Field Scale Demonstration of Novel and Economical Greywater Treatment System

A. Singh, Santhini S. Nair and S. T. Mehetre

Research Journal of Agricultural Sciences
An International Journal

P- ISSN: 0976-1675
E- ISSN: 2249-4538

Volume: 12
Issue: 05

Res Jr of Agril Sci (2021) 12: 1637–1640

CARAS

Res. Jr. of Agril. Sci. (Sep-Oct 2021) 12(5): 1637–1640
www.rjas.org

Full Length Research Article

Field Scale Demonstration of Novel and Economical Greywater Treatment System

A. Singh[1], Santhini S. Nair*[2] and S. T. Mehetre[3]

Received: 05 Jun 2021 | Revised accepted: 25 Aug 2021 | Published online: 22 Sep 2021

ABSTRACT

Grey water accounts for about 75% of the total household wastewater and is reusable if treated properly for activities like gardening, toilet flush, irrigation, car wash etc. and helps in saving 50-60% the total water we consume. This paper describes demonstration of novel and economical system capable of treating greywater and making it suitable for the above-mentioned purposes. The system has been designed by integrated scientific approach and successfully tested in the laboratory. Further a pilot plant for treatment of 400 L/day capacity has been installed for treating greywater generated at a hostel campus as a 'Lab to Land' model. The system consists a of 3 stage process comprising of bacterial treatment followed by filtration and disinfection at the end. Consortium of bacteria was used for treatment of waste water and resulted in complete removal of BOD and TSS levels to the extent by 90-95% and 75% respectively. The finally treated greywater was used for gardening purpose. The overall system helped in saving 50% of water consumed in the kitchen (approximately 400 L/day) and demonstrated a sustainable example of effective waste management and optimizing resource utilization.

***Key words*:** Demonstration, Field scale, Greywater, Microbial treatment

Globally about 2.1 billion people suffer from water scarcity, of these 844 million do not have even a basic drinking water service, this includes 263 million people who spend over 30 minutes per trip collecting water from sources outside the home and 159 million still drink untreated surface water received from streams or lakes [1]. In such a time it is crucial to manage water effectively and minimize its wastage so that it can be made available to those in need. Greywater comprises of household wastewater generated from kitchen sinks, bath and laundry excluding water from toilets and it amounts to 75% of the total household wastewater generated [2]. This water is an important untapped resource which has the potential to substitute drinking water for activities like toilet flush, gardening, irrigation and construction. Greywater characteristics vary from source to source and lifestyle of the residents, with values typically ranging from pH 6-9, turbidity 12-2131 NTU, TSS 11- 2180 mg/L, BOD 23-942 mg/L and COD 55-2000 mg/l [3].

There are many reports of systems to treat greywater including membrane bioreactors (MBR), biological aerated filters, rotating biological contractor (RBC), filtration-based systems of sand filters, reed bed or constructed wetlands [4-6]. However, these systems are either too costly, have high maintenance requirements, require skilled labour or too much space to operate smoothly [7]. This paper reports design of an economical and efficient greywater treatment system for processing kitchen water to make it suitable for garden purpose. Based on the testing of lab scale system, 06 bacterial strains were isolated and consortium has been developed for microbial treatment at first step [8]. Treated water was then passed through filtration stage to enhance the removal of colour, turbidity and suspended solids. Finally, disinfection was carried out using 2 ppm chlorine in order to eliminate any potential pathogens and make the water safe for reuse [9]. The entire process was initially tested and optimized at the lab level [10] and then scaled up for field implementation. The field setup has been installed at Indian Women Scientists Association (IWSA) campus at Vashi, Navi Mumbai. The campus has a working women's hostel and the installation was carried out with the objective of treating their kitchen greywater and reuse for gardening purposes in the campus itself.

MATERIALS AND METHODS

Design of the system

The greywater treatment system has been designed by series of plastic tanks for collection of raw greywaters,

* Santhini S. Nair
✉ santhini.nair@ves.ac.in

[1-2] VES College of Arts, Science and Commerce, Chembur, Mumbai - 400 071, Maharashtra, India

[3] NABTD, Bhabha Atomic Research Centre, Mumbai, Maharashtra, India

bacterial treatment, filtration followed by disinfection and storage of the treated greywater (Fig 1-2). Kitchen sink greywater was collected in a 250 L tank (Tank 1) and further passed to a 200 L overhead tank (Tank 2) for bacterial treatment (BT) using an electric pump. Aeration was done by using fish tank sparger (@ 10L/min) for uniform mixing of the greywater. This water was passed through a filtration stage (Tank 3) made up of different layers of gravel, geotextile cloth and charcoal with a head space of 20-25L. Finally, water was passed to tanks 4 and 5 for disinfection & storage respectively with a common outlet pipe for sending water for gardening and irrigation purpose. The treated water was tested after each step for parameters like BOD, TSS, pH, coliforms and odour to check its feasibility as per national guidelines for reuse [11]. All the tests were done as per the Indian standards IS 3025: 1983 and IS 1622: 1981.

Fig 1 Constructed greywater treatment system at IWSA (1) Greywater collection tank (White), (2) Aeration tank (up), (3) Filtration tank, (4-5) Disinfection and Storage tanks for treated water

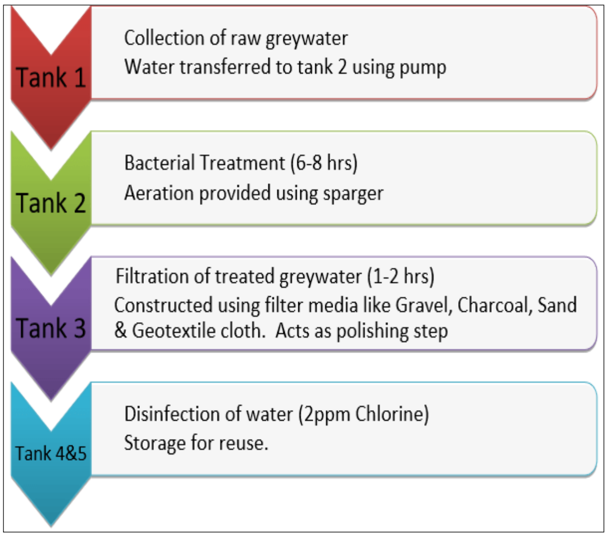

Fig 2 Flow diagram of the greywater treatment process

Flow of the greywater treatment process

- The water from the kitchen sink was collected in first tank (capacity 250 L) by passing through a steel mesh for removal of solids and coarse food particles. It was then transferred to tank 2 by using a pump after settlement.
- Tank 2 has been designed for microbial treatment of greywater with the provision of supplying air @ 10L/min by using fish tank sparger. Consortium of bacteria was selected on the basis of laboratory testing of 6 different strains (Singh et al., 2018a). Sufficient inoculum was taken to keep the culture density 5mg/L on the tank (amounting to 10^6 cfu/ml). Aeration also helped in thorough mixing thereby enhancing the circulation of nutrients in water. Microbial treatment was continued 6-8 hrs and further 90 % water was allowed to flow to next Tank 3. Water remained in the Tank 2 was used as a source of microorganisms (BS) for the next batch of greywater. Thus, the system was operated in a continuous manner and there was no need for addition of fresh inoculum for next treatment cycle.
- Tank 3 consists of filtration system developed by using different layers of sand, charcoal and gravels with 20-25 L head space to hold water.
- Further the water was collected in Tanks 4 and 5 for disinfection and storage purpose. Disinfection was carried out using chlorine (2 ppm). Residual chlorine level was checked at regular interval by using standard chlorine test strips. From tanks 4 and 5 treated water was taken directly through a common outlet and used for gardening and irrigation purposes.

Analysis of greywater

Greywater sample was analyzed at each stage of treatment process to check its suitability for reuse as per guidelines given by Central Pollution Control Board (CPCB, 2017). Parameters like BOD, TSS, Coliform count (MPN test), pH, DO and odour were analyzed as per the Indian standards IS 3025: 1983 and IS 1622: 1981.

RESULTS AND DISCUSSION

All the results are depicted in (Table 1) graphically represented in (Fig 2). BOD value of the inlet was in the range of 40-140 mg/L which was subsequently reduced to 9-17 mg/L and 2-6 mg/L after bacterial treatment (BT) and filtration stage respectively. Thus, there was 82% ± 5% reduction in BOD after bacterial treatment and 94% ±2% reduction after filtration stage.

Untreated greywater | After Bacterial treatment | After filtration

Fig 3 Greywater samples from the treatment system at IWSA

TSS values was in the range 80-250 mg/L for inlet water which was subsequently reduced to 40-110 mg/L and

20-60 mg/L respectively after bacterial treatment and filtration stages respectively. Thus, there was an average reduction 48% ± 11% in TSS after bacterial treatment and which was further reduced by 75% ± 5% at the end of filtration stage. pH of inlet samples was between 5.5 -6.5 and for outlet was 6.8-7.5 while DO values for inlet samples were 3-4 ppm and continuous aeration helped to maintain the DO of the outlet samples at the same levels. There were no offensive odours as conditions remained aerobic.

All these values were in the range of parameters as per national guidelines for reuse of treated greywater (CPCB, 2017). The finally treated water was clear, odourless, without any impurities (Fig 3) and suitable for reuse.

Table 1 BOD and TSS of test greywater treated with BT and BT + F

Sample	BOD value (mg/l)			BOD % removal		TSS Value (mg/l)			TSS % removal	
	Inlet (A)	BT (B)	Outlet BT + F (C)	A – B BT	A – C BT + F	Inlet (D)	BT (E)	Outlet BT + F (F')	D – E BT	D – F BT + F
1	89	17	6	80	93	190	80	50	58	69
2	40	9	2	78	95	80	50	20	37	75
3	140	15	6	89	96	250	110	60	56	76
4	60	12	5	80	92	100	60	20	40	80
Average	82.2	13.25	4.75	81.7	94	155	75	37.5	47.7	75
STDEV	43.4	3.5	1.89	4.92	1.82	79.37	26.45	20.61	10.7	4.54

A-B and D-E indicate sample tested after bacterial treatment (BT)
A-C and D-F' indicate sample tested after bacterial treatment + filtration (BT + F)

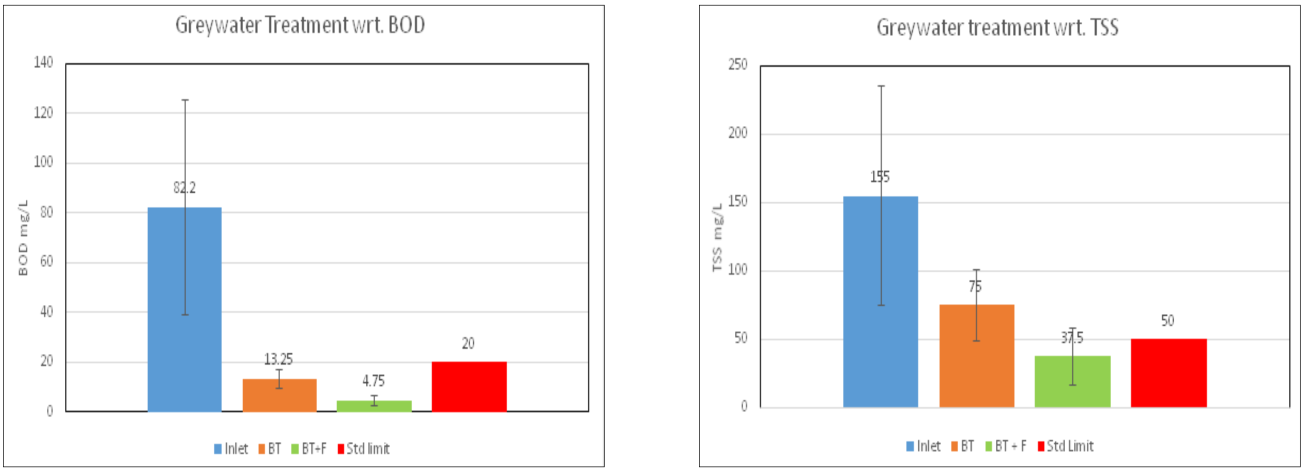

Fig 4 Graphical representation of BOD and TSS reduction

Microbial assessment of water

The microbial assessment of greywater was done for determining the coliform content of inlet and outlet water samples. The analysis was carried out as per the Indian standard guidelines and MPN values have been determined by multiple tube dilution method (IS 1622:1981). The treatment process recommends a disinfection step after filtration with 2 ppm chlorine and a residual Chlorine level of around 1 ppm post disinfection so that the treated water is free from coliforms and other faecal pathogens and be safely reused for gardening.

Table 2 MPN analysis of treated greywater samples by 15 tube method

Sample No.	Type of sample	No. of Positive presumptive tubes			MPN value
		0.1 ml	1.0 ml	10 ml	
1	Inlet	5	5	5	>1600
2	Outlet	0	0	0	>2
3	Inlet	5	5	5	>1600
4	Outlet	0	0	0	>2
5	Inlet	5	5	5	>1600
6	Outlet	1	0	0	2
7	Inlet	5	5	5	>1600
8	Outlet	0	1	0	2

The results of MPN analysis are given in (Table 2). It was observed that all the tubes were positive at initial stage containing high levels of coliforms which may be derived from raw vegetables or other sources. The organic matter present in greywater provides abundant nutrients for organisms to rapidly grow and multiply. However, at the end of treatment disinfection with chlorine led to most of the samples being negative and the coliform levels easily met the required guidelines (CPCB 2017). Thus, there was complete removal of coliform bacteria at the end of the treatment making water safe for reuse. The microbial treatment also helped in stabilizing the inlet greywater which otherwise is prone to fluctuation and shock loads [12] which can damage the sand and carbon filter. Thus, microbial step also helped in shielding the filter and increasing its life. The disinfection step reduced coliform levels and making water suitable for reuse.

There are many reports of small-scale demonstration plants of effluent water treatment. Friedlier *et. al*. [13] worked on a pilot plant that combined biological treatment (RBC) with physicochemical treatment (sand filtration and disinfection). This system produced effluent that met drinking water standards, thus ensuring safe reuse of the treated greywater for toilet flushing. Hussein *et. al*. [14] designed a treatment process incorporating different steps like addition of effective microorganism (EM), settling and aeration. This system gave overall removal rates of 98.4, 90.4, 95.7 and 98.4% for TSS, COD, BOD and oil and grease respectively. Zipf *et. al*. [15] evaluated the efficiencies of simplified treatments for greywater reuse using slow sand filtration, followed by granular activated carbon filters. They achieved average removal efficiencies of 61, 54, 56, and 56% for turbidity, apparent colour, COD and BOD respectively, For the sand filter, surfactant removal was around 70%, while the pH reached values of around 7.80. The average removal efficiencies of the total and thermotolerant coliforms were of 61% and 90%, respectively.

CONCLUSION

Newly developed greywater treatment process reduced BOD and TSS levels to 5 mg/L and 37.5 mg/L respectively after bacterial treatment and filtration which are well within the Indian guidelines for unrestricted reuse of treated wastewater. Apart from these other parameters like pH, DO, odour etc were also reduced significantly. Microbial treatment helped in removal of majority of pollutants and reduced BOD and TSS significantly. This reduction was further enhanced by the filtration step and the treated greywater was not only free from pollutants but also became more aesthetically acceptable. Thus, a novel and economic system has been successfully designed which is capable of treating kitchen greywater and reusing for purposes like toilet flush, gardening, car washing etc, which can significantly contribute in saving drinking water along with reducing the overall water demand and cutting down water bills as well. This technology has the potential to be implemented on a large scale and help in easing the current water crises that is afflicting not just India but also globally.

Acknowledgements

Author kindly acknowledges help and support of Padmashri Dr. Sharad P. Kale, Ex Head, NABTD, Dr. Surekha Zingde, IWSA and Ms. Vijayalaxmi Tilak.

LITERATURE CITED

1. WHO/ UNICEF. 2017. Progress on drinking water, sanitation and hygiene 2017 update and SDG baselines.
2. Eva Eriksson KA. 2004. Characteristics of grey wastewater. *Urban Water* 4: 85-104.
3. Ghaitidak D, Yadav K. 2013. Characteristics and treatment of greywater—A review. *Environmental Science and Pollution Research International*. doi:10.1007/s11356-013-1533-0
4. Hasan M, Shafiquzzaman M, Nakajima J, Kader TA, Shafiul AM. 2015. Application of a low-cost ceramic filter to a membrane bioreactor for greywater treatment. *Water Environment Research* 87: 233-241.
5. Friedler E, Kovalio R, Galil NI. 2005. On-site greywater treatment and reuse in multi-storey buildings. *Water Science and Technology* 51(10): 187-194.
6. John RB, Seabloom RW. 2004. Aerobic treatment of wastewater and aerobic treatment units. University of Arkansas, Fayetteville: University Curriculum Development for Decentralized Wastewater Management.
7. Li FB. 2008. Resources and nutrients-oriented greywater treatment for non-potable reuses. *Water Science and Technology* 1901. doi:0.2166/wst.2008.601
8. Singh A, Nair SS, Mehetre ST. 2018. Designing of a novel lab scale process for greywater treatment. *International Journal of Creative Research Thoughts* 6(1): 538-544.
9. EPA. 2017. Environment (Protection) Rules (EPA) Ministry of Environment and Forests (Department of Environment, Forest and Wildlife), (CPCB), New Delhi, India. (n.d.).
10. Singh A, Nair SS, Mehetre ST. 2018. Development of effective microbial consortium for greywater treatment. *International Journal of Scientific Research in Science and Technology* 4(5): 96-103.
11. Anonymous. 2006. Guidelines for drinking-water quality Recommendations. 3rd Edition. Geneva: World Health Organization.
12. Leal L. Hernández GZ. 2007. Characterisation and biological treatment of greywater. *Water Science and Technology* 193-200.
13. Friedler E, Kovalio R, Galil NI. 2005. On-site greywater treatment and reuse in multi-storey buildings. *Water Science and Technology* 51: 187-94. https://doi.org/10.2166/wst.2005.0366
14. Hussein I, Abdel-Shafy AMS. 2014. Greywater treatment via hybrid integrated systems for unrestricted. *Journal of Water Process Engineering*. 101-107.
15. Zipf MS, Pinheiro IG, Conegero MG. 2016. Simplified greywater treatment systems: Slow filters of sand and slate waste followed by granular activated carbon. *Journal of Environmental Management* 176: 119-127.