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Removal of Physicochemical Parameters of Grey Water Using Biofiltration Techniques

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Abstract

Wastewater from household use discharged to the environment without any sort of treatment, which causes harmful effects to the surroundings and surface ground water pollution. There are various treatment methods available for treating the grey waters with and without help of physical methods, chemical and biological materials. In the present study, the grey water samples were collected from the student hostel of Bharathidasan University on a daily basis around 35 days (300 liters/day). A total of 10,500 liter grey water was treated in this study through continuous (four different bio-bed) treatment tank processes with the help of natural absorbents such as sand, pea gravel, coir waste, charcoal, and *Lipianodiflora* and *Canna indica*. The combinations of these ingredients were aligned in the treatment tank with different propositions as well as different orders. The before and after treatment grey water samples were analyzed by physiochemical analysis. The range of physiochemical parameters such as pH, EC, TDS, total alkalinity (TA), total hardness (TH), dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD) in untreated and treated grey water were 8.3–8.7, 1812.0–1980.0 µS/cm, 1129.7–1220.0 mg/L, 272–330 mg/L, 384.2–455.0 mg/L, 0.2–0.6 mg/L, 137.6–157.1 mg/L, 362.9–420.0 mg/L; and 7.94–8.2, 642.3–760.0 µS/cm, 410–490.0 mg/L, 136–160 mg/L, 139.6–165.0 mg/L, 3.9–4.9 mg/L, 16.34–20.3 mg/L, and 68.2–78.0 mg/L, respectively. The 1–3-fold level of pollution was decreased in treated grey water than untreated grey water owing to the efficacy of bio-filters.

Keywords: Grey water, bio-bed filters, *Lipianodiflora*, *Canna indica*, physiochemical parameters.

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Introduction

Wastewater from your bathroom sinks, showers, tubs, washing machines, and other house hold wastewater are called grey water. It also does not have contact with fecal materials and toilet waste, washing diapers, and septic tanks (Little *et al*., 2001). It may contain traces of dirt, food, grease, hair, household cleaning products, and fewer pathogens. Normally, it is usually safer to handle and easier to treat and recycle onsite for toilet flushing, landscape or crop irrigation, and other non-potable uses. Gray water is distinct from black water in the amount and composition of its chemical and natural contaminates. However, the use of non-toxic and low-sodium soap and personal care products is recommended to keep vegetation not get affected when reusing grey water for irrigation purposes (Dixon *et al*., 1999).

The recycled grey water is used for toilet flushing, irrigation, etc., and this can considerably reduce potable water consumption (FBR, 2005). The contaminant load of grey water is less than that of domestic manure but it has the occurrence of fecal indicator bacteria in grey water (Casanova *et al*., 2001). This study investigated the presence of specific pathogens and indicator bacteria in grey water and calculated the performance of leading challenger treatment technologies for grey water reuse. The recycled grey water is loaded with nutrients such as nitrogen, potassium, and phosphorous, which can be used for irrigation, landscaping, and gardening. Benefits of grey water recycling and use include reduced fresh water use, decrease in the amount of wastewater to septic tanks or treatment plants, less chemical use, recharge of groundwater, useful for plant growth, and also raises awareness of natural cycles (Emerson, 1998).

The variety of conventional intensive technologies is in competition with natural systems to treat the grey water of medium and small size communities. The unique important feature of biological treatment is that it stabilizes the organic matter in a prohibited manner that otherwise causes problems, such as mosquito breeding, water and soil contamination, and blockage in the distribution systems used for irrigation and toilet flushing (Eriksson *et al*., 2002; Lina Abu Ghunmi*et al*., 2010). Experiences of treating gray water by natural and eco-friendly treatment systems have not been widely reported. To the best of our knowledge, this is the first report to treat the grey water through bio-bed process with a combination of soil and stones, and this is

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a less time-consuming and low-cost process.

Materials and Methods

Study Area and Sampling

The grey water samples were collected from the student hostel of Bharathidasan University, Tiruchirappalli, Tamil Nadu, India, on a daily basis for about 35 days. In this hostel, nearly two thousand students were staying and the ground water source was used for all purposes. 300 liters of water samples was collected and processed every day and a total of 10,500 liters were processed during this study.

Designing of treatment tank

Kadappa slabs were used for the construction of four same sized rectangular bio-beds with proper dimensions [55.0 cm (l) x 39.5 cm (b) x 23.0 cm (h)] **(Figure 1)**. All the treatment tanks were washed with tap water before treatment starts.

Experimental set-up of bio-bed 1

The treatment tank (TT) 1 was filled vertically with gravel (6–8 mm) and sand (2 mm) materials at 17 cm and 10.5 cm, respectively. The whole tank was filled with the same manner and it consists of 4 columns (2 gravel and 2 sand columns). The vertically assigned gravel and sand column was extended up to 20 cm in height (h). The remaining 3 cm was unfilled to allow the water samples entering into the structure. The TT was initially washed with tap water to release the trapped air packs and void spaces. Then, the *Lipianodiflora*was transplanted into the TT 1 and the set-up was not disturbed up to 60 days for allowing sufficient growth of *L. nodiflora*. During this period, the water was added to the TT1 regularly for *Lipianodiflora* and it acts as a vegetative cover of TT1. The TT1 was kept just below the grey water collection tank outlet in order to pass the grey water. The flow rate of grey water was adjusted to 3.4 mL/sec.

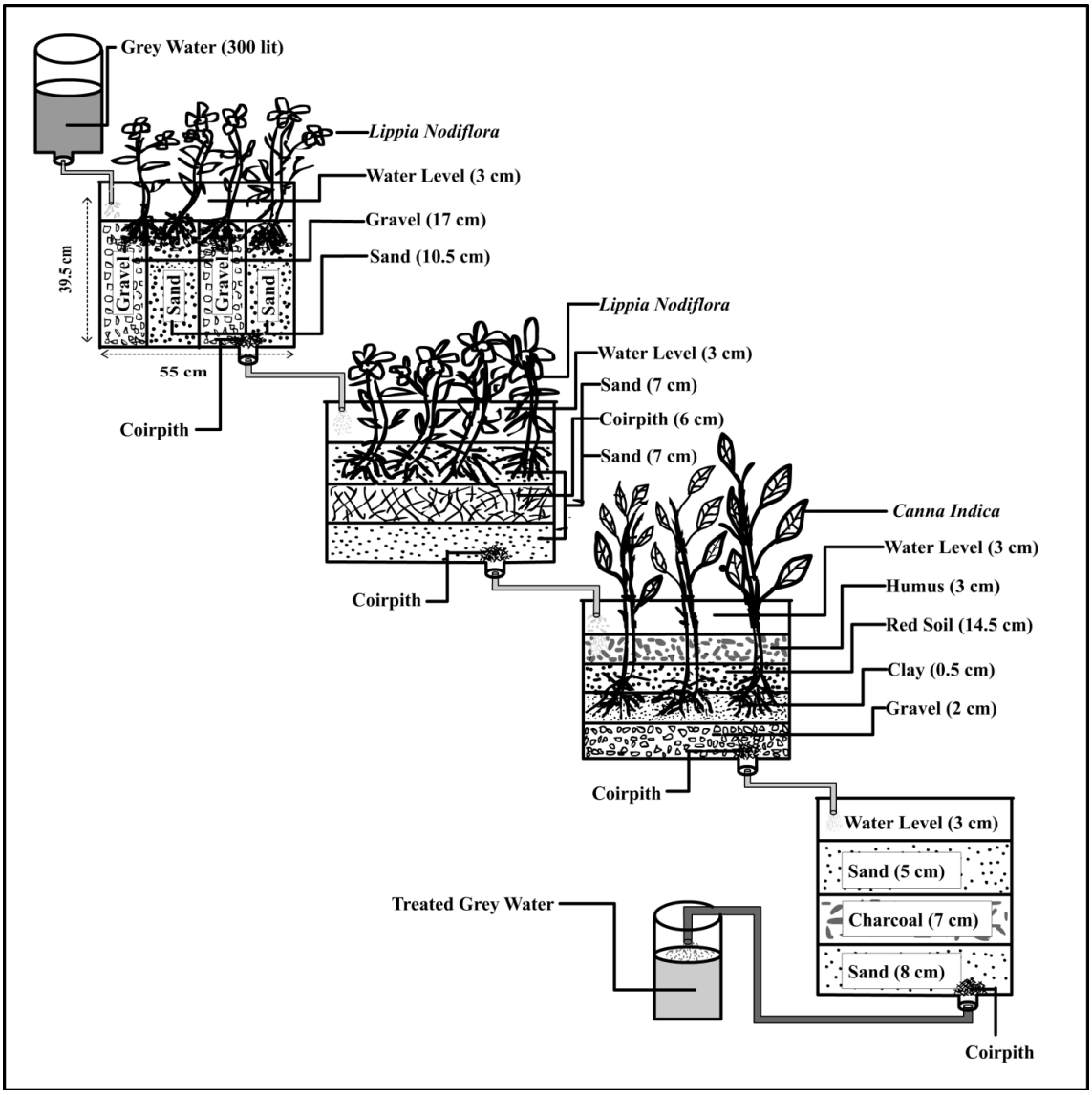


Figure I. Experimental set-up: Design of treatment tanks

Experimental set-up of bio-bed 2

Sand (7 cm), coir waste (6 cm), and sand (7 cm) materials were filled the TT2 horizontally up to 20 cm (h). The remaining 3 cm was unfilled to allow the water samples entering into the structure. Similar to TT1, the *Lipianodiflora*was transplanted into the TT2 and the set-up was not disturbed up to 60 days for allowing sufficient growth of *L. nodiflora*. The separate pipeline (outlet) from TT1 was connected with TT2, and the TT1 treated grey water was passed through this pipeline.

Experimental set-up of bio-bed 3

The gravel (2 cm) was added in the bottom of the TT3 followed by creamy layer of clay (which was collected from where it grew), red soil (14.5 cm), and humus (partially degraded plant debris) (3 cm). The remaining 3 cm was unfilled to allow the water samples entering into the structure. Then, the *Canna indica*(60 tillers) was transplanted into the TT3 with 15 cm depth, and each plant was transplanted with 5-cm gap. This set-up was not disturbed up to 60 days for allowing sufficient growth of *Canna indica*. A separate pipeline (outlet) from TT2 was connected with TT3, and the TT2 treated grey water was passed through it.

Experimental set-up of Filter bed 4

The TT4 was filled horizontally from the bottom with sand (8 cm) followed by charcoal (7cm) and sand (5cm).The remaining 3 cm was unfilled to allow the water samples entering into the structure. No plant materials were transplanted in the TT4.A separate pipeline (outlet) from TT3 was connected with TT4, and the TT3 treated grey water was passed through it.

A total of 10,500 liter of grey water was treated through TT system over a period of 35 days. The reason for keeping the standard 8-hour running period is in real-time situation, grey water generation at homes is taking place on an average for 8 hours (morning 10.30 a.m to evening 5.30 p.m).

Treatment processes

Physicochemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS) (Henna, HI 9811-5), and dissolved oxygen (DO) (Lutron, DO-5509) were measured using field kit on the site, and other parameters (total alkalinity, carbonate, bicarbonate, total hardness, calcium hardness, calcium, magnesium, chloride, nitrate, phosphate, sulphate sodium, potassium, dissolved oxygen, biological oxygen demand, chemical oxygen demand, and total organic carbon) were measured in the laboratory using the standard procedures (APHA, 2005; Vignesh *et al*., 2014, 2015, 2016). The physiochemical parameters were analyzed in both raw and treated (after it passed 4 TT) grey water samples every day.

Results and discussion

The range of physiochemical parameters such as pH, EC, TDS, total alkalinity (TA), total hardness (TH), dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD) in untreated grey water were 8.3–8.7, 1812.0–1980.0 µS/cm, 1129.7–1220.0 mg/L, 272–330 mg/L, 384.2–455.0 mg/L, 0.2–0.6 mg/L, 137.6–157.1 mg/L, 362.9–420.0 mg/L, respectively. The mean concentration of physiochemical parameters such as phenolphthalein alkalinity (PA), total alkalinity (TA), total hardness (TH), calcium hardness (CH), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), calcium (Ca), magnesium (Mg), chloride (Cl^-), nitrate (NO_3^-), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), sodium (Na), and potassium (K) in untreated grey water were 15.3, 272, 384.2, 205.5, 18.3, 294.6, 82.5, 43.4, 270, 18.09, 3.5, 45.20, 118.4, and 18.97 mg/L, respectively. During this study period (around 35 days), the parameters were not highly fluctuated and the untreated gray samples were collected from same place. The EC value of untreated grey water (routine kitchen waste of the Bharathidasan University hostel) was not crossed 1000 µs/cm as well as standard permissible level of WHO (2003) and BIS (1991). The physiochemical parameters of untreated and treated grey water samples were summarized in (Figures II–XV).

Waite (2006) reported that grey water in two sites at Oman had a mean EC of 817.0 µS/cm and 1045.2 µS/cm, respectively. Various studies on grey water quality in different countries have been published and the EC ranges from 325.0 to 1140.0 µS/cm (Jeppesen, 1996). Based on the Jeppesen (1996) report, the average EC level in our study was slightly increased when compared to the previous reports. According to the standard classification of EC of grey water (Eriksson *et al*., 2002), the results from the studied samples were within the range of around 1700–2000. This untreated grey water may be used for garden irrigation and the EC increases on a frequent basis, and for a prolonged period, certain sensitive plants could suffer salt injury (Eriksson *et al*., 2002).

Table 1
Comparison of untreated and treated grey water: physicochemical parameters in Canna plant (T-test)

Parameters	Greywater		t value	P value
	Untreated	Treated		
	Mean±SD	Mean±SD		
pH	8.33±00.21	7.94±00.10	9.722	<0.001**
EC (µS/cm)	1812.00±92.86	642.29±60.30	62.503	<0.001**
TDS (mg/L)	1130±00.06	410±00.04	60.839	<0.001**
TA (mg/L)	272.00±32.00	136.00±12.59	23.399	<0.001**
PA (mg/L)	15.29±15.00	0	6.030	<0.001**
CO_3^{2-} (mg/L)	18.34±18.00	0	6.030	<0.001**
HCO_3^- (mg/L)	294.66±12.26	166.03±15.37	38.699	<0.001**
TH (mg/L)	384.29±36.74	139.66±14.31	36.709	<0.001**
CaH (mg/L)	205.60±18.50	78.86±08.68	36.697	<0.001**
Ca^{+2} (mg/L)	82.34±07.41	31.60±03.46	36.697	<0.001**
Mg^{+2} (mg/L)	43.40±04.63	14.80±02.23	32.887	<0.001**
Cl^- (mg/L)	270.00±17.37	102.69±08.45	51.237	<0.001**
NO_3^- (mg/L)	18.09±03.33	5.57±00.85	21.550	<0.001**
PO_4^{-3} (mg/L)	3.55±00.17	0.93±00.09	80.239	<0.001**
SO_4^{-2} (mg/L)	45.20±03.27	8.89±01.13	62.084	<0.001**
Na^+ (mg/L)	118.40±18.67	25.43±03.23	29.026	<0.001**
K^+ (mg/L)	18.97±03.90	3.86±00.81	22.452	<0.001**
DO (mg/L)	0.19±00.16	3.93±00.51	41.446	<0.001**
BOD_3 (mg/L)	137.69±10.65	16.34±02.76	65.218	<0.001**
COD (mg/L)	362.91±29.56	68.23±06.70	57.521	<0.001**

Note : 1. ** denotes significance at 1% level

Table 2
Percentage reduction of Physicochemical and biological characteristics of Untreated and Treated greywater

Parameters	Untreated grey water	Treated grey water	% Removal
pH	8.33±00.21	7.94±00.10	5
EC (µS/cm)	1812.00±92.86	642.29±60.30	65
TDS (mg/L)	1130±00.06	410±00.04	64
TA (mg/L)	272.00±32.00	136.00±12.59	100
PA (mg/L)	15.29±15.00	0	50
CO_3^{2-} (mg/L)	18.34±18.00	0	100
HCO_3^- (mg/L)	294.66±12.26	166.03±15.37	44
TH (mg/L)	384.29±36.74	139.66±14.31	64
CaH (mg/L)	205.60±18.50	78.86±08.68	62
Ca^{+2} (mg/L)	82.34±07.41	31.60±03.46	62
Mg^{+2} (mg/L)	43.40±04.63	14.80±02.23	66
Cl^- (mg/L)	270.00±17.37	102.69±08.45	62
NO_3^- (mg/L)	18.09±03.33	5.57±00.85	69
PO_4^{-3} (mg/L)	3.55±00.17	0.93±00.09	74
SO_4^{-2} (mg/L)	45.20±03.27	8.89±01.13	80
Na^+ (mg/L)	118.40±18.67	25.43±03.23	79
K^+ (mg/L)	18.97±03.90	3.86±00.81	80
DO (mg/L)	0.19±00.16	3.93±00.51	95
BOD_3 (mg/L)	137.69±10.65	16.34±02.76	88
COD (mg/L)	362.91±29.56	68.23±06.70	81

(**Concentration is reported as Mean values ± Std. deviation**).

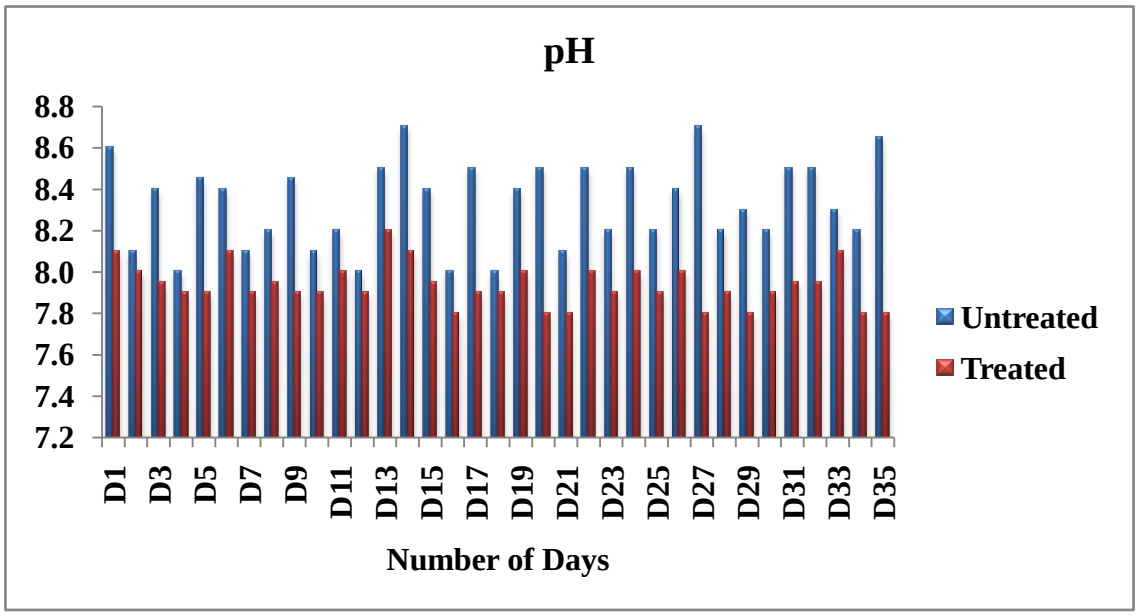
This treatment study demonstrated that there is potential for application of low-technology grey water treatment at small-scale level. The pollutant (organic matter, nutrients, and bacteria) removal efficiencies achieved by treating grey water with a sand, gravel, and two important plants indicated that the bio-filters could reduce (1-3-fold) the pollution load in grey water. The range of physiochemical parameters such as pH, EC, TDS, total alkalinity (TA), total hardness (TH), dissolved oxygen (DO), biological oxygen demand (BOD) and chemical oxygen demand (COD) in treated grey water were 7.9–8.2, 642.3–760.0 µS/cm, 410–490.0 mg/L, 136.0–160 mg/L, 139.6–165.0 mg/L, 3.9–4.9 mg/L, 16.34–20.3 mg/L, and 68.2–78.0 mg/L, respectively. The mean concentration of physiochemical parameters such as phenolphthalein alkalinity (PA), calcium hardness (CH), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), calcium (Ca), magnesium (Mg), chloride (Cl^-), nitrate (NO_3^-), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), sodium (Na), potassium (K) in treated grey water were 0.0–0.0, 78.8–95 mg/L, 0.0–0.0, 166.03–195.2 mg/L, 31.60–38.1,14.8–19.4, 102.69–117, 5.5–6.9, 0.9–1.2, 8.8–13.7, 25.43–33.2, and 3.8–5.1 mg/L, respectively. Pollutant removal processes may delay through the usage of different filters and also biofilm formation, particle agglomeration, and loss of efficiency in biological things (Campos *et al*., 2002). The treatment system successfully reduced the load of the pollution in a large extent due to the absorption efficacy of plants.

Conclusion

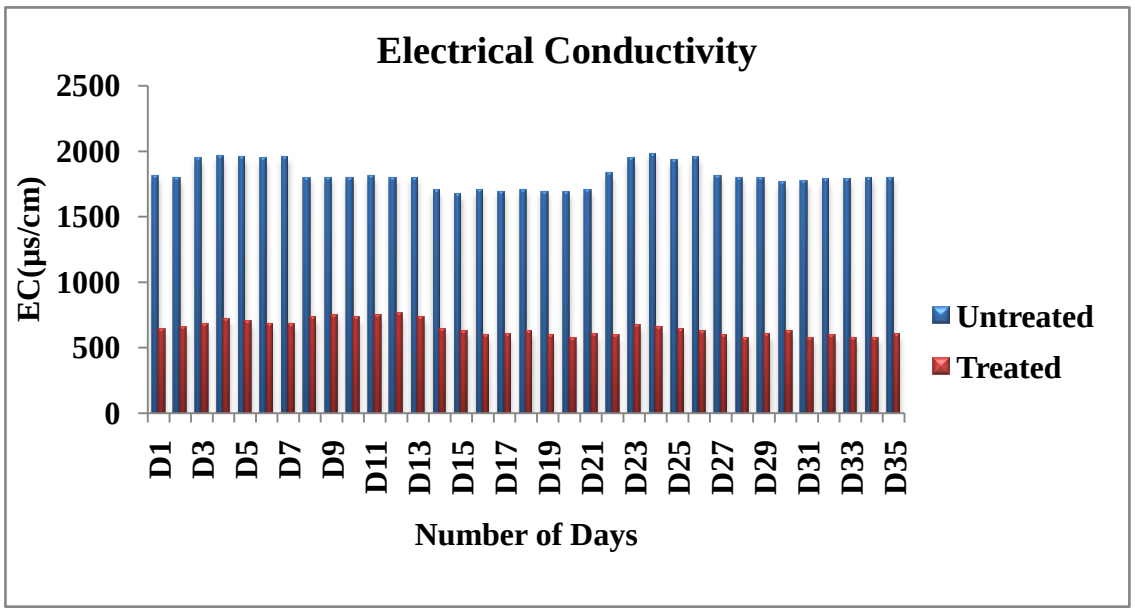
The continuous treatment (bio-bed) system greatly improved the grey water quality with a low-cost process and the process is less time consuming. The different bio-bed filters were designed with low cost and easily available raw materials and eco-friendly materials for treatment process. The bio-bed filters gradually reduced the pollution due to use of natural filters such as sand, pea gravels, and plants. Even though the different bio-beds reduced the level of physiochemical parameters in grey water, the treated water contained low range of all the parameters, except a few parameters. Based on the findings of this study, this treatment technology could be considered as an alternative methodology to treat the grey water in both small- and large-scale level. The benefits found are low energy demand, less operating and maintenance cost, highly effective purification, and less area occupied. Hence, this study concluded that bio-bed-based treatment is effective than other natural treatment processes.

Figure

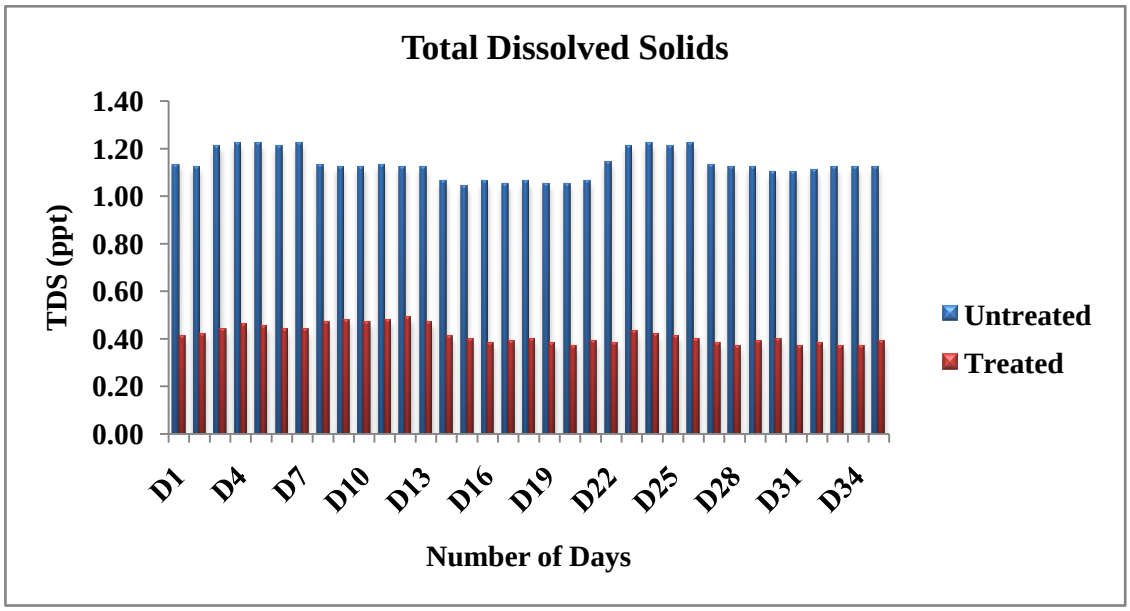
1. pH of Untreated grey water and Treated Grey water



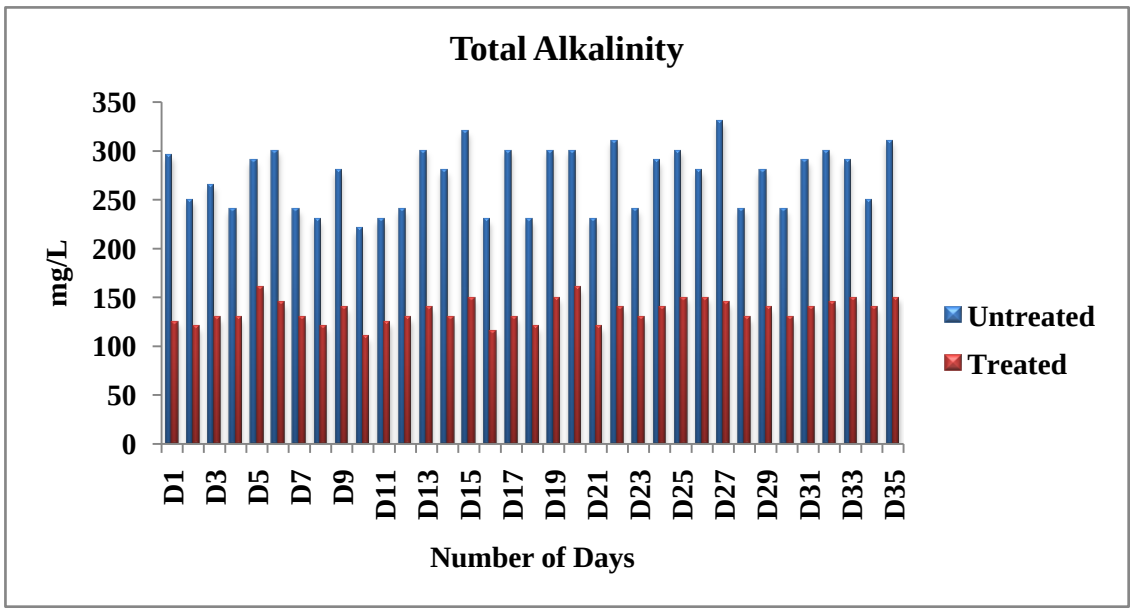
2. Electrical Conductivity of Untreated grey water and Treated Grey water



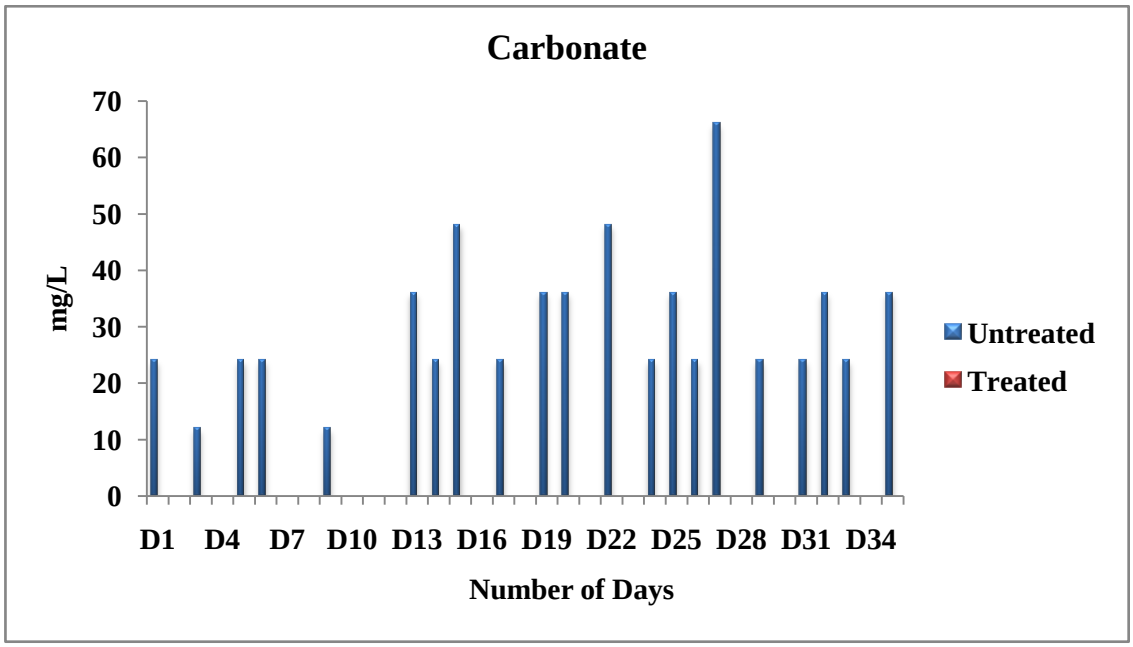
3. Total Dissolved Solids of Untreated grey water and Treated Grey water



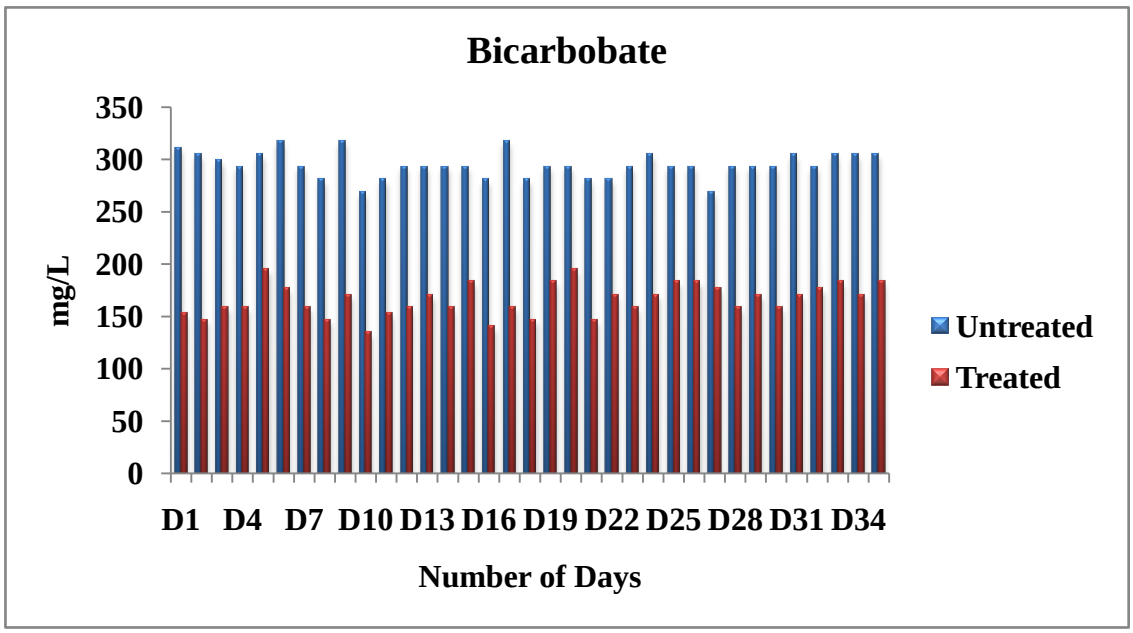
4. Total Alkalinity of Untreated grey water and Treated Grey water



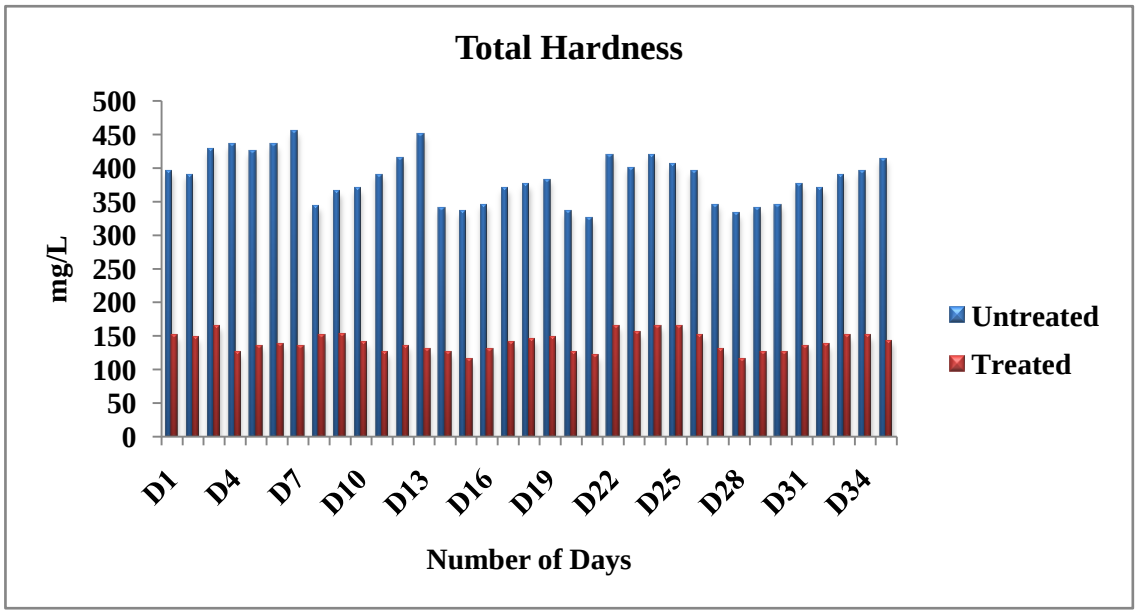
5. Carbonate of Untreated grey water and Treated Grey water



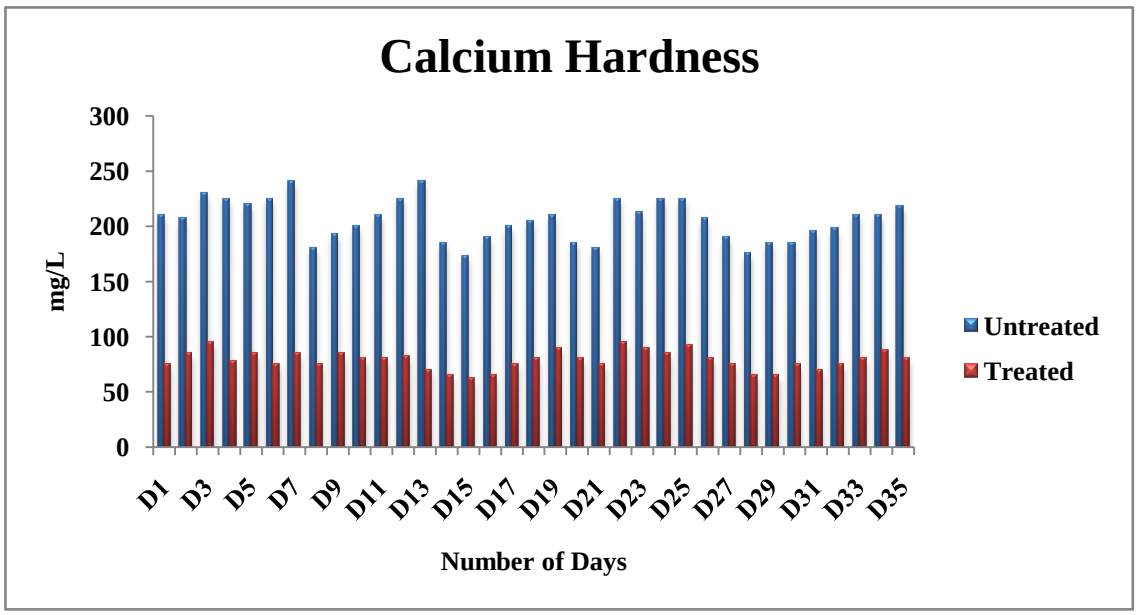
6. Bicarbonate of Untreated grey water and Treated Grey water



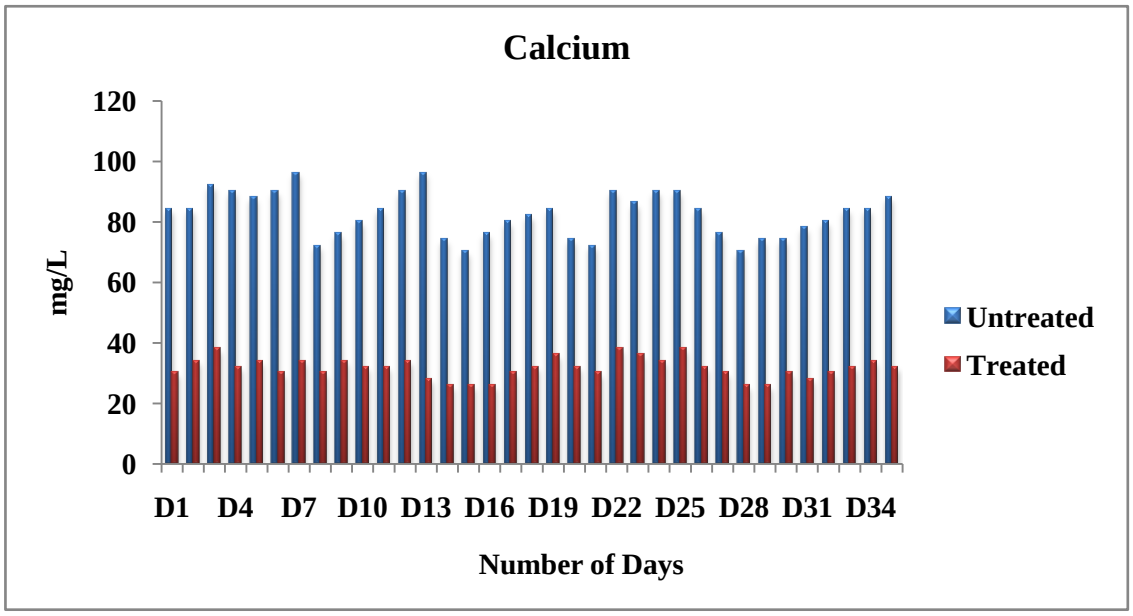
7. Total Hardness of Untreated grey water and Treated Grey water



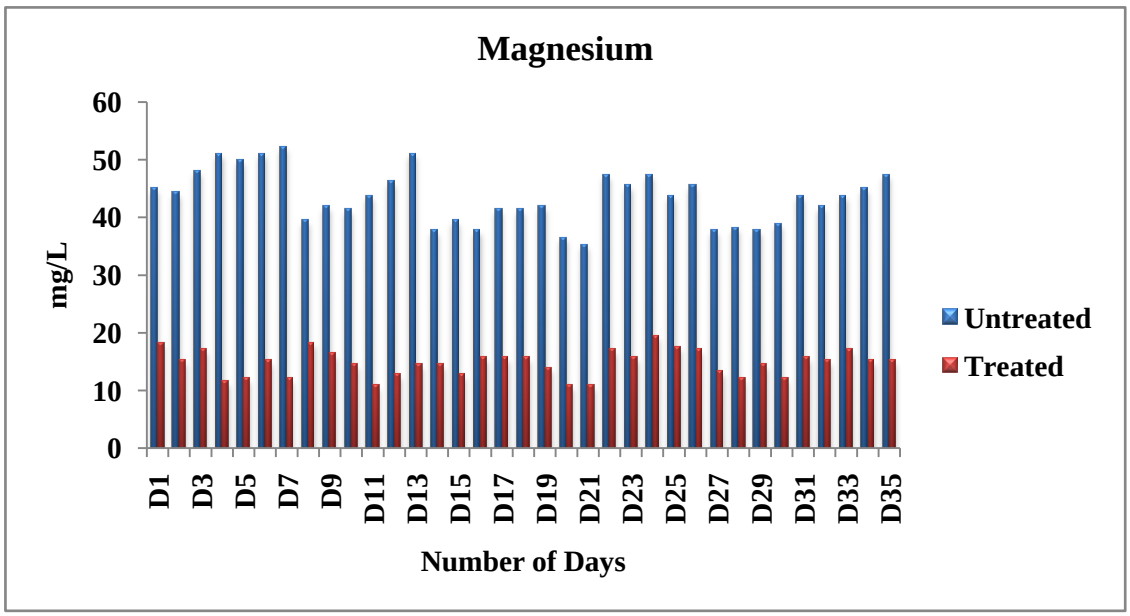
8. Calcium Hardness of Untreated grey water and Treated Grey water



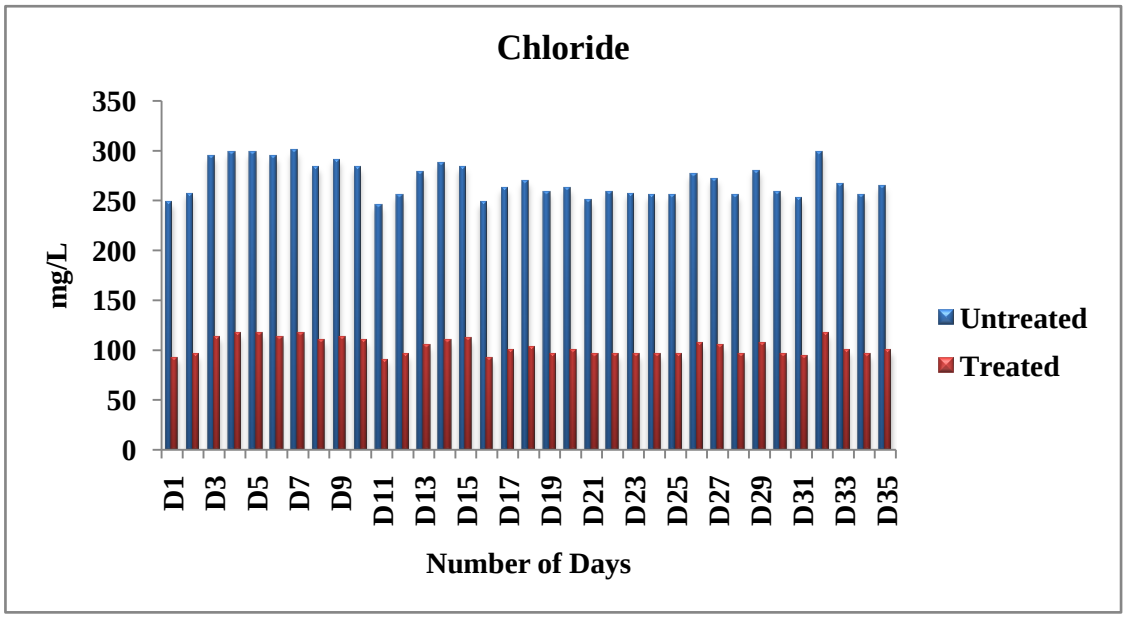
9. Calcium of Untreated grey water and Treated Grey water



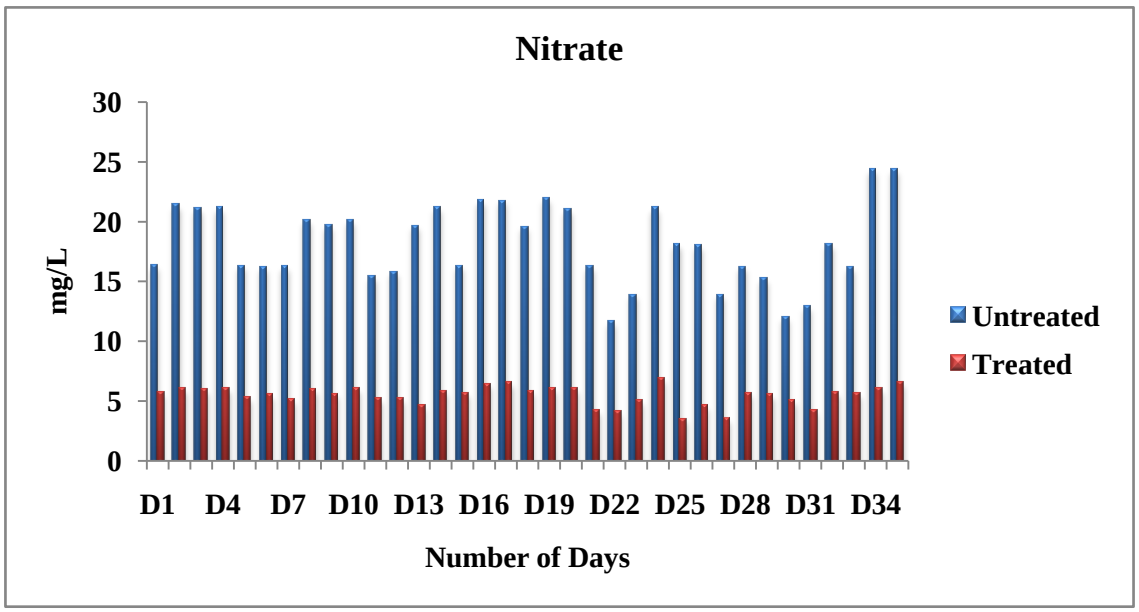
10. Magnesium of Untreated grey water and Treated Grey water



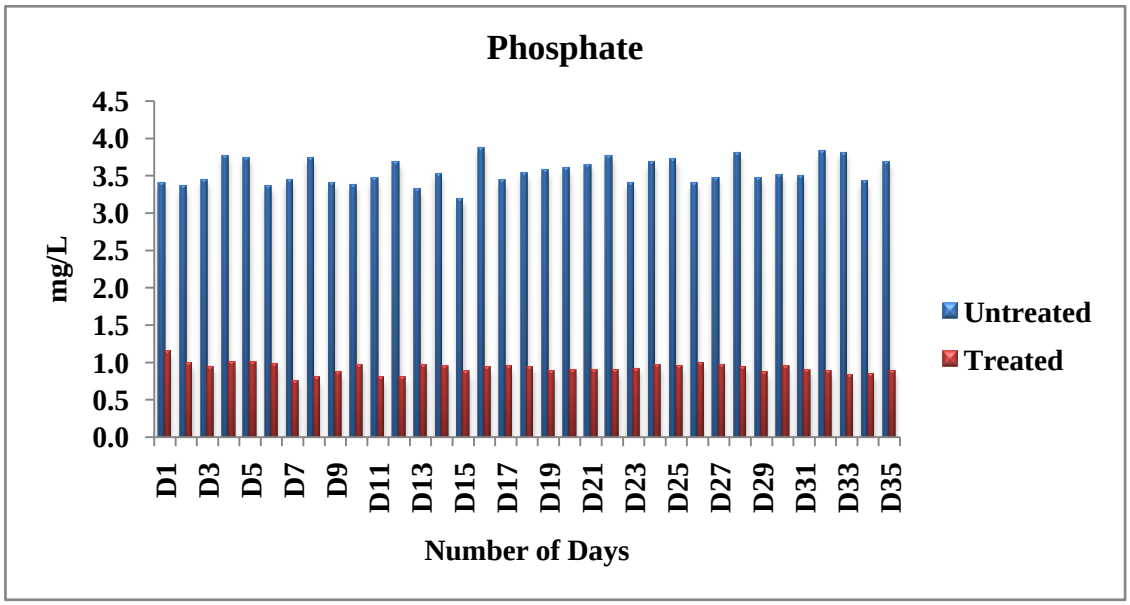
11. Chloride of Untreated grey water and Treated Grey water



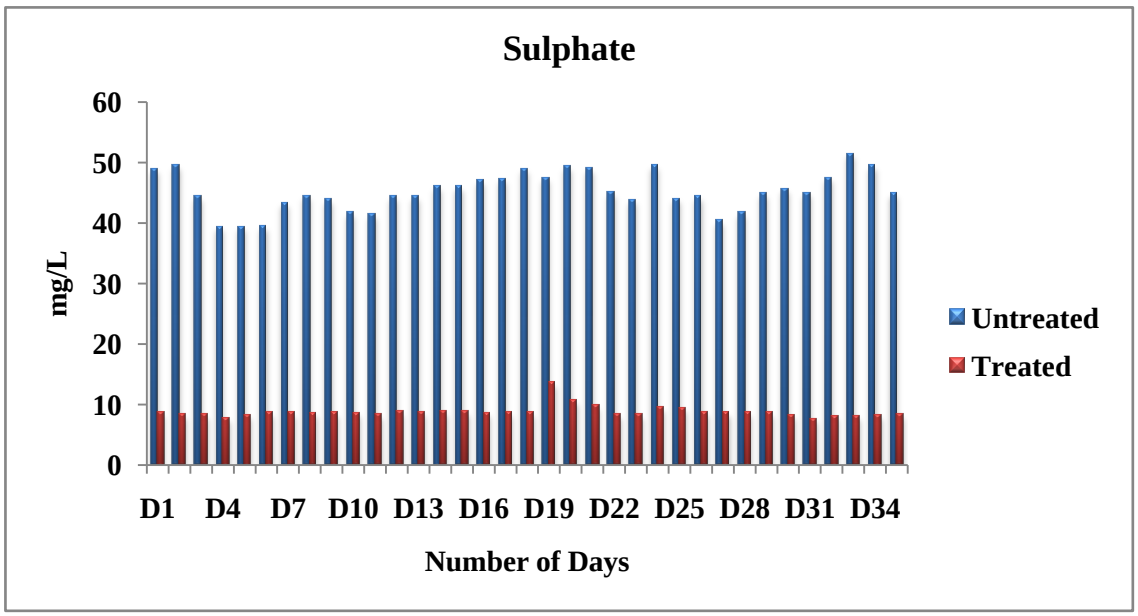
12. Nitrate of Untreated grey water and Treated Grey water



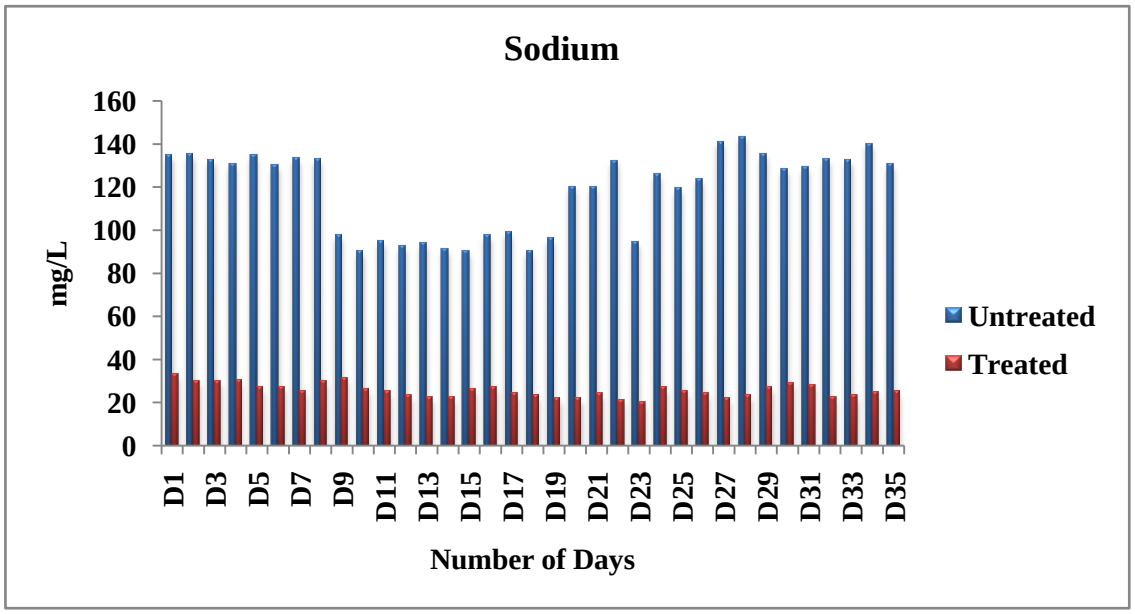
13. Phosphate of Untreated grey water and Treated Grey water



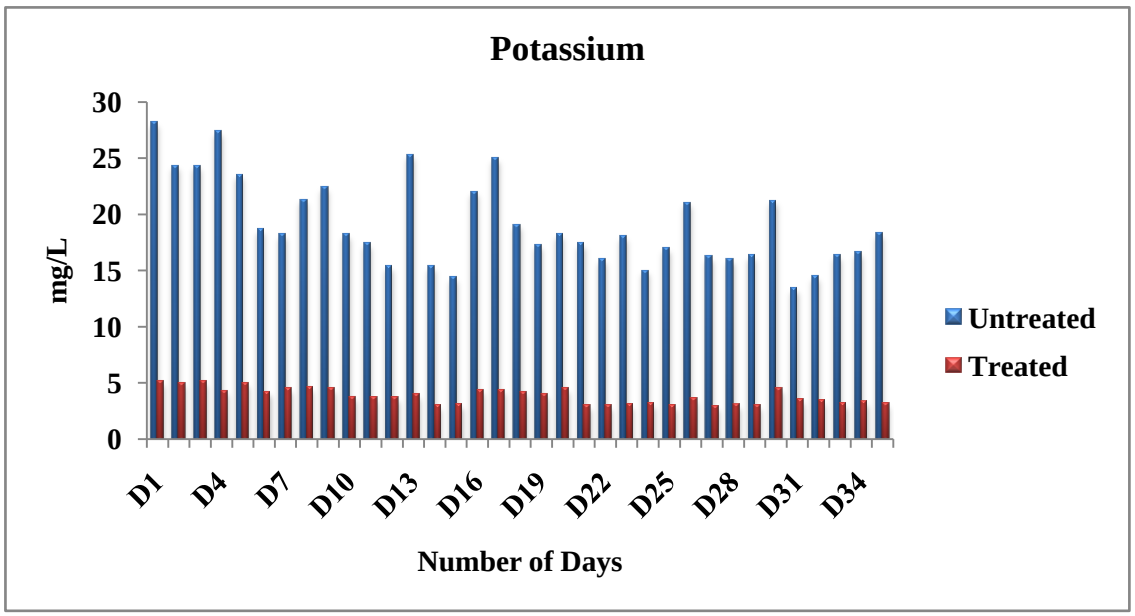
15. Sulphate of Untreated grey water and Treated Grey water



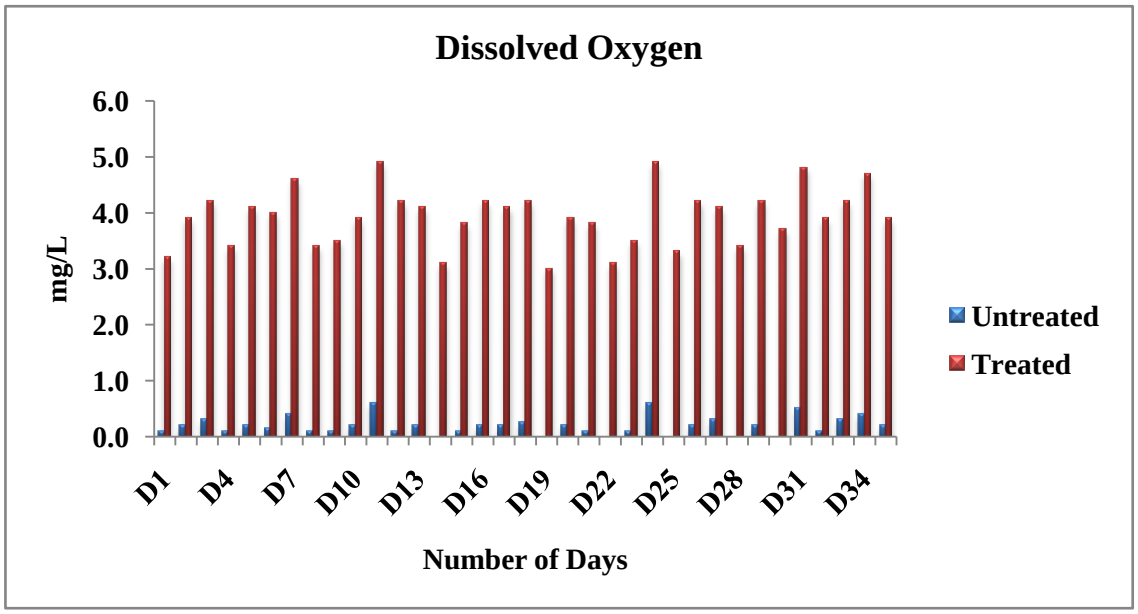
16. Sodium of Untreated grey water and Treated Grey water



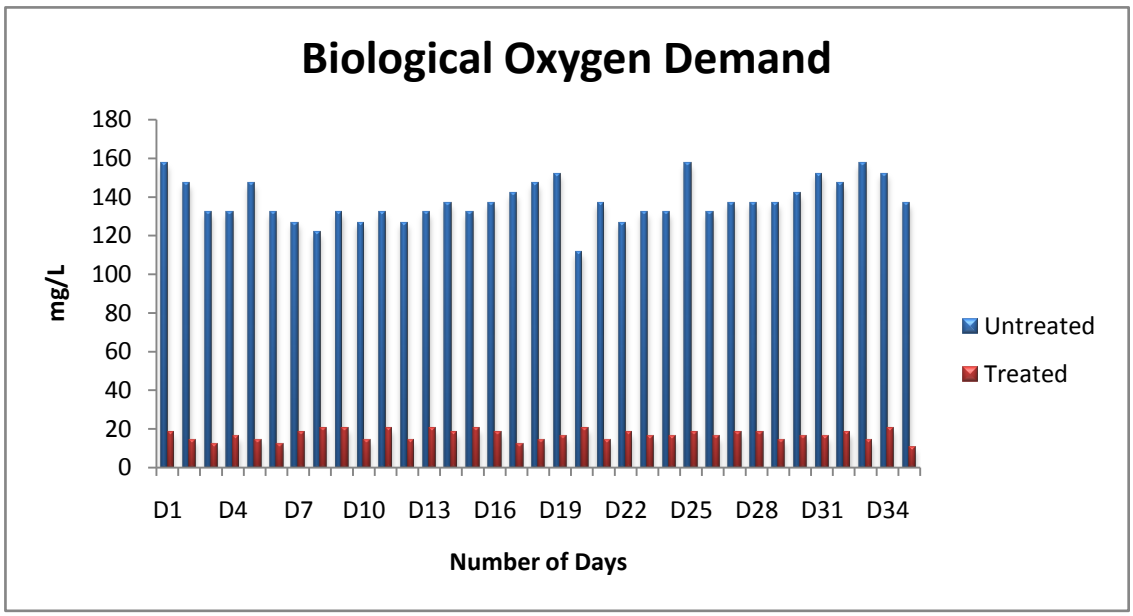
17. Potassium of Untreated grey water and Treated Grey water



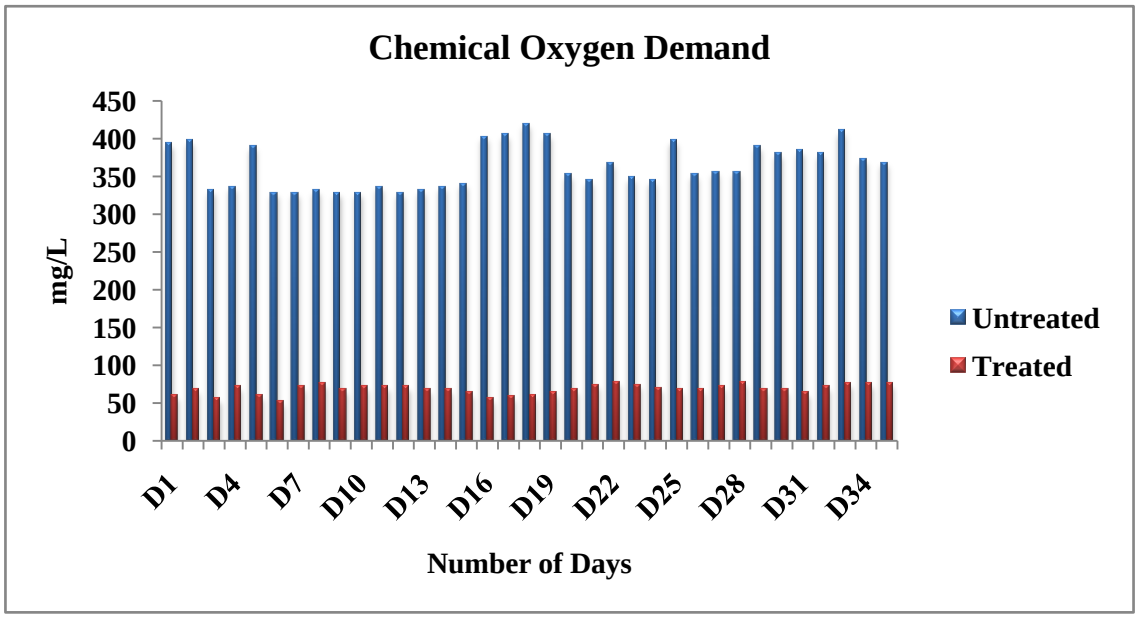
18. Dissolved Oxygen of Untreated grey water and Treated Grey water



19. Biological Oxygen Demand of Untreated grey water and Treated Grey water



20. Chemical Oxygen Demand of Untreated grey water and Treated Grey water



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