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ORIGINAL ARTICLE

Small-Scale Wetland Units for Domestic Greywater Treatment

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Abstract

Constructed wetlands (CW) are eco-friendly systems which mimic the functions of natural wetland. It is low-cost alternative system for the treatment of wastewater even up to domestic level. Therefore, this study was designed to assess the feasibility of pilot scale CW units on greywater treatment at domestic level. The sub-surface flow constructed wetland units were designed using small plastic containers with the size of 55cm length, 25cm width, and 28cm height. Three types of plants, Vetiver (*Vetiver iazizanioides*), Water spinach (*Ipomoea aquatic* L.) and Lasia (*Lasiaspinosa* L.) were used. One container was used without plant as a control. The experiment was conducted in a Completely Randomized Design (CRD) with three replicates in greenhouse conditions during two months period by using synthesized wastewater at a flow rate of 0.73L/h. The Hydraulic Retention Time of the system was 41 hours. The quality of the influent and effluent were monitored at two weeks interval by analyzing water quality parameters such as Biological Oxygen Demand (BOD_5), Total Dissolved Solids (TDS), pH, Electrical Conductivity (EC), PO_4^{-3}-P, NO_3^--N and NH_4^+-N. According to the results, removal efficiency of contaminants increased with monitoring period. Vetiver showed significantly ($p<0.05$) higher RE for BOD_5, PO_4^{3-}-P, NO_3^--N, NH_4^+-N by 46%,71%,83% and 89%, respectively compared to other plants. Hence, it can be concluded that the pilot scale CW units are a feasible technology for greywater treatment at domestic level with Vetiver as the wetland plant since its' dense fibrous root system leads to removing more pollutants from the domestic wastewater.

Keywords: *Constructed wetlands, Greywater treatment, Removal efficiencies, Wetland plants*

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1. Introduction

Urbanization and industrialization cause to increase the water demand, pollute the water sources and making them unsuitable for beneficial uses. Wastewater is generated through industrial, agricultural and domestic activities. Therefore, purification and recycling of wastewater become vital to reduce the risk of waste-related disease, water pollution and consequent damage to the aquatic environment etc. (Tanaka et al. 2011).

Among the several wastewater treatment technologies, use of constructed wetlands (CW) is becoming widespread throughout the world due to the demand for water quality improvement and the increasing need for wastewater reclamation and reuse (Jinadasa et al. 2006). Constructed wetlands are engineered systems that have been designed to utilize the natural processes involving wetland vegetation, soils, and the associated microbial assemblages to assist in treating wastewaters (Vymazal 2010). The CW are a cost-effective, technically feasible, and less expensive to build than other treatment options. Further, CW has a great potential to be used as the wastewater treatment method for rural and urban areas since it can be practiced even in a limited land area with few modifications of the system. Therefore, this study aimed to investigate feasibility of using small container constructed wetland units to treat the domestic greywater discharged from urban areas with selected wetland plants.

2. Materials and Methods

2.1 Location, Experimental Setup and Analyses

The study was conducted at Faculty of Agriculture, Rajarata University of Sri Lanka, *Puliyankulama, Anuradhapura*. Twelve plastic containers (55cm *25cm *28cm) were used to design sub-surface flow constructed wetland units. The wetland units were filled with aggregates (5cm depth) and top soil (15cm layer) from the bottom.

Considering the local availability, three wetland plants were selected as; Vetiver grass (*Vetiveria zizanioides*), Lasia/*Kohila* (*Lasia spinosa* L.) and Water spinach/ *Kangkung* (*Ipomoea aquatic* L.). for the study. Plants were collected from local natural environment and planted in polythene bags with top soil one months prior to the experiment. Plants were watered with clean water (tap water) for two weeks. For the establishment, shoots of Vetiver and Water spinach were planted with the spacing of 20cm by 20cm and rhizomes of Lasia were planted with the density of 2 plants/m^2 in wetland units. Three containers were used as control without plants. Altogether, twelve containers were used for the experiment, arranged in a completely randomized design (CRD) under greenhouse condition, nine were planted with Vetiver, Lasia and Water spinach with three replicates for each. Wastewater was synthesized (Hemanthika 2016) with uniform composition similar to the domestic greywater and applied continuously at the rate of 0.73 L/h during two months under subsurface flow system. Table 1 shows the composition of synthesized wastewater used in the research. The hydraulic retention time (HRT) of the each wetland unit was calculated as 41 hours. For the analysis, two water samples were collected from inlet (influent) and outlet (effluent) of CW unit at two week intervals up to two months and Biological Oxygen Demand (BOD_5), Total Dissolve Solids (TDS), pH, Electrical Conductivity (EC), Phosphate - Phosphorous (PO_4^{3-}—P), Nitrate - Nitrogen (NO_3^-—N) and Ammonium – Nitrogen (NH_4^+-N) were analyzed using standard methods. In every two weeks, pollutant removal efficiency (RE) for each water quality parameter was calculated using following equation.

$$Pollutant\ Removal\ Efficiency = \frac{(Inlet\ [pollutant] - Outlet[pollutant])}{(Inlet\ [pollutant])} \times 100\ \%$$

Water quality analyses were conducted at Soil and Water Science Laboratory, Faculty of Agriculture, Rajarata University of Sri Lanka and Regional Laboratory, National Water Supply and Drainage Board (NWSDB) in Anuradhapura, Sri Lanka.

Table 1: Composition of Synthetic Wastewater

Chemical Compound	Amount
Sodium Hydroxide	7g
Ammonium Chloride	17.5 g
Magnesium Sulphate	7 g
Urea	105 g
Sugar	70 g
Di-Potassiumhydrogen Orthophosphate	14 g
Iron Sulphate	1.75 g
Manganous Sulphate	0.7 g
Calcium Chloride	0.7 g
Copper Sulphate	0.7 g
Kitchen Wastewater	2 L
Tap Water	350 L

2.2 Statistical Analysis

The statistical analysis was performed using one-way ANOVA and means were separated using Tukey's HSD test.

3. Results and Discussion

3.1 Ammonium - Nitrogen (NH_4^+-N)

Nitrogen removal efficiency in constructed wetland depends on vegetation, hydraulic retention time, wastewater drawdown, microorganisms and the media as it can be removed by assimilation through plants, adsorbing to substrate or with the de-nitrification process (Zhang et al. 2009). In this study, the average NH_4^+-N concentration in influents was 2.35mg/l. Effluent concentration showed a decreasing trend with the time as shown in fig. 1(a). However, in every two weeks, effluents were recorded lower NH_4^+-N concentrations compared to the influent.

Fig. 1 (b) shows the REs of NH_4^+-N. REs were gradually increased in Vetiver, Water spinach and Lasia. Vetiver showed the significantly ($p<0.05$) highest RE (89%) at the end of the two months and statistically similar REs were recorded in Water spinach and Lasia at the end of the three months. Altogether, Vetiver, Water spinach and Lasia were recorded higher performance in removal of NH_4^+-N compared to the control treatment.

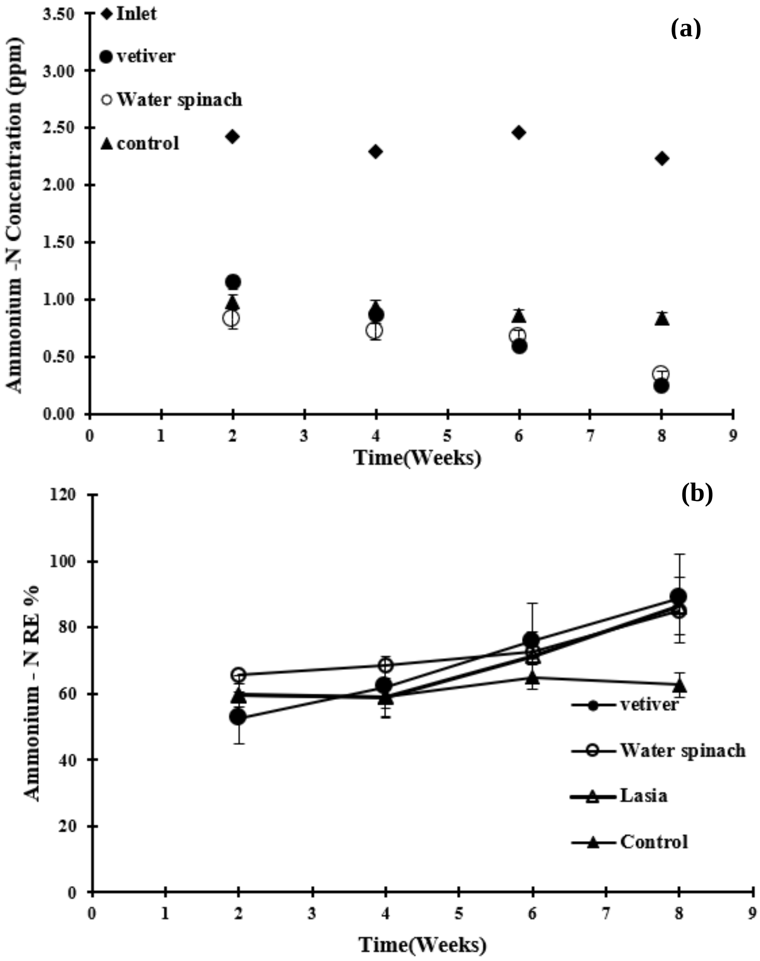


Figure 1: (a) Variation of NH_4^+-N concentrations in influent and effluents in two weekly intervals; (b) Removal Efficiencies of NH_4^+-N with Time (%).

3.2 Nitrate -Nitrogen (NO_3^--N)

Fig. 2(a) illustrates the NO_3^--N concentration in influent and effluents in two week intervals. The average influent NO_3^--N concentration was 4.67 ppm. During the treatment process NO_3^--N concentrations of effluents were decreased compared to influents. It has been estimated that wetlands may remove between 70% and 90% of Nitrogen (N) entering to the environmental system (Baskar et al. 2009) .

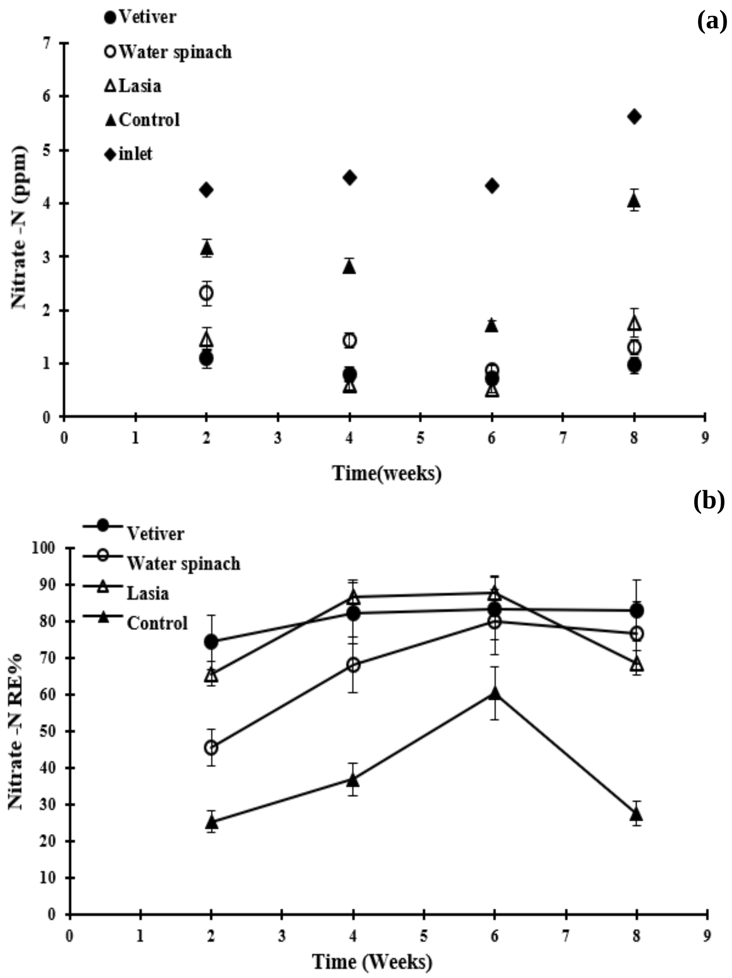


Figure 2: (a) Variation of NO_3^--N concentrations in influent and effluents in two week intervals; (b) Removal Efficiencies of NO_3^--N with Time (%).

The removal efficiencies of NO_3^--N are illustrated in fig. 2(b). At the end of the two months period, Vetiver plant showed highest performance (83%) in pollutant removal compared to other plants through its' root system.

3.3 Phosphate - Phosphorous (PO_4^{3-}-P)

Phosphorous occur in organic and inorganic forms in the wetlands. Removal of phosphorous is mainly due to plant uptake and retention in soil. Up taking of phosphorous by macrophytes is usually highest during the initial plant growth before maximum growth rate is attained. Removal of these elements by vegetation is a most cost effective and environmental friendly method of controlling algal growth (Richardson 1985; Reilly 1991; Vymazal 2001). The PO_4^{3-}—P concentration of influent and effluents and removal efficiencies were shown in fig.3. The average PO_4^{3-}-P concentration of inlet was 5.25 mg/L. During the treatment process, effluent PO_4^{-3}-P concentration has been decreased with time. All the treatment combinations have been enhanced their REs during the remediation process. At the end of the two months of experimental period, significantly (*$p<0.05$*) highest RE was recorded in Vetiver (71%). The dense fibrous root systems of Vetiver plants provide large surface to microbial growth, help to filter solid that may increase pollutant removal efficiency. This phosphorous accumulate in plant bodies and soil, due to biological uptake and chemical bounding (Mohammed et al. 2013).

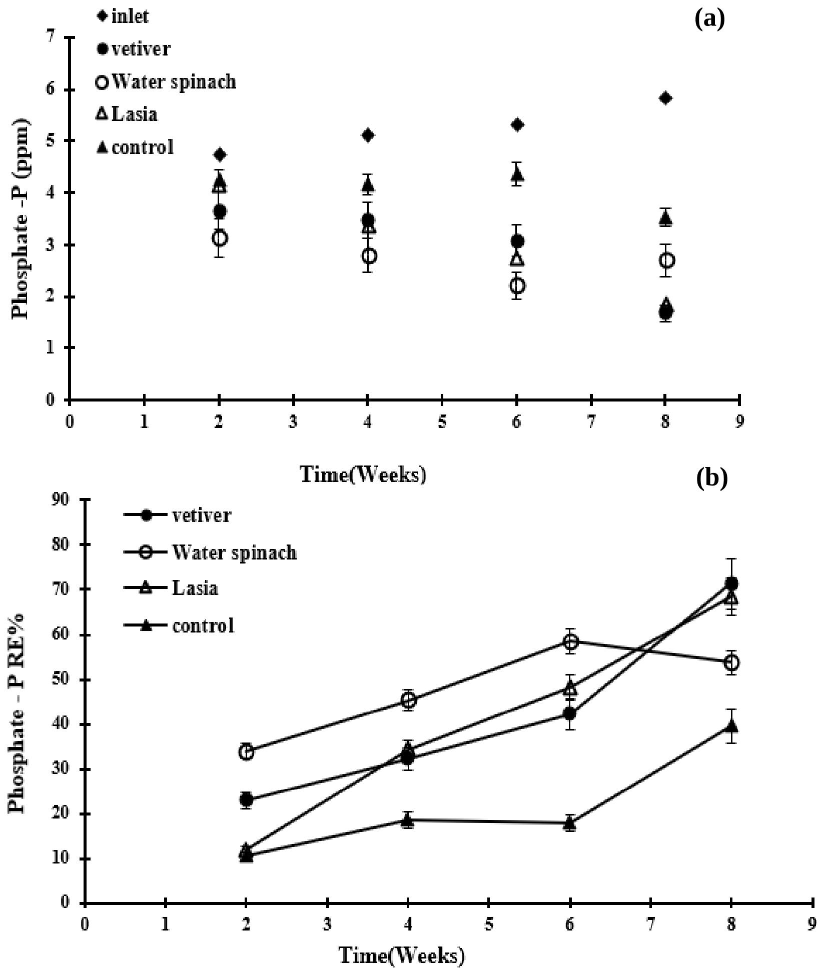
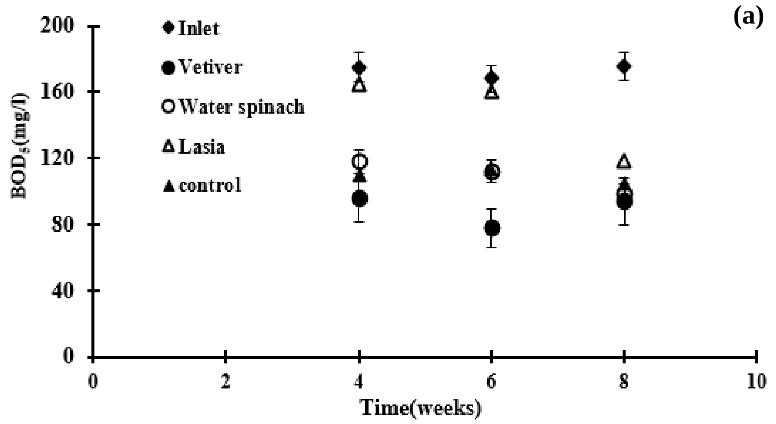


Figure 3: (a) Variation of PO_4^{3-}-P concentrations in influent and effluents in two week intervals ; (b) Removal Efficiencies of PO_4^{-3}-P with Time (%).

3.4 Biological Oxygen Demand

Biological Oxygen Demand is an indication of the organic pollutant content of a given water sample.



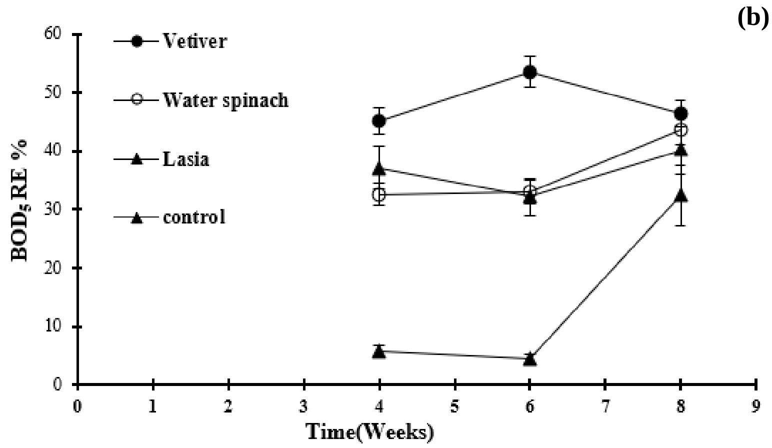


Figure 4: (a) Variation of BOD_5 concentrations in influent and effluents in two weekly intervals ; (b) Removal Efficiencies of BOD_5 with Time (%).

Fig.4 (a) shows the variation of BOD_5 in influents and effluents. Influent BOD_5 values varied around 168 mg/l - 175.5 mg/l. During the remediation process, effluent BOD_5 were gradually decreased. The REs of BOD_5 were shown in Fig.4 (b). Vetiver plant showed the significantly highest ($p<0.05$) REs (46%) of BOD_5 since its' fibrous root system may be enhance the remediation through enormous microbes around the rhizosphere.

3.5 pH , EC and TDS

The pH values of influents and effluents were not showed considerable variation through the treatment process. Both influents and effluents were ranged between the tolerance limits for industrial wastewater discharged for irrigation purpose as 5.5-9.0 (National Environmental Regulation 2008) (Fig. 5).

Electrical Conductivity values of influents and effluents were shown in and effluent values were within the tolerance limits for industrial wastewater discharged for irrigation purpose as below the 2.25 dS/m (National Environmental Regulation 2008)(Fig. 5).

Lower TDS values were recorded in effluents, compared to influent. It may be due to filtration capacity of soil layer (Baskar et al. 2009). All the TDS values including influents and effluents were ranged below the tolerance limits for industrial wastewater discharged for irrigation purpose as below the 2100mg/l (National

Environmental Regulation 2008) (Fig. 5).

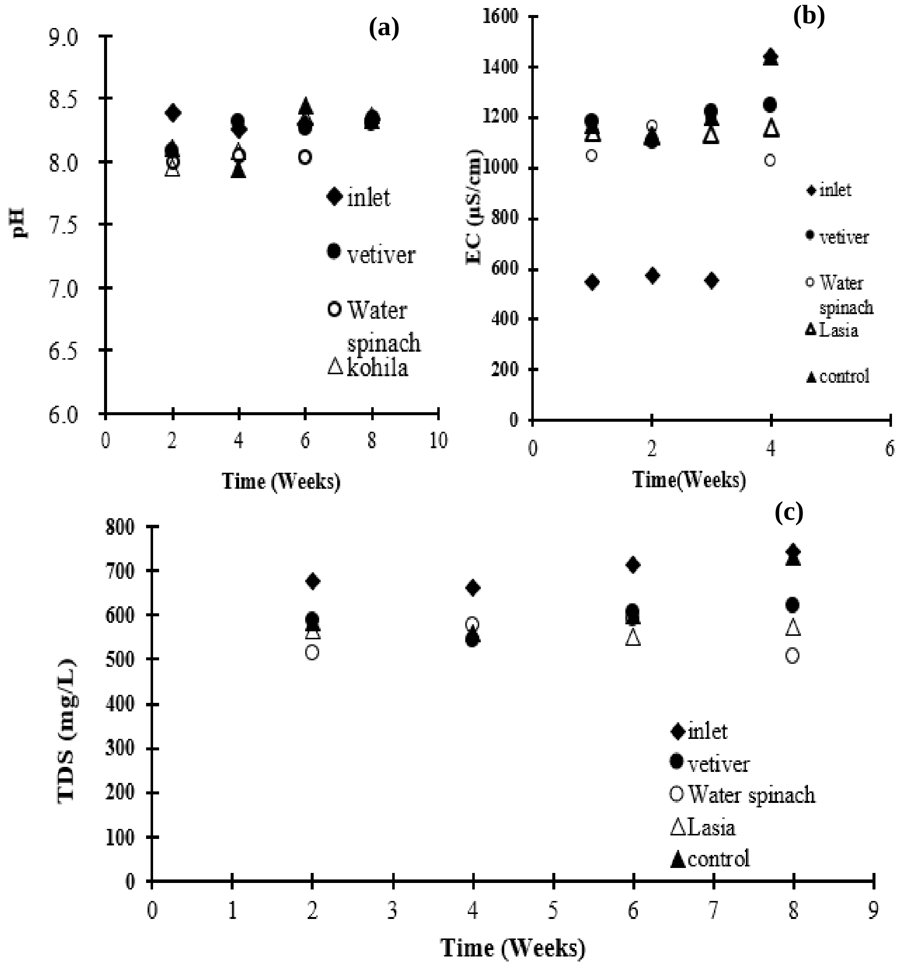


Figure 5: Variation of (a) pH, (b) EC, (c) TDS during the two months of experimentation period.

4. Conclusion

Three plants; Lasia, Water spinach and Vetiver were tested for their performance on wastewater treatment using small scale constructed wetland units. Over a two months period, Vetiver plant showed higher performance in removal of NH_4^+-N,NO_3^- - N, PO_4^{-3}-P with the REs of 89%, 83% and 71% compared to Lasia and Water spinach. Biological Oxygen Demand removal efficiency also has increased up (46%) during the treatment process with Vetiver plant.

Overall, it can be concluded that small scale CW units are a viable technology for greywater treatment at domestic level with the Vetiver (*Vetiveria zizanioides*) plant since its' dense fibrous root system leads to removing more pollutants from the domestic wastewater.

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