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Research Article
Grey Water Treatment Using Effective Micro-organisms and its Impact on Water Qualities

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Abstract

Background and Objective: Scientific knowledge, pertinent to the bio-remediation method adapted in sewage treatment plant for grey water effluent recycling has to be developed. Physico-chemical and biological water quality monitoring and analysis from the treatment would proven to the treatment efficiency. The present study was attempted to treat the domestic effluent of grey water category using Effective Micro-organisms (EM) in the sewage treatment plant (STP) of Thiagarajar College, Madurai, India and the physico-chemical qualities and microbial population were examined, for the water samples collected from different treatment points of the STP. **Methodology:** Effective micro-organisms in the extended form, following fermentation was used as the bio-remediation way of grey water recycling. Water samples were collected at different treatment points of the STP, for water quality analysis. Microbial population was analyzed using presumptive test and the colony growth was determined and bacterial growth curve was analyzed for the survival potential of isolated bacterial organism in the water treatment environment. Multi-variate statistical analysis was performed to compare between the treatment points on their water quality. **Results:** A considerable reduction in the BOD, acidity, nitrogen level, moderation of acidic pH, close to neutral. Dendrogram analysis revealed that a greater variability was found for conductivity of the water sample either with TDS and hardness, whereas the later two components show closer similarity. The BOD, alkalinity, hardness and sulfate showed the strongest weight age, when compared to the other analyzed parameters, through Principal Component Analysis. **Conclusion:** Microbial method of effluent recycling efficiently controls the physical, chemical and biological pollutants and contaminants from the domestic grey water. *Staphylococcus aureus* microbial population was found removed completely, following the recycling done in this experiment.

Key words: Grey water recycling, effective micro-organisms, physico-chemical water quality, microbial population, bacterial growth analysis

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Grey water (GW) is a low strength effluent, mainly released from point sources viz., house-hold bathrooms, kitchen and residential places. Direct discharge of grey water into the land or careless land-filling of effluent have always resulted in deleterious effects on land and water resources, eventually causing poor hygienic conditions, further posing health risks[1]. The major challenge in treating the grey water discharged from domestic sources is the prevalent of deteriorating water quality, mainly due to the contaminants released after the utilization of water in domestic purpose[2]. Removal of contaminants has often been experienced with a significant reduction of environmental risk, thereby maintaining an acceptable level of water quality[3]. Grey water, after recycling has been found with potential reuse values in farming practices, landscaping, recharging of aquifers, by means of safe land-filling and hence this practice enables the preservation of the fragile water resources, which has been under heavy exploitation[4].

Domestic effluents contain several complex substances, besides the existence of pathogenic microbes[5]. The presence of contaminants hampers the efficiency of recycling through the conventional treatment process, leads to difficulty of achieving the goal of purifying water by recycling[6]. The treatment of effluents, released from slaughter houses, using bed reactor significantly controlled the BOD (biochemical oxygen demand), COD (chemical oxygen demand) and TSS (total suspended solids) levels, however, the foul odor could not be removed[7]. Anaerobic digestion, employed in the palm oil mill effluent treatment emitted natural gas, besides the tainted odor removal[8].

Effluent treatment with a relatively high buffering activity was proven with a considerable reduction of sludge formation and therefore the operative cost could be reduced[9]. An alternate, cost-effective bioremediation principle[10], using micro-organisms and their metabolic substances including microbial enzymes, synthesized in this process, oxidize the pollutants into simpler, non-polluting substances and debris, thereby contributing to efficient recycling of wastewater[11]. Emphasizing the importance of the bioremediation process, which contributes substantially towards a safe environment owing improved human health[12,13], this experiment was focused on the domestic effluent treatment through bio-augmentation. In an earlier study, using Effective Micro-organisms™ (EM), grey water recycling experiment was executed in simulated laboratory conditions and in a constructed wetland, achieved with desirable water quality[14], through combined EM and STP treatment of grey water. The extent of physical, chemical and biological qualities could be achieved in the grey water treatment using Effective Micro-organisms™ (EM), in the Sewage Treatment Plant (STP) and whether the different time intervals on the treatment of grey water, using EM has any difference or not in the water quality, following treatment has to be understood[15]. To address this research problem, the present study was attempted grey water recycling using Effective Micro-organisms, applied on daily basis in a STP. Water quality analysis was performed repeatedly for three experimental periods, for the water samples collected from different treatment points in the STP. Further, multivariate analysis was performed on the water quality data, to test the efficacy of the treatment process.

MATERIALS AND METHODS

Site description: The experiment was carried out in the Sewage Treatment Plant of Thiagarajar College, Madurai, Tamil Nadu, India. The eco-climate of Madurai is semi-arid and temperature ranges between 38°C (maximum) and 24°C (minimum). Grey water is made to be collected to that STP, from bathrooms of the students' hostels, kitchen and canteen at an average of 14,000 L of wastewater, on daily basis.

Description of STP: The design of the STP is depicted in Fig. 1. It has an inflow collection tank where primary treatment is employed by adding extended or fermented effective micro-organisms. Effluent is pumped into the aeration tank, where aeration is done using one 10 HP mechanical air compressor. Then the aerated effluent is pumped into a settling tank and further the purified water is collected for storage, from where, the treated water is used for landscaping and irrigation of garden plants.

EM preparation and application: Extended form of EM through fermentation of the original form of the culture was prepared by dissolving commercially available EM, mixed in country sugar solution in 1:20 ratio (V/V), using non-chlorinated water. The prepared culture was kept in a clean plastic bottle, closed air-tight and stored in darkness for a week with the occasional release of air, collected over the surface above the fermented culture. The preparation of EM *Bokashi* (Jp: fermented) is elaborated in the previous study[16]. Every day morning on the experimental period, one *Bokashi* ball weighing approximately 100 g was introduced in the inflow tank of the STP, to facilitate perpetuation of microbial population and their biological activity of oxidizing the organic matter.

Collection of water samples: Water samples were collected for three periods, viz., December, 2015 (winter), March (summer) and July, 2016 (monsoon period) from the STP at four treatment points, during the recycling viz., (i) Raw sewage from the inflow tank, (ii) Aeration tank, (iii) Settling tank and (iv) Treated water from storage tank. Samples were collected from each treatment process, during of the study period. Water samples were collected in separate, clean polythene bottles and stored at 20°C in the refrigerator for further analysis.

Physical nature and water chemistry analysis: Water analysis was done in terms of physical nature, water chemistry and biological organisms and their activity. Standard methods of APHA[17] was followed in the analysis of pH, DO, salinity, conductivity and TDS using water analyzer Kit (Systronics Make, Model: 371). The combined values of alkalinity and conductivity were taken as the total hardness of the water samples. Total nitrogen and sulphate were estimated using wet chemical analysis.

Microbial study: Water samples were prepared using double distilled water to obtain 10^{-3}, 10^{-4} and 10^{-5} dilutions and from this, 0.1 mL sample was inoculated into sterilized Petri plates, containing nutrient agar, to test for the existence of bacterial organisms. Similarly, another set of experiments were performed using 10^{-6} and 10^{-7} dilutions of waste water samples, from the four collection points of STP into Potato Dextrose Agar (PDA) medium contained Petri plates, to analyze the fungal organisms. All the preparations were done under sterilized conditions in the Microbiology lab. Growth of the bacterial and fungal organisms were monitored and the colonies grown in the respective plates were isolated and cultured further to identify the presence or absence of colic bacteria, presumptive test was done to confirm the gas and acid producing ability of microbial population, isolated from the grey water samples, subjected under different treatment stages in the constructed wetland.

The EMB and ENDO agar streak tests were performed for the purpose of presumptive test, for which the experimental culture plates were incubated at 37°C for 2 days. The IMViC test was performed to check the presence of enteric bacterial group in the collected waster samples. Bacterial growth curve was plotted by transforming the bacterial count into the corresponding log normal values, to determine survival potential of the isolated bacterial organisms.

Statistical analysis: Statistical procedure was applied to compute the data using SPSS (version 16.0) for descriptive statistics, one-way ANOVA test, analyzed at 95% confidence level, correlation, cluster analysis and Principal Component Analysis (PCA).

RESULTS

Physical and chemical qualities of grey water: The acidic pH of raw domestic effluent was increased and thereby, reached to near neutral pH, following the treatment process. A considerable reduction in the TDS and BOD levels and about 50% reduction of acidity could be achieved in the recycling experiment (Fig. 2). It was also observed that the water samples collected from the settling tank and storage tank for the recycled water showed a significant reduction in BOD value when compared with the water samples, collected from initial stage and during aeration. The treatment effect has also found with a strong influential reducing effect of nitrogen, phosphate, sulphate and calcium concentration of grey water (Fig. 2). Temporal phenomenon was also shown an influential effect as the treatment process during March, 2015 was shown to be more effective recycling than in rest of the sampling periods (Fig. 2).

Relationship among the analyzed variables: Conductivity and TDS showed a significant positive correlation, which could be towards the reduction of dissolved solute substances, because of the grey water treatment. In addition phosphate is high positively correlated to salinity, salinity and alkalinity were found with a negative correlation with pH, however, calcium content and total hardness was found with a positive correlation (Table 1) and very low negative correlation was found between TDS and conductivity. Hardness had a high positive correlation with BOD and negatively correlated with conductivity.

Cluster analysis: The data collected on the physico-chemical quality parameters were subjected for making dendrogram, through which proximity level among the variables were determined. Six clusters were found with the grouping of the analyzed data in which, a closer proximity was found between those variables, lie on those clusters (Fig. 3). DO, acidity, TDS, alkalinity and hardness were found aggregated together in a cluster. Acidity and calcium components were found to be similar with DO and acidity. A greater variability was found for

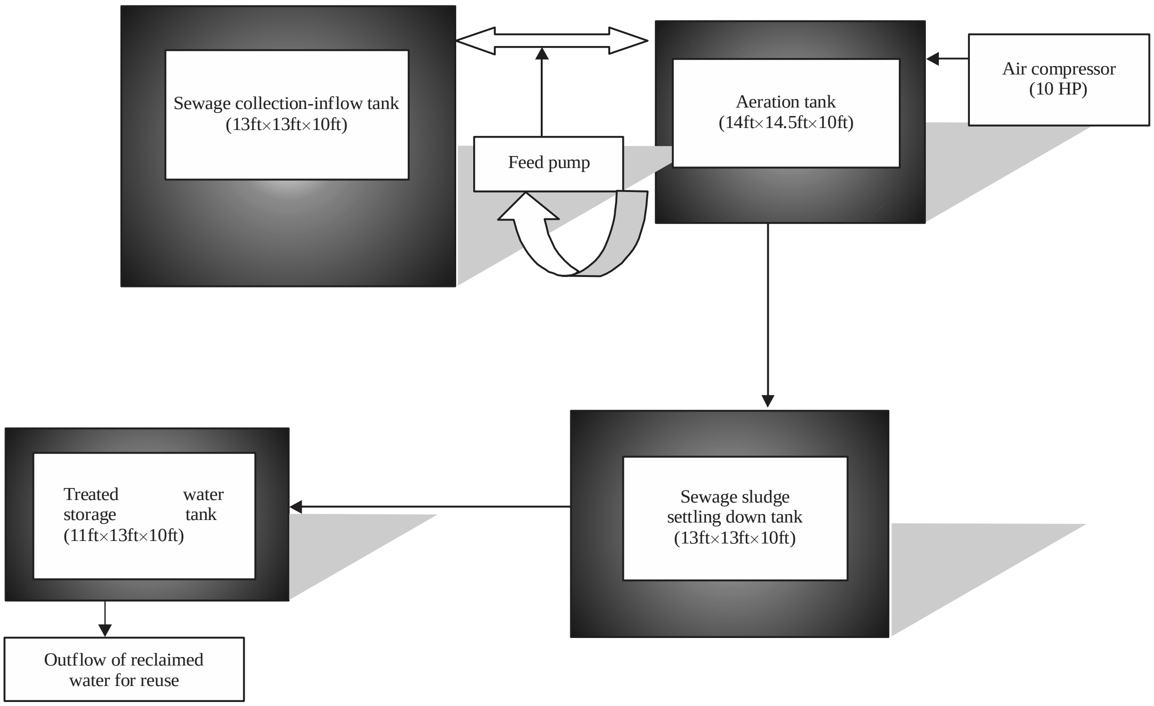

Fig. 1: Scheme of operation of sewage treatment plant, Thiagarajar college Madurai, India

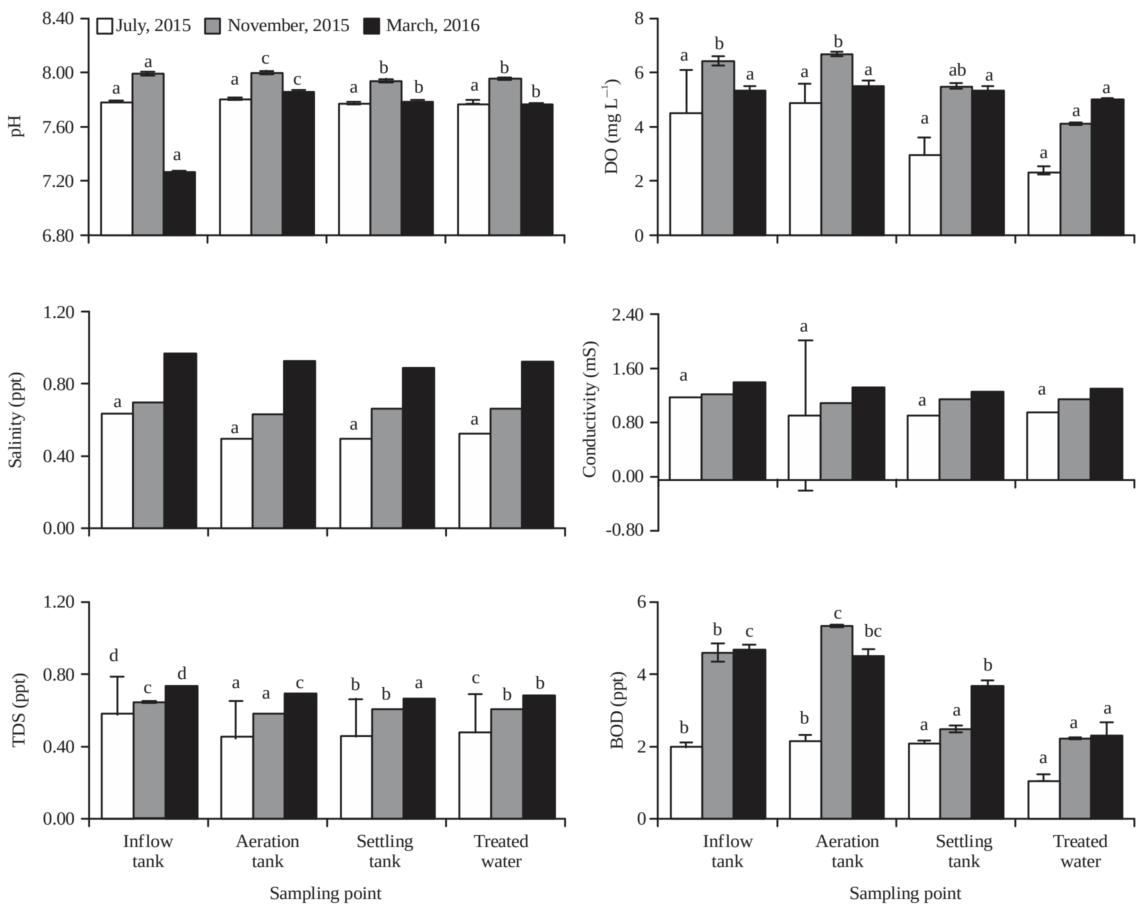

Fig. 2: Continue

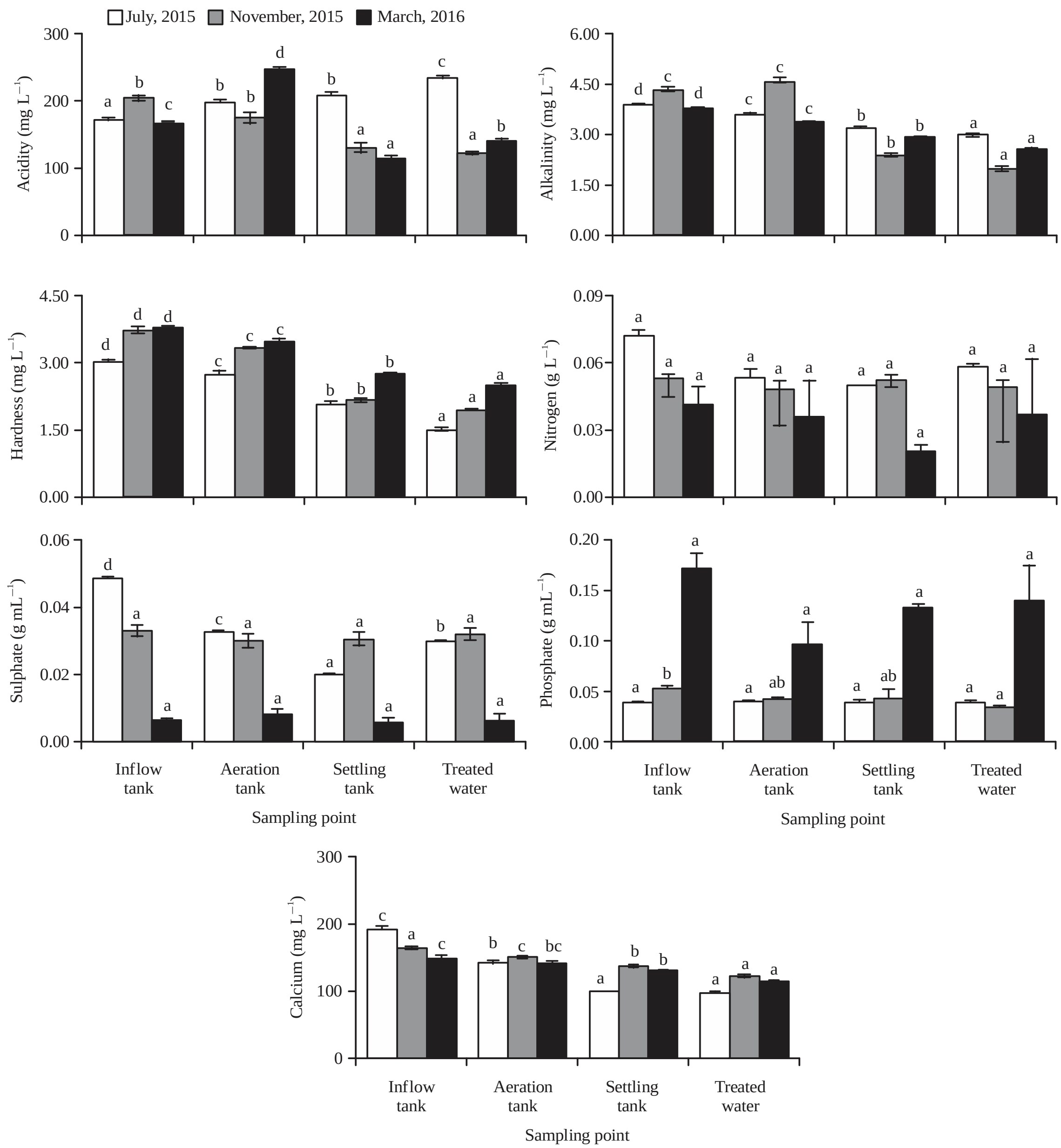

Fig. 2: Physical quality and water chemistry of water samples collected from 4 different sampling points in the domestic effluent treatment of Thiagarajar college, Madurai, India

Vertical bar represent the SE (n = 3). Different alphabets indicate significant difference (p>0.05)

conductivity of the water sample either with TDS and hardness, whereas the later two components showed closer similarity.

Principal component analysis: All the analyzed parameters showed a different levels of weight age in this experiment (Fig. 4). The BOD, alkalinity, hardness and sulfate showed the strongest weight age, when compared to the other analyzed parameters (Table 2). The weaker negative loading includes DO, salinity, harness, whereas, phosphate. Acidity, nitrogen and calcium were found with a moderate weight age (Table 2).

Microbial diversity and their growth: A complete removal of this pathogenic bacterium, following the treatment in this experiment e current study was observed and also *Bacillus substilis* and *B. megaterium* were observed with their better survival nature in treatment points, when compared to *Flavobacterium*, *Micrococcus* sp. and *Staphylococcus aureus*

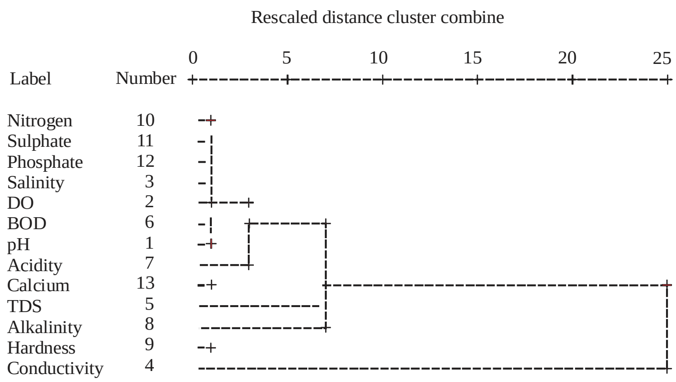

Fig. 3: Dendrogram of water quality variables, computed using cluster analysis, during different experimental periods

Table 1: Correlation of coefficient value of physical and chemical qualities of water samples collected from four different sampling points of the domestic sewage treatment plant (STP), Thiagarajar college, Madurai, India

Parameters	pH	DO	Sal	Cont	TDS	BOD	Acidity	Alkali	TH	N_2	SO_4	PO_4	Calci
pH	1												
DO	-0.067	1											
Salinity	-0.391*	0.399*	1										
Conductivity	0.061	-0.590**	-0.700**	1									
TDS	0.061	-0.590**	-0.700**	1.000**	1								
BOD	-0.273	0.715**	0.556**	-0.686**	-0.685**	1							
Acidity	-0.140	-0.197	-0.286	0.438**	0.438**	0.000	1						
Alkalinity	-0.344*	0.389*	-0.076	0.149	0.149	0.567**	0.474**	1					
Total Hardness	-0.503**	0.677**	0.514**	-0.375*	-0.375*	0.847**	0.145	0.731**	1				
Nitrogen	0.050	-0.215	-0.532**	0.503**	0.503**	-0.344*	0.237	0.162	-0.155	1			
Sulphate	0.298	-0.098	-0.755**	0.515**	0.516**	-0.304	0.086	0.221	-0.158	0.688**	1		
Phosphate	-0.534**	0.218	0.857**	-0.477**	-0.477**	0.392*	-0.260	-0.033	0.405*	-0.602**	-0.791**	1	
Calcium	-0.195	0.500**	0.131	-0.009	-0.008	0.459**	-0.047	0.595**	0.706**	0.267	0.449**	-0.020	1

*Correlation is significant at $p \leq 0.05$ level, **Correlation is significant at $p \leq 0.01$ level

Table 2: Distribution of proportionate weightage among the variables analyzed for the water samples collected from the domestic Sewage Treatment Plant (STP), Thiagarajar college, Madurai, India, using principal component analysis

	Rotated component matrix[a]		
Components	1	2	3
pH	0.556	-0.347	-0.0474
DO	-0.106	0.737	-0.482
Salinity	-0.821	0.272	-0.314
Conductivity	0.503	-0.285	0.758
TDS	0.504	-0.285	0.757
BOD	-0.380	0.807	-0.284
Acidity	0.069	0.142	0.729
Alkalinity	0.090	0.813	0.441
Hardness	-0.323	0.928	0.053
Nitrogen	0.692	0.073	0.326
Sulphate	0.931	0.153	0.125
Phosphate	-0.910	0.127	-0.069
Calcium	0.268	0.828	0.012
Total	4.010	3.825	2.639
Variance (%)	30.845	29.425	20.299
Cumulative (%)	30.845	60.270	80.569

[a]Rotation converged in 6 iterations

(Table 3-5). Virulent growth behavior of *Bacillus megaterium* and *B. substilis* were observed frequently with a longer period of survival in the log phase (Fig. 5) in the water samples, collected from the four different treatment points on March, 2016 when compared to the growth of *Micrococcus* and *Flavobacterium* sp., during the same sampling period. Growth curves observed for *Staphylococcus aureus* and *Escherichia coli* demonstrated moderate log phase growth and *Pseudomonas* exhibited poor survival (Fig. 5).

A total of eight fungus species were isolated in the serial dilution of grey water samples, in which, *Chrysosporium* sp. was found in the sample collected in the month of July (Table 3). *Rhizophus*, *Mucor*, *Fusarium* and *Alternaria* were found in less numbers in the samples collected from the treatment points (Table 3-5). This feature could be attributed to the low alkalinity in the raw grey water (Table 2).

DISCUSSION

A major setback of domestic effluent is its deteriorating water quality, mainly caused through nutrient loading[18]. This eutrophication leads in the proliferation of deteriorating microbial population and their harmful activities, greatly

Table 3: Determination of microbial organisms occurrence in the water samples, collected from treatment points in the STP of Thiagarajar College Madurai, India during July, 2015

	Water samples collected																			
	Sewage inflow tank					Aerating tank					Settling tank					Final treatment				
	Serial dilutions made					Serial dilutions made					Serial dilutions made					Serial dilution made				
Organisms	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}
Bacillus substilis	+	+	+	-	-	+	+	+	-	-	+	+	+	-	-	+	+	+	-	-
Bacillus megaterium	+	+	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Micrococcus sp.	-	+	-	-	-	+	+	+	-	-	+	+	+	-	-	+	+	+	-	-
Flavobacterium sp.	-	-	+	-	-	+	+	+	-	-	+	+	+	-	-	+	+	-	-	-
Staphylococcus aureus	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudomonas sp.	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Escherichia coli	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Aspergillus niger	-	-	-	-	+	-	-	-		+	-	-	-	-	-	-	-	-	-	-
A. flavus	-	-	-	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-
A. terius	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Chrysosporium sp.	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Rhizophus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Mucor sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	+	-
Fusarium sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Geotrichum sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Alternaria sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-

+: Presence, -: Absence

Table 4: Determination of microbial organisms occurrence in the water samples, collected from treatment points in the STP of Thiagarajar college Madurai, India during November, 2015

	Water samples collected																			
	Sewage inflow tank					Aerating tank					Settling tank					Final treatment				
	Serial dilutions made					Serial dilutions made					Serial dilutions made					Serial dilution made				
Organisms	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}
Bacillus substilis	+	+	+	-	-	+	+	+	-	-	+	+	+	-	-	+	+	+	-	-
Bacillus megaterium	+	+	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Micrococcus sp.	+	+	-	-	-	+	-	+	-	-	+	+	+	-	-	-	-	-	-	-
Flavobacterium sp.	-	-	+	-	-	+	+	+	-	-	-	+	+	-	-	+	-	-	-	-
Staphylococcus aureus	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudomonas sp.	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Escherichia coli	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aspergillus niger	-	-	-	-	+	-	-	-	-	+	-	-	-	+	-	-	-	-	+	-
A. flavus	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-
A. terius	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chrysosporium sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-
Rhizophus sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Fusarium sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Geotrichum sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-

+: Presence, -: Absence

Table 5: Determination of microbial organisms occurrence in the water samples, collected from treatment points in the STP of Thiagarajar College Madurai, India during March, 2016

	Water samples collected																			
	Sewage inflow tank					Aerating tank					Settling tank					Final treatment				
	Serial dilutions made					Serial dilutions made					Serial dilutions made					Serial dilution made				
Organism	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}	1×10^{-3}	1×10^{-4}	1×10^{-5}	1×10^{-6}	1×10^{-7}
Bacillus substilis	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Bacillus megaterium	+	+	+	-	-	+	+	+	-	-	+	+	+	-	-	+	+	+	-	-
Micrococcus sp.	+	-	-	-	-	+	+	-	-	-	+	+	+	-	-	+	+	+	-	-
Flavobacterium sp.	-	-	+	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-
Staphylococcus aureus	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudomonas sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Escherichia coli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Aspergillus niger	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-
A. terius	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Rhizophus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Mucor sp.	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Fusarium sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Alternaria sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-

+: Presence, -: Absence

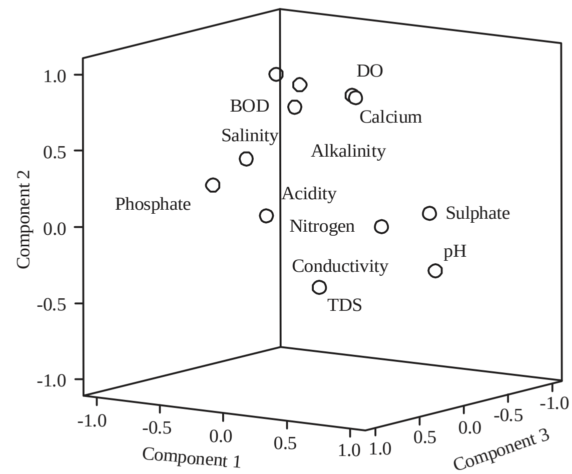

Fig. 4: Rotated compound matrix of five-factor PCA model, using varimax rotation for the analyzed parameters of water samples, collected from sewage treatment Plant, Thiagarajar College, Madurai, India at the different experimental periods

reduced the quality of the water. The efficient recycling of wastewater is either reusable or safe enough to recharge the groundwater through land-filling. Katayon *et al.*[19] reported the treatment efficacy due to membrane bio-reactor was also found with similar rise of pH. The same thing is observed in grey water treatment using effective micro-organisms. Inorganic nutrients, such as nitrogen and phosphorous were reduced using the biological treatment process[20,21]. However, intermittent aeration using aerobic membrane bio-reactor increased the yield by the fair removal of nitrogen from the effluent[22].

Boyjoo *et al.*[23] reported the existence of varying concentrations of dissolved nitrogen and phosphate in the grey water due to the various means of domestic utility, which has substantial influential effect to produce into polluting nature. Ali *et al.*[24] suggested that calcium is often removed by chemical treatment, membrane crystallization method, to avoid the undesired scaling phenomena. Correlation is the mutual relationship between two variables Jothiven katachalam *et al.*[25]. Chaubey and Patil[26] reported TDS and conductivity found positive correlation in the ground water quality assessment and the similar results were observed. However, Industrial wastewater treatment paid a special attention to the correlation analysis of water quality[23] and the results obtained in this study are aggreable[24].

The relationship found between calcium and total hardness, TDS and conductivity were similar to the earlier reports of bio-remediation method of food industry effluent treatment[16]. The level of BOD in the river water found

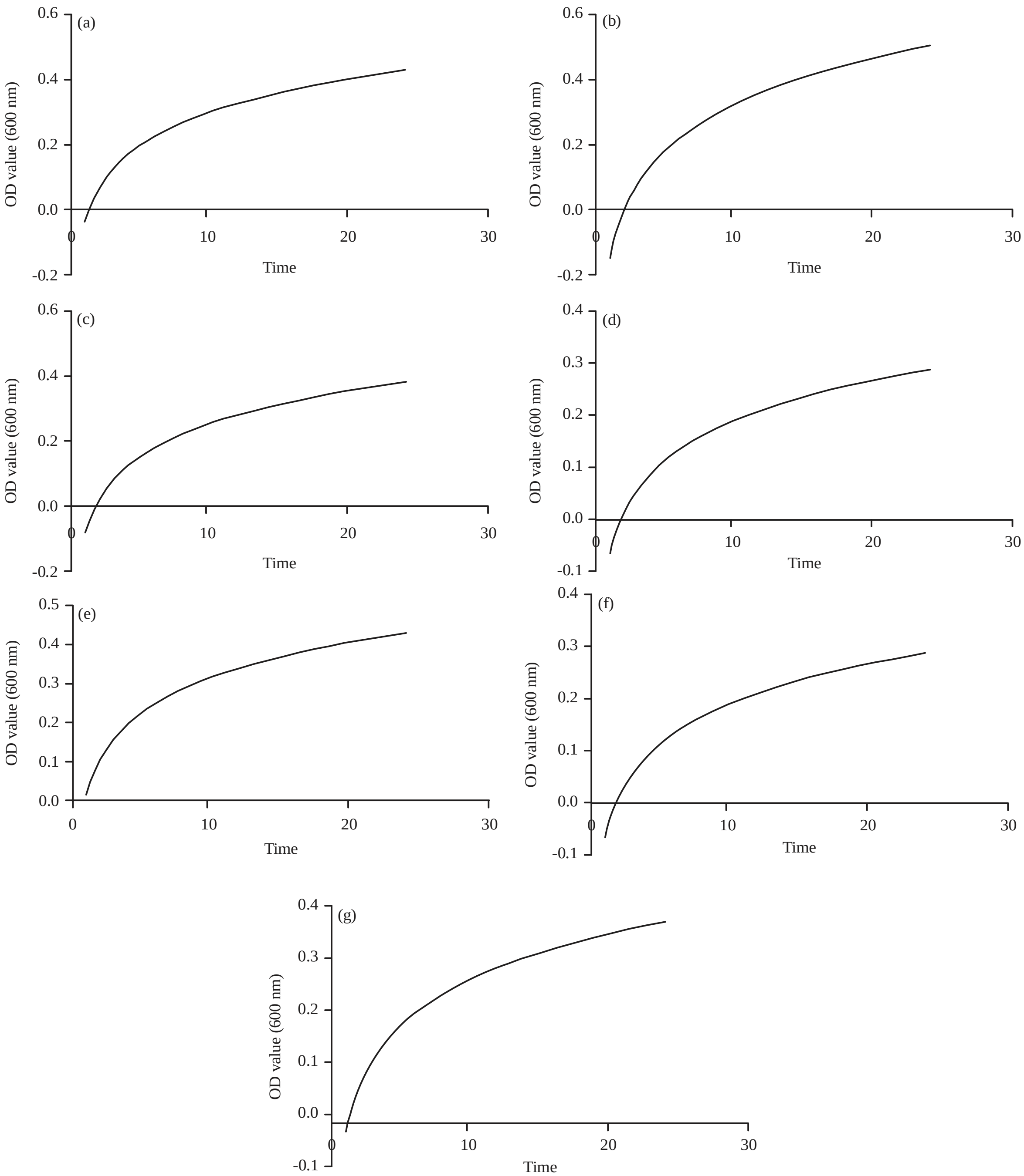

Fig. 5(a-g): Growth curve analysis done for different bacterial organism isolated from domestic water samples, subjected under different treatment conditions using effective micro-organisms applied in STP, Thiagarajar College, Madurai, India (a) *Bacillus substilis*, (b) *Bacillus megaterium*, (c) *Flavobacterium*, (d) *Micrococcus*, (e) *Staphylococcus aureus*, (f) *Pseudomonas* and (g) *E. coli*

positively correlated to conductivity[27] and in an another report done by Patil and Patil[28], pH was found to have negative correlation.

A general argument has been made on the pathogenic microbes present in grey water could reduce the pH, with the prevailing environmental conditions[29]. Further, a strong emphasis laid on the pH neutralization effect on the grey water treatment has been made through water recycling[30], which has been achieved using effective micro-organisms, used in this study. The results of the principal component analysis are in concordance with the study done for the sludge activation process in the treatment of wet grinding food industry effluent using EM[16]. *Staphylococcus aureus* found in the raw sample could pose a risk to human health[31,32]. Adeleye *et al.*[33] attributed the dynamic existence and disappearance of bacterial population at different sampling periods due to the seasonal variations. Sahu[34] examined the increased alkalinity factor favoured the prolific multiplication of fungal organisms, leading to cause the deleterious effect. The presence of *Staphylococcus aureus* in the raw water sample (Table 3-5) indicated its ability to increase the pollution load of the grey water. It is evident from the results that the establishment of controlling the prolific multiplication of pathogenic microbes, improved the biological water quality.

Among the analyzed parameters, pH, DO, conductivity, BOD, TDS and nitrogen and sulphate and phosphate were within the standard limits of EPA[35] and Central Pollution Control Board Standard, Government of India (CPCB)[36].

CONCLUSION

The experimental results further confirm the study of on the usefulness grey water treatment through biological means to achieve desirable physical, chemical and biological water qualities. Effective micro-organism treated water has observed with removal of foul odour with the attainment of near neutral pH. The trend towards increment over DO leading to the simultaneous reduction of BOD level. The analyzed multiple quality parameters of the treated grey water were found within the standards of US-EPA and Central Pollution Control Board, GOI. Therefore, the reuse of the recycled effluents could be prescribed for domestic utility, irrigation and landscaping. The results of this experiment provide substantiate information, pertinent to the management of grey water, for the improvement land and soil environment.

SIGNIFICANCE STATEMENT

The manuscript highlights the essential features of grey water recycling, by the application of Bio-augmentation process. Water quality in terms of physical, chemical and biological nature of the collected water samples, from the different treatment points, in the STP was assessed. This study will help the researcher to uncover the critical area of domestic effluent treatment and water quality analysis.

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