended solids (TSS), nitrate (NO_3), chemical oxygen demand (COD), biochemical oxygen demand (BOD) and faecal coliforms (F.C.) were investigated under continuous flow operation using a hydraulic retention time (HRT) ranging from 1 to 4 hours.

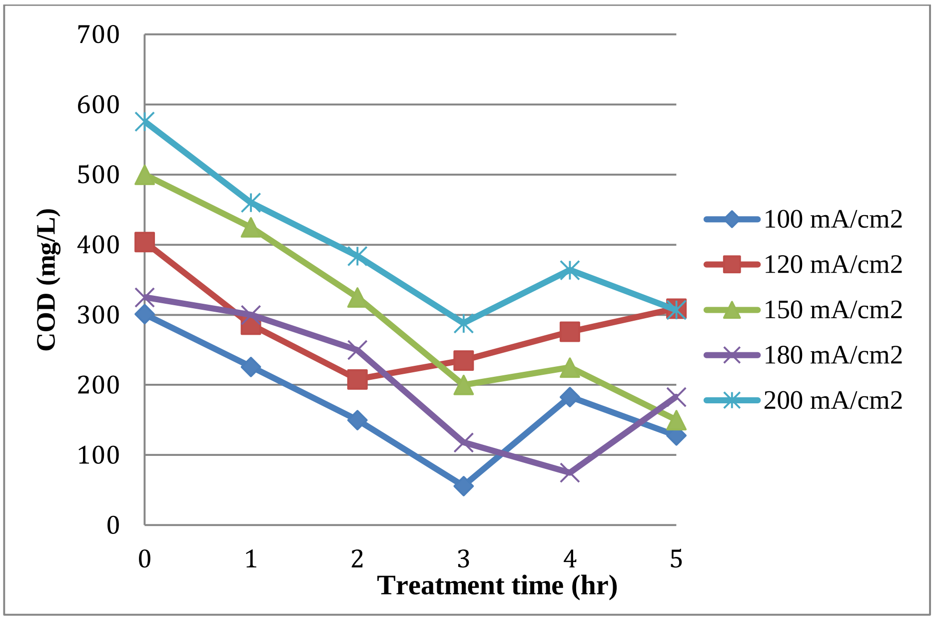

Fig. 4: COD reduction as a function of electrolysis time

Table 3: Physico-chemical parameters of treated grey water sample

Parameters	Units	Synthetic grey water	Real grey water
pH	-	6.5	7.2
TDS	mg/L	510	580
TSS	mg/L	<1.0	6
COD	mg/L	75	80
BOD	mg/L	20	26
Coliform	CFU/100 ml	NIL	NIL
Turbidity	NTU	0.8	0.6

The system demonstrated satisfactory removal in synthetic and real grey water sample. The removal efficiencies of COD were 85% and 90 %, the efficiencies of TSS removal were 98% and 86 %, and faecal coliforms with removal efficiencies of 99% and 96 % respectively. The study revealed that the UF membrane filtration system was able to efficiently remove the solid particles however, soluble nutrients such as ammonia and phosphorus were able to pass through the UF membrane and remain in permeate. The permeate exhibited low turbidity value (below 1 NTU) and was found to be devoid of suspended solids and coliform and thus had an excellent physical appearance. GWT system produced water with both pH and electrical conductivity suitable for reuse according to statutory guidelines.

3.2.3. COD removal

3.2.3.1. Synthetic grey water: The COD concentration in the raw grey water varied from 372 mg/L to 862 mg/L and for treated water, the concentration ranged from 78 mg/L to 178 mg/L. Studies were conducted at 180 mA/cm^2 (180 lph). The COD removal percentage varies from 52 to 90. Removal of COD removal rate has been depicted in the figure given below.

3.2.3.2. Real grey water: The COD concentration in the raw grey water varied from 364 mg/L to 627 mg/L and for treated water, the concentration ranged from 76 mg/L to 450 mg/L. Studies were conducted at 180 mA/cm^2 (400 lph). The COD removal percentage varies from 26 to 84. Removal of COD has been depicted in Figure given below.

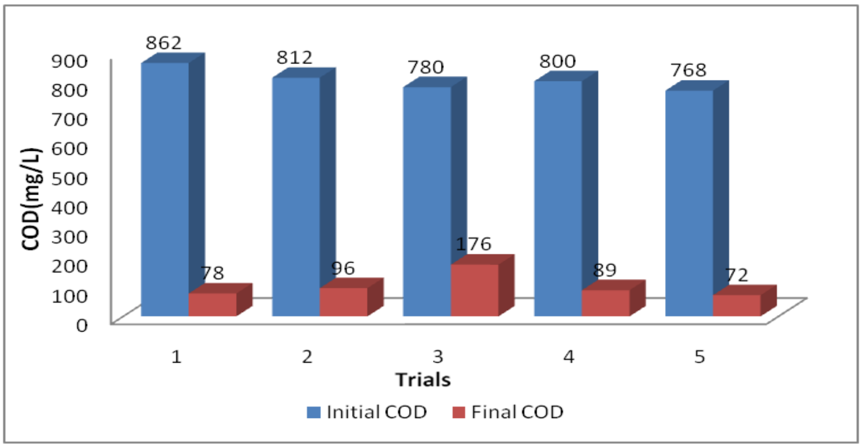

Fig. 5: Percentage COD removal in SGW

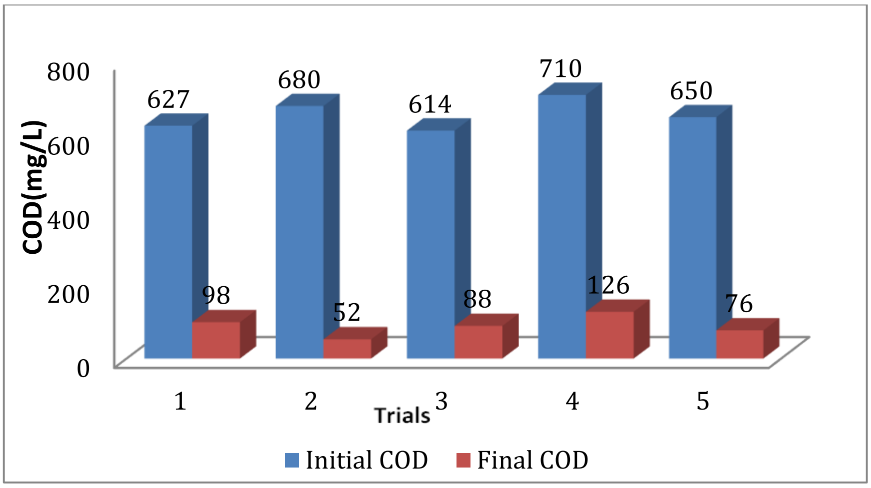

Fig. 6: Percentage COD removal in RGW

4. CONCLUSIONS

Synthetic grey water and real grey water were formulated and treated using advanced oxidation process and ultrafiltration. As the composition of both samples is highly variable, some remarkable differences were recorded. The system demonstrated satisfactory removal in synthetic and real grey water sample. The removal efficiencies of COD were 85% and 90 %, the efficiencies of TSS removal were 98% and 86%, and faecal coliforms with removal efficiencies of 99% and 96 % respectively. The study explored low turbidity value for treated water (below 1 NTU) as the treated water found to be free of suspended solids and coliform and thus had an excellent physical appearance. Current treatability study proved the possibility for electrochemical oxidation of contaminants in grey water and thus enhancement of grey water quality to make it fit for reuse. Electrolytic cells offer multiple technical benefits as it can be easily operated, possesses compact and modular reactor design, has an ability to adjust to variable organic loads in wastewater and there is no need to store and handle chemicals. The study concludes that the Grey water Treatment system can emerge as a sustainable and promising treatment technology.

5. REFERENCES

[1] Birks R, Hills S (2007).Characterisation of indicator organisms and pathogens in domestic greywater for recycling. Environ Monit Assess.129, 61–69.

[2] Butkovskyi, A., Jeremiasse, A. W., Hernandez Leal, L., van der Zande, T., Rijnaarts, H., & Zeeman, G. (2014).Electrochemical conversion of micropollutants in gray water.Environmental science & technology, 48(3), 1893-1901.

[3] Fangyue Li, Knut Wichmann, and Ralf Otterpohl. (2009) Evaluation of appropriate technologies for grey water treatments and reuses, Water science and technology, 59.2, 249-260.

[4] Gross A., Azulai N., Oron G., Ronen Z., Arnold M., Nejidat A., (2005).Environmental impact and health risks associated with greywater irrigation: a case study. Water Science and technology, 52(8), 161-169.

[5] García-Espinoza, J. D., Mijaylova-Nacheva, P., & Avilés-Flores, M. (2018). Electrochemical carbamazepine degradation: effect of the generated active chlorine, transformation pathways, and toxicity. Chemosphere, 192, 142-151.

[6] Gonza´lez-Naranjo V, Boltes K (2013). Toxicity of ibuprofen and perfluorooctanoic acid for risk assessment of mixtures in aquatic and terrestrial environments. Int J Environ Sci Technol. DOI:10. 1007/s13762-013-0379-9

[7] Henze, M., Harremoes, P., la Cour Jansen, J. & Arvin, E. 2000 Wastewater Treatment, Biological, and Chemical Processes, 3rd edition. Springer Verlag, Berlin. Kohler J (2006) Detergent phosphates: an EU policy assessment. J Bus Chem 3(2):15–30

[8] Lambe J. S. and Chougule R. S. Greywater -Treatment and Reuse. IOSR Journal of Mechanical and Civil Engineering. 20-26.

[9] Le-Clech, P., V. Chen, A.G. Fane. (2006). Fouling in membrane bioreactors used for wastewater treatment – A review. Journal of Membrane Science, 284(1-2): 17-53

[10] Li, F., Wichmann, K. &Otterpohl, R. Review of the technological approaches for grey water treatment and reuses. The science of the Total Environment 407 (11), 3439–3449.

[11] Li, Z., Gulyas, H., Jahn, M., Gajurel, D. R., &Otterpohl, R. (2004).Greywater treatment by constructed wetlands in combination with TiO2-based photocatalytic oxidation for suburban and rural areas without a sewer system.Water Science and Technology, 48(11-12), 101-106.

[12] Morel A. and Diener S. (2006). Greywater Management in Low and Middle-Income Countries, Review of Different Treatment Systems for Households or Neighbourhoods. Swiss Federal Institute of Aquatic Science and Technology (EAWAG), Dübendorf, Switzerland. 107

[13] Nazim F. and Meera V. Treatment of Synthetic Greywater using 5% and 10% Garbage enzyme solution. Bonfring International Journal of Industrial Engineering and Management science. 3.4. 111-117

[14] Newcomer, E., Boyd, C., Nyirenda, L., Opong, E., Marquez, S., & Holm, R. (2017).Reducing the burden of rural water supply through greywater reuse: a case study from northern Malawi. Water Science and Technology: Water Supply, 17(4), 1088-1096.

[15] Oliveira, F. H., Osugi, M. E., Paschoal, F. M., Profeti, D., Olivi, P., & Zanoni, M. V. B. (2007). Electrochemical oxidation of an acid dye by active chlorine generated using Ti/Sn (1− x) Ir x O 2 electrodes. Journal of Applied Electrochemistry, 37(5), 583-592.

[16] Rana D. B., Yenkie M. K. N., and Khaty N. T., (2016). Grey Water Treatment by Combine Processes like Vertical Flow Constructed Wetland and H2O2/UV Photo-Assisted Oxidation Process to Obtain Water of Suitable Quality that can be Reused Directly. Journal of Chemistry and Chemical Sciences, Vol. 6(4), 339-349.

[17] Sirés, I., Brillas, E., Oturan, M. A., Rodrigo, M. A., & Panizza, M. (2014). Electrochemical advanced oxidation processes: today and tomorrow. A review. Environmental Science and Pollution Research, 21(14), 8336-8367.
[18] Shoults, D. C., &Ashbolt, N. J. (2017). UV Disinfection of Hand-Rinse Greywater and Performance Testing Using Indigenous Staphylococcus spp. Water, 9(12), 963.
[19] Taghipour H, Mosaferi M, Armanfar F, Gaemmagami SJ (2013). Heavy metals pollution in the soils of suburban areas in big cities: a case study. Int J Environ Sci Technol, 10(2), 243–250.