

Study on the efficiency of continuous flow-based constructed wetland system for grey water treatment

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*Article History:

Received: 02/06/2017

Accepted: 05/06/2017

DOI: <https://doi.org/10.7439/ijasr.v3i5.4198>

Abstract

Water is inevitable for our life. Due to the population growth, there is a tremendous pressure on the existing fresh water resources such as surface water and ground water. Increasing water demand and improper usage of potable water lead to scarcity of fresh water resources. Globally, treating grey water is a real constraint to minimize the problem of water scarcity. The continuous flow-based constructed wetland system for grey water treatment is a technique for reusing the domestic grey water and it is a low-cost method. The current study was aimed to evolve a suitable user-friendly treatment system for handling the household grey water. In the present study, grey water has been collected from the Bharathidasan University and it has been treated with biofiltration and rhizodegradation techniques using continuous flow-based constructed wetland system. The system has been found as more effective for treating the Physico-chemical parameters such as suspended solids, pH, electrical conductivity, TS, TDS, DO, BOD, COD, TOC, CO₃, HCO₃, SO₄, NO₃, PO₄, Ca, Mg, Na, K, total hardness, calcium hardness, chloride, and total alkalinity. The results reported the reduction in the biological oxygen demand (89%), chemical oxygen demand (81%), DO (95%), carbonate (100%), sodium (65%), and potassium (85%). It also examined the benefits and risks associated with the results in the reuse of domestic grey water for the purpose of vegetable gardening, irrigation, and toilet flushing. Consequently, this biofiltration method is natural, simple, and low cost-effective treatment in a holistic manner.

Keywords: Grey water, biofiltration, Rhizodegradation, phytoremediation.

1. Introduction

Water scarcity in the world is increasing day by day. It is essential to recover and reuse the wastewater from various routine activities. In domestic activities, there are three options for water reuse: rain water, grey water, and black water. In this study, grey water reuse by biological treatment and its reuse options were investigated. India is facing a stark water crisis and by 2025, it is estimated that India's population will be suffering from severe water scarcity; one in three will live in conditions of absolute water scarcity [1,2]. Grey water is wastewater generated from domestic activities such as laundry, dishwashing, and bathing that can be recycled on-site for reuse in landscape irrigation and constructed wetlands [3]. Grey water

comprises 50–80% of residential wastewater [4] and has lower concentration of organic compounds and fewer pathogens as compared to domestic wastewater [5]. Grey water reuse practice may reduce the demand for more water suited to domestic purposes.

Although the primary benefit of grey water reuse is that it conserves water resources for potable uses, despite it reduces the service demand on the potable water supply (source, treatment, and transmission), demands on the downstream wastewater infrastructure (collection, treatment, and disposal), and potential impacts on the receiving environment [6]. Grey water from single house premises may also be considered to be a potential resource and may be reused on-site for garden and lawn watering,

toilet flushing, and laundry use depending on the type of grey water and its level of treatment.

India is facing severe water scarcity due to rapid population growth and irregular monsoon. Total annual utilizable resources of surface water and ground water are 690 km³ and 396 km³, respectively [7]. There is a need for reuse of wastewater for preserving the precious fresh water resources. This study will focus on grey water treatment and its use as an alternative water resource in rural areas through an economical way. Our designed grey water treatment process is like a low technology systems, also called extensive or natural systems

2. Materials and Methods

2.1 Grey water sample collection

Grey water sample was collected from Bharathidasan University, Trichy. It was stored in syntax tank of 300 liter capacity. Continuous vertical flow based on constructed wetland system tank was constructed.

2.2 Designing of treatment tank

The kadappa slabs were used for the construction of four same rectangular bio-beds with proper dimensions [55.0 cm (l) x 39.5 cm (b) x 23.0 cm (h)]. All the treatment tanks were washed with tap water before treatment starts.

2.3 Experimental setup

Four experimental setups were designed for grey water treatment and their structures are given as follows.

2.3.1 Experimental setup of bio-bed I

The bio-bed I was divided into four vertical columns, each of 20 cm height. The first and third columns were made up of gravel (pea gravel), each 17 cm wide. The second and fourth columns contained sand (fine construction grade), each 10 cm wide making up (l X b X h) 55 cm X 39.5 cm X 20 cm. Water column of 3 cm height was allowed on top of this. The bio-bed I was initially washed with tap water to release the trapped air packs and void spaces. Then, the surface cover creeping plant (*Lipia nodiflora*) was transplanted into the bio-bed I, and the setup was undisturbed for 60 days, allowing sufficient growth of the plant. During this period, the tank was watered regularly for the growth of the plant. The bio-bed I was placed just below the outlet of the raw grey water collection tank for the easy flow of grey water. The flow rate of grey water was adjusted to 12.25 L/hrs.

2.3.2 Experimental setup of bio-bed II

Sand (7 cm), coir waste (6 cm), and sand (7 cm) were filled one above the other in the bio-bed horizontally up to 20 cm (h). The remaining 3 cm was to allow the water

sample. Similar to bio-bed I, *L. nodiflora* was transplanted into bio-bed II and the setup was kept undisturbed up to 60 days, allowing sufficient growth of the cover plant. The outlet from bio-bed I was connected to bio-bed II for the flow of treated grey water. Also, another outlet was set below bio-bed II for the treated grey water to flow into bio-bed III.

2.3.3 Experimental setup of bio-bed III

Gravel (2 cm) was added at the bottom of the bio-bed III followed by a thin layer (0.5 cm) of soft clay. Above these, red soil (14.5 cm) and humus (3 cm) were filled. The remaining 3 cm was allowed to hold the grey water. Bio-bed II-treated grey water was flown out into bio-bed III. The tillers of *Vetiveria zizanioides* were transplanted into the bio-bed III at the depth of 15 cm with interspaces of 5cm. This setup was kept undisturbed up to 60 days for allowing the sufficient growth of the plant. After the treatment of 10,500 L (at the rate of the 300lit/day) through the continuous vertical flow constructed wetland system, the bio-bed III was replaced with *Canna indica*. The system was thoroughly washed with tap water for the next operation; similarly, bio-bed III was replaced with *Typha angustifolia* after the treatment of another 10,500 L of grey water. A separate outlet from bio-bed III was connected to filter bed IV.

2.3.4 Experimental setup of filter bed IV

The filter bed IV was filled horizontally from the bottom to top with sand (8 cm) followed by charcoal (7cm) and again sand (5cm). The remaining 3 cm was unfilled to hold and allow the treated water samples from bio-bed III to enter into the structure. There is no plant material in filterbed IV. The separate outlet from filterbed4 was connected in order to receive the total treated water.

2.4 Grey water analysis

The grey water (clear supernatant wastewater after gravity settlement) samples were collected in a well-cleaned 25-l PVC container and stored in a 300L Sintex tank for further analysis. The grey water samples from each tank were collected at regular 1-hr intervals, and the parameters such as pH, EC, TDS, and DO were analyzed. The Physico-chemical parameters were determined for raw and treated (after it passed filter bed IV) grey water samples every day. The parameters such as pH, EC, and TDS were measured using field kit on the site, and other parameters (TA, CO₃²⁻, HCO₃⁻, TH, Ca H, Ca, Mg, Cl⁻, NO₃⁻, PO₄⁻³, SO₄⁻², Na, K, DO, BOD, and COD) were measured in the laboratory using the standard procedure (Table 1).

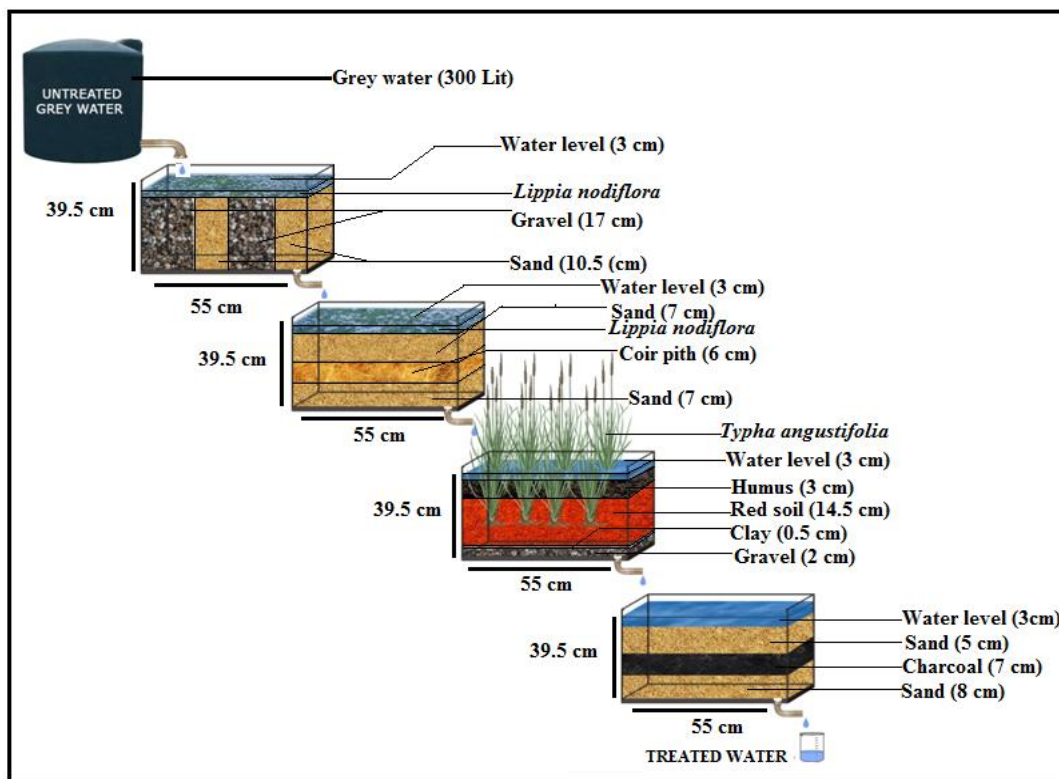


Figure 1: Experimental design: Continuous vertical flow based on constructed wetland system

3. Results and discussion

Table 1: Comparison of untreated and treated grey water continuous vertical flow constructed wetland techniques (flow rate 3.4ml/sec)

Parameters	Unit	Grey water				t value	P value
		Untreated		Treated			
		Mean	SD	Mean	SD		
pH	-	8.41	0.20	8.05	0.10	9.63	<0.001**
EC	μS/cm	1783.14	85.84	701.43	98.19	49.068	<0.001**
TDS	mg/L	1190	0.06	450	0.06	53.672	<0.001**
TA	mg/L	292.57	28.32	134.57	9.88	31.165	<0.001**
PA	mg/L	24.14	14.06	0.00	0.00	10.156	<0.001**
CO ₃ ²⁻	mg/L	28.97	16.88	0.00	0.00	10.156	<0.001**
HCO ₃ ⁻	mg/L	298.03	27.09	164.18	12.05	26.709	<0.001**
TH	mg/L	393.57	25.28	152.49	11.96	50.999	<0.001**
CaH	mg/L	211.66	12.22	85.29	7.76	51.645	<0.001**
Ca	mg/L	84.80	4.90	34.11	3.10	51.669	<0.001**
Mg	mg/L	44.29	3.23	16.29	2.09	43.012	<0.001**
Cl ⁻	mg/L	277.63	16.15	102.49	9.93	54.666	<0.001**
NO ₃ ⁻	mg/L	17.97	3.59	6.26	1.17	18.337	<0.001**
PO ₄ ³⁻	mg/L	3.52	0.16	1.00	0.14	70.992	<0.001**
SO ₄ ²⁻	mg/L	45.49	2.85	11.23	1.75	60.55	<0.001**
Na	mg/L	128.97	6.91	44.91	4.68	59.591	<0.001**
K	mg/L	20.49	5.38	3.14	0.36	19.043	<0.001**
DO	mg/L	0.17	0.12	3.35	0.27	63.493	<0.001**
BOD ₃	mg/L	143.00	8.21	15.71	2.75	87.001	<0.001**
COD	mg/L	390.11	14.43	73.89	5.33	121.606	<0.001**

Note: 1. ** denotes significance at 1% level (Test of significance through t test)

Comparison between untreated grey water and treated grey water shows more differences between untreated grey water and treated grey water with regard to *Typha angustifolia* plant, since P value is less than 0.01. Based on mean score, it is found that all the Physico-chemical parameter values are less in treated grey water than untreated water.

The biofiltration setups were performed by using low-cost materials, and their performances were evaluated. The low-cost materials such as sand, gravels, coir pith, red soil, clay, humus, and activated carbon were used in the biofiltration unit. The grey water sample was taken before and after biofiltration. The flow rate of biofiltration is 3.4ml/Sec. The samples were analyzed for the physical and chemical parameters to check the quality of grey water, and the data were subsequently used for the selection of treatment process. The data revealed that the pH of grey water was alkaline in nature. Table 1 shows the concentration of various parameters to remove load of pollutants before and after biofiltration of the grey water treatment system. The levels of pH were reduced from 8.41 to 8.05. The alkaline in the grey water is due to the soap and detergents. The effect of reduced alkaline was through biofiltration using the plants, which had absorbed the nutrients from the soil resulting in reduced alkaline during the study period. This result was in accordance with the results of Katell Chaillou *et al* [8]. Grey water was passed through a biofiltration bed. The biofiltration bed was designed to stabilize the flowing water or water is allowed to flow at a very low velocity. The heavier inorganic particles settled at the bottom of biofiltration bed and the lighter inorganic impurities float on the surface of liquid. It was observed that biofiltration bed Untreated grey water EC and TDS 1783.14($\mu\text{s}/\text{cm}$) and 1190 (mg/L), treated grey water 701.43 ($\mu\text{s}/\text{cm}$) and 450 (mg/L) of suspended matter and about 75% of bacterial load from water [9].

The data showed that biofiltration improved the quality of grey water. Total alkalinity was reduced from 292.57 to 134.57 mg/L, carbonate reduced from 28.97 to 0mg/L, bi-carbonate reduced from 298.03 mg/l to 164.18 mg/L, total hardness reduced from 393.57 to 152.49 mg/L, calcium hardness reduced from 211.66 to 85.29, calcium reduced from 84.8 to 34.11 mg/l, magnesium reduced from 44.29 to 16.29 mg/L, chloride reduced from 277.63 to 102.49 mg/L, nitrate reduced from 17.97 to 6.26 mg/ L, phosphate reduced from 3.52 to 1 mg/L, sulphate reduced from 45.49 to 11.23 mg/ L, sodium reduced from 128.97 to 44.91 mg/L, and potassium reduced from 20.49 to 3.14 mg/ L. The parameters such as DO increased from 0.17 to 3.35 mg/L, BOD reduced from 143 to 15.71 mg/L, whereas COD from 390.11 to 73.89 mg/L. The result showed that biofilter beds which were used instead of biofilter and

activated carbon showed better performance to remove the selected parameters of grey water [10,11]. After the investigation, due to the low energy demand, low operation and maintenance cost, and lesser time-consuming operation, this proved as a significant and efficient method for rural communities and small industrial units for treatment and reuse of grey water. In another study conducted for treatment of grey water by Physical (sedimentation, clarification and filtration), Chemical (oxidation) processes, hardness removal [12].

Percentage reduction of Physico-chemical and biological characteristics of grey water

Figure 2a: Percentage reduction of electrical conductivity and total dissolved solids

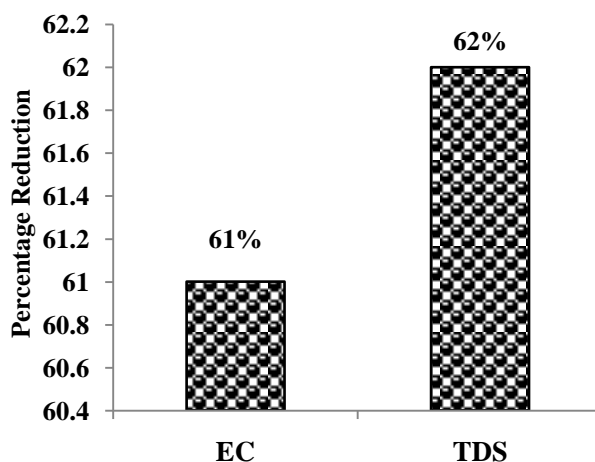


Figure 2b: Percentage reduction of phenolphthalein alkalinity, total alkalinity, carbonate, bicarbonate, total hardness, calcium hardness, calcium, and magnesium.

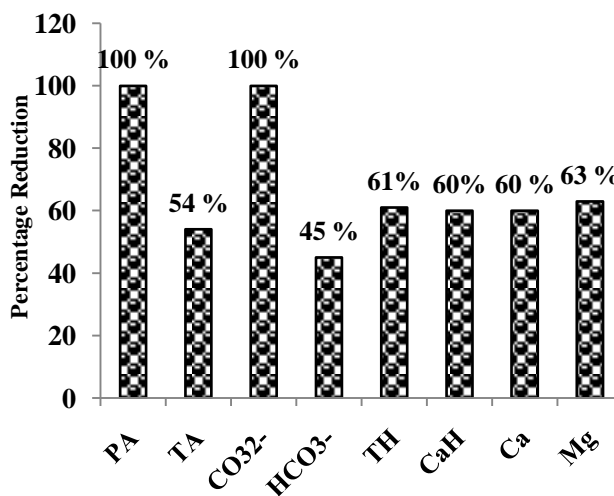


Figure 2c: Percentage reduction of chloride, nitrate, phosphate, and sulphate.

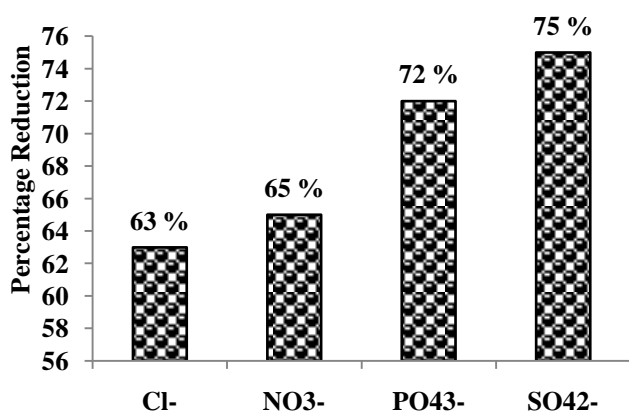


Figure 2d: Percentage Reduction of sodium and potassium

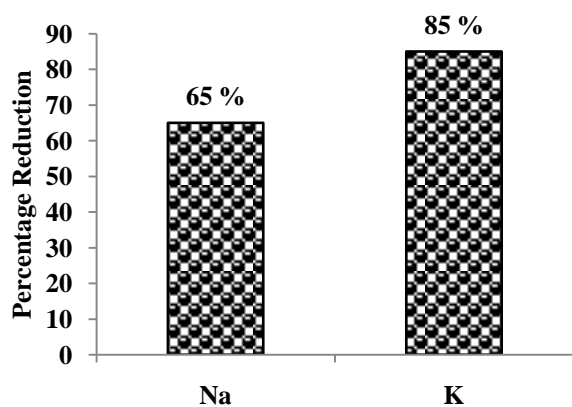
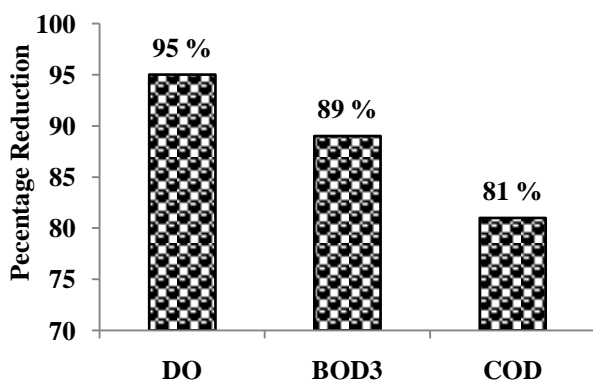


Figure 2e: Percentage reduction of Dissolved Oxygen, Biological Oxygen Demand and Chemical Oxygen Demand



4. Conclusion

The present study showed that the treated wastewater from continuous vertical flow constructed wetland can be utilized for landscape irrigation, gardening, plant growths, and toilet flushing. Based on the findings of this study, this treatment technology can be considered as a feasible alternative to conservative treatment plants. The designed low-cost technology for grey water treatment was found to produce grey water characterized by high potential

for BOD, COD, chloride, PO₄, and carbonate. The turbidity of the treated grey water is significantly reduced. Flocculation and disinfection unit need to be improved. There is a need to assess if the treatment and disinfection are effective against other microorganisms and viruses that are usually present in grey water. The consumable materials used in this system such as flocculants and disinfectants are reasonable and locally available materials such as sand, gravel, clay, red soil, humus, coir waste, charcoal, *Lippia nodiflora* and *Typha angustifolia* used in the grey water treatment were found to be effective purifiers. Hence, this method is environmental friendly, without chemical operation, and cost-effective. Furthermore, treated grey water becomes reusable after treatment and can be used for irrigating the garden or flushing the toilet and would not cause sewage sickness as that of sewage. However, the absolute efficiency of reusing treated water in flushing and gardening activity is yet to be known.

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