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Phytoremediation potential of different wetland plants suitable for mini- wetland units

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Abstract

Phytoremediation by plants has been a significant technology to remediate wastewater in constructed wetlands (CWs). However, the requirement of a larger land area is a major limitation for its use. Small scale CW units can be the best option for domestic greywater treatment since it reserves limited land area. This study aimed to identify the most effective plant combinations for phytoremediation using mini- wetland units. The CW units were constructed using plastic containers (55*30*30 cm). Eight treatments; in a combination of selected wetland plants Vetiver (Vetiveriazizanioides), Kangkung (Ipomoea aquatic), Kohila (Lasiaspinosa)were tested and soil without amendments were served as a control. Wastewater was synthesized, similar to the domestic greywater, and fed into CW units at the rate of $0.5Lh^{-1}$. The hydraulic retention time was 63hours. Phosphate Phosphorus (PO_4^{-3}-P), Nitrate Nitrogen (NO_3^- - N), Ammonium Nitrogen (NH_4^+-N), Total Dissolved Solids (TDS), pH, Electrical Conductivity (EC), and certain trace elements were monitored both in influent and effluent in two-week intervals for two months. The experiment was conducted in a completely randomized design (CRD) with three replicates. Results revealed that each combination of wetland plants recorded an increasing pollutant (NH_4^+-N, NO_3^- - N, PO_4^{-3}-P, TDS, pH,) removal efficiencies (REs) throughout the monitoring period. Plant combination of Kangkung, Kohila, and Vetiver showed significantly ($p<0.05$) higher performance in removal of NH_4^+-N, NO_3^- - N, PO_4^{-3}-P with the REs of 62%, 66%, and 65% respectively. After the treatment process; in all treatments, pH and TDS of the effluents were ranged around the permissible level following the general standards for wastewater. The overall results conclude that small-scale CW units are a viable technology for greywater treatment at the domestic level with the combination of Kangkung, Kohila, and Vetiver. Further studies are recommended for a concrete conclusion.

Keywords: *Constructed wetlands, Greywater treatment, Removal efficiencies, Wetland plant.*

1. Introduction

The use of constructed wetlands for wastewater treatment 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 (CWs) are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and the associated microbial assemblages to assist in treating wastewaters(Vymazal, 2005) also have been identified as a sustainable wastewater management option for developing countries(Mejare and Bulow 2001).

In most countries, constructed wetlands have been used for domestic wastewater treatment, and this technology can be useful for application in rural settings and, possibly, urban areas where space is not a constraint. The Constructed wetlands are cost-effective, technically feasible, and less expensive to build than other treatment options, Low operation and maintenance expenses. In this regard, the limited land area is the major constrain with this CW technology in urban cities. Therefore, this study is mainly focused to treat wastewater by using a small container constructed wetland unit with some selected wetland plants and identify the most effective combination of wetland plants for phytoremediation of pollutants in wetlands.

Methodology

The study was conducted at the Faculty of Agriculture, Rajarata University of Sri Lanka under greenhouse conditions. Small plastic containers (55×30×30 cm) were filled with aggregates from the bottom (5 cm) and then topsoil (15 cm) as filling materials. PVC pipes 125 mm diameter with valves were used to feed the synthesized wastewater. Domestic wastewater was synthesized (Hemanthika, 2016) and applied at the rate of 1.25 ml/ s using perorated PVC pipes.

Different combination of selected wetland plants; Vetiver grass (*Vetiveria zizanioides*), Lasia/ Kohila (*Lasia spinosa*), Water spinach/ Kangkung (*Ipomoea aquatica*) were used as treatments (Table:1). Clean water was fed to wetland units for up to two weeks to initiate the wetland plant growth. Eight treatments (Table 1) were tested in Completely Randomized Design (CRD) with three replicates. The experiment was continued for up to two months.

Table 1: Treatments used for the experiment

Treatment	
T1	Vetiver plant only
T2	Kohila plant only
T3	Kangkung plant only
T4	Vetiver + Kohila
T5	Vetiver + Kangkung
T6	Kohila+ Kangkung
T7	Vetiver + Kohila + Kangkung
T8	Control

Water samples were taken at two weeks interval for two months both from inlet and outlet and analyzed for pH, Electrical conductivity (EC), Total Dissolved Solids (TDS) using a multi-parameter. Dissolved Oxygen (DO) concentration was measured using a DO meter. Phosphate-phosphorous (PO_4^{3-}-P) (Olsen *et al.,* 1954)and Nitrate-nitrogen (NO_3^--N) (Yang *et al.,* 1998) were also determined using standard analytical procedures. Total N (Bremmer, 1982) and P (Olsen *et al.,* 1954) contents of wetland plants were determined initially and at the end of the two months as pant analyses.

Removal efficiencies for each pollutant were calculated using the equation 01 and expressed using Microsoft Excel. SAS software was used for data analysis.

$$\text{Pollutant Removal Efficiency} = \frac{\text{Inlet [Nutrient]} - \text{Outlet [Nutrient]}}{\text{Inlet [Nutrient]}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ 01$$

3. Result and Discussion

A. Water Quality Analysis

Phosphate -phosphorus (PO_4^{-3}-P)

Phosphorous occurs as phosphate in organic and inorganic compounds in the wetlands. Removal of phosphorous from the soil solution is mainly occurred by plant uptake and retention/adsorption into soil colloids. Phosphorous uptake by macrophytes is usually highest during the initial plant growth before the maximum growth rate is attained. As soluble N and particularly P are usually considered to be key elements in water pollution, which normally leads to blue-green algal bloom in inland waterways and lakes, the removal of these elements by vegetation is the most cost-effective and environmentally friendly method of controlling algal growth (Vymazal, 2007). In this study, PO_4^{-3}-P (ppm) concentration of influent and effluents was measured during two weeks interval removal efficiencies were calculated (Fig.3).

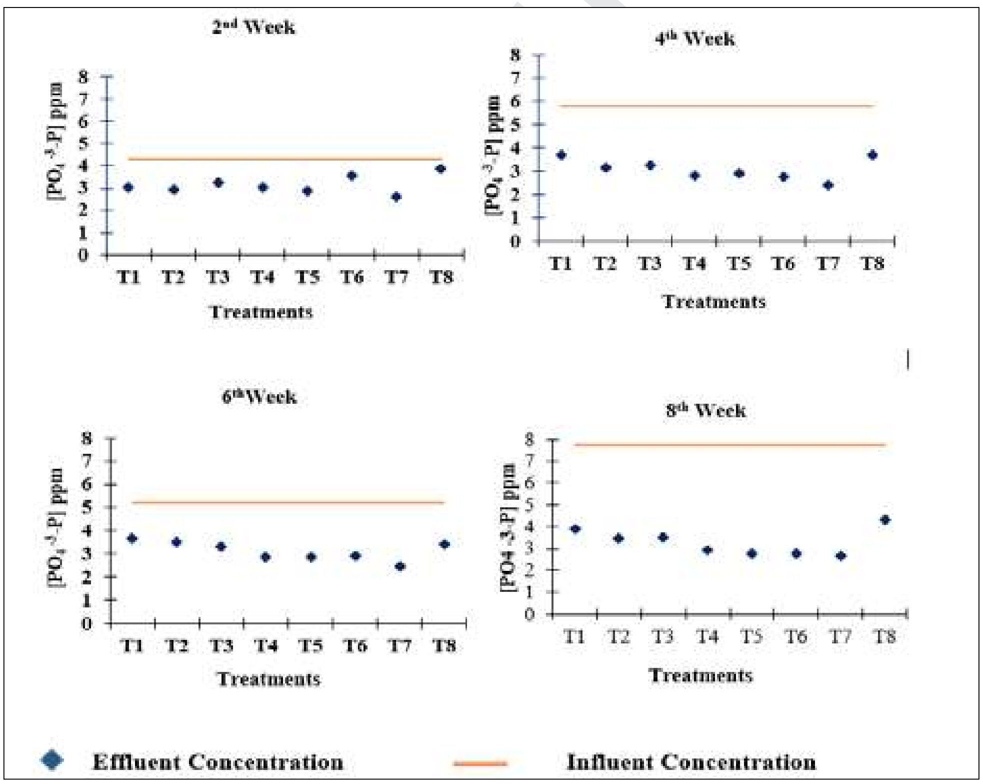


Fig.2:
Measured PO_4^{-3}-P concentration of the influents and the effluents in two weeks intervals

The average PO_4^{-3}-P concentration of inlet was 5.75 ppm. During the treatment process, effluent PO_4^{-3}-P concentration has been decreased (figure 4.5)every two weeks. Starting with the lowest REs, all the treatment combination have been enhanced their REs during the remediation process. At the end of the two months of the experimental period, significantly ($p<0.05$) highest RE (65%) was recorded in T7 or Kangkung * Kohila *Vetiver plant combination. Combined dense root systems of Kangkung, Kohila, and Vetiver could be the reason for the highest P pollutant removal efficiency with Kangkung * Kohila *Vetiver plant combination. Developed root systems provide a surface to microbial growth which helps to filter solid that may increase pollutant removal efficiency. Phosphorous accumulation take place in plant bodies and soil, as a result of biological uptake and chemical bounding (Cheng *et al.,* 2002).

T1	**Vetiver**	**T5**	**Vetiver + Kangkung**
T2	**Kohila**	**T6**	**Kohila+ Kangkung**
T3	**Kangkung**	**T7**	**Vetiver + Kohila + Kangkung**
T4	**Vetiver + Kohila**	**T8**	**Control**

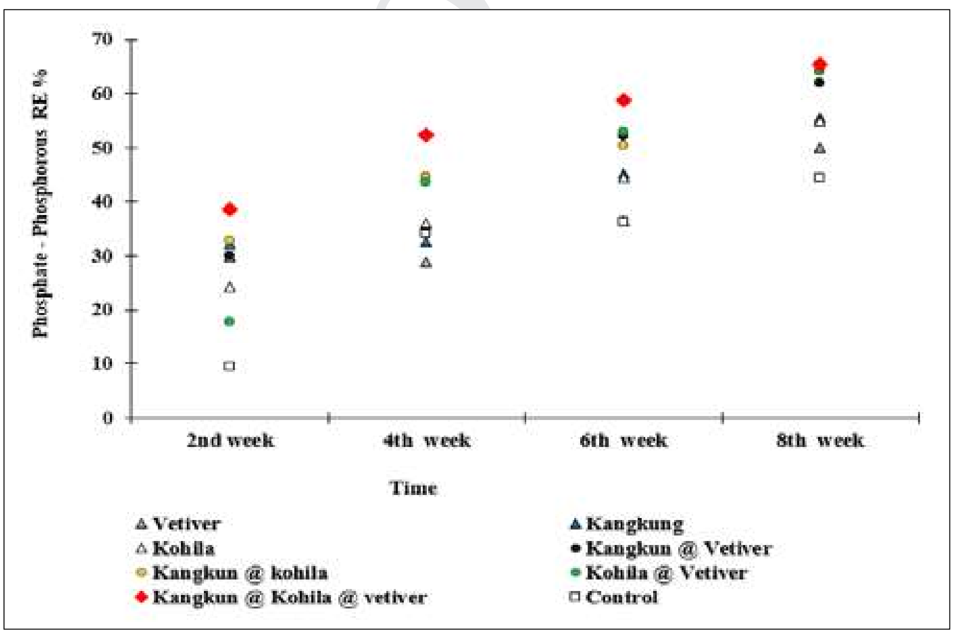


Fig.3 :
Removal Efficiencies of PO_4^{-3}-P with Time (%).

Ammonium -nitrogen (NH_4^+-N)

In constructed wetland systems, N pollutant removal efficiency is mainly depending on vegetation, hydraulic retention time, wastewater drawdown, microorganisms, and the type of the media. Similarly, N can be removed by assimilation through plants, adsorbing to the substrate, or with the de-nitrification process (Zhang *et al.,* 2009). In this study, the average NH_4^+-N concentration in influents was 2.3ppm. Effluent concentration was slowly decreased with time as shown in fig. 4. However, in every two weeks, effluents were recorded low NH_4^+-N concentrations compared to the influent.

Fig. 5 shows the REs of NH_4^+-N concentration of the influents and the effluents in two weeks intervals. Removal efficiencies were gradually increased in all the tested treatments. Kangkung *Kohila * Vetiver plant combination recorded significantly (p<0.05) highest RE (62%) at the end of the two months sampling period.

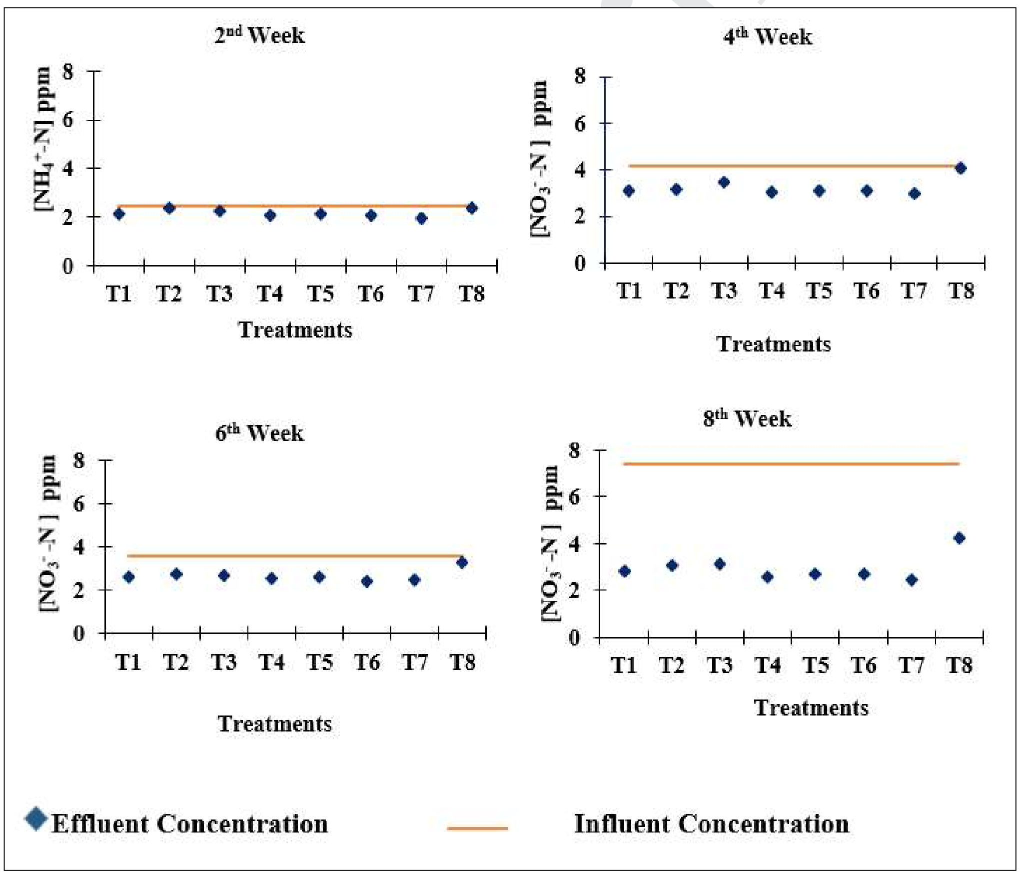
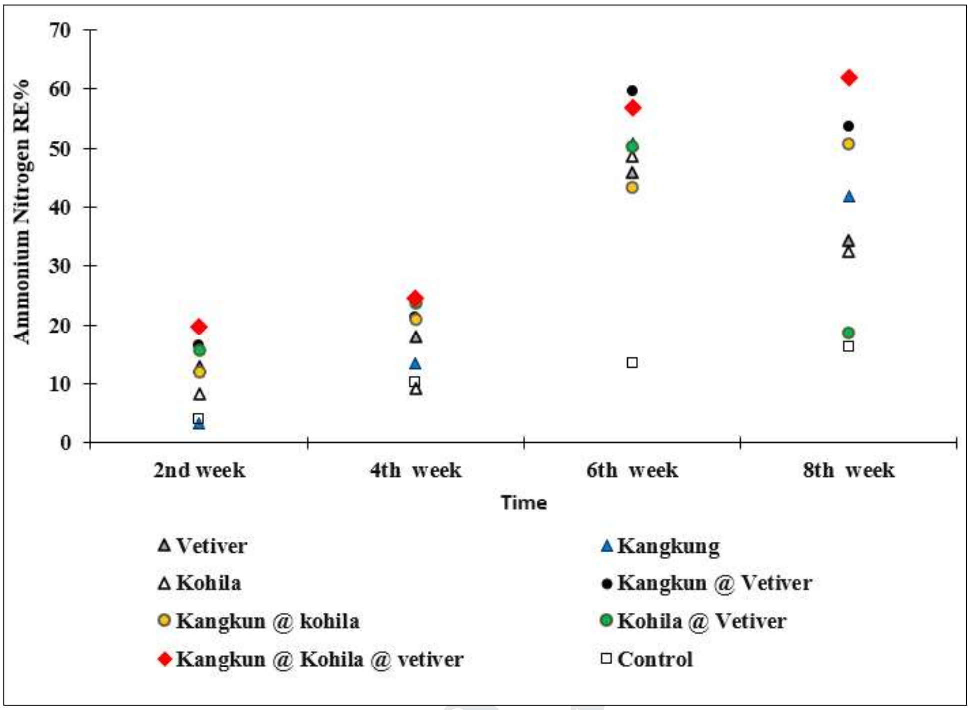


Fig. 4:
Variation of NH_4^+-N concentration of the influents and the effluents in two weeks intervals.



T1	**Vetiver**	**T5**	**Vetiver + Kangkung**
T2	**Kohila**	**T6**	**Kohila+ Kangkung**
T3	**Kangkung**	**T7**	**Vetiver + Kohila + Kangkung**
T4	**Vetiver + Kohila**	**T8**	**Control**

Fig. 5:
Removal Efficiencies of NH_4^+-N with Time (%).

Nitrate - nitrogen (NO_3^- - N)

Figure 6 illustrates the NO_3^--N concentration in influent and effluents in two weeks intervals. The average influent NO_3^--N concentration was 4.7 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 the system (Bachand and Horne, 1999).

At the end of the two months remediation process inside the wetlands system, T7 or three plant combination was performed highest compared to other plant combination (Figure 07). The combined effect of Kangkung *Kohila * Vetiver was efficient in removing significantly (p<0.05) the highest amount of NO_3^- - N pollutant (66%) through their effective root combination.

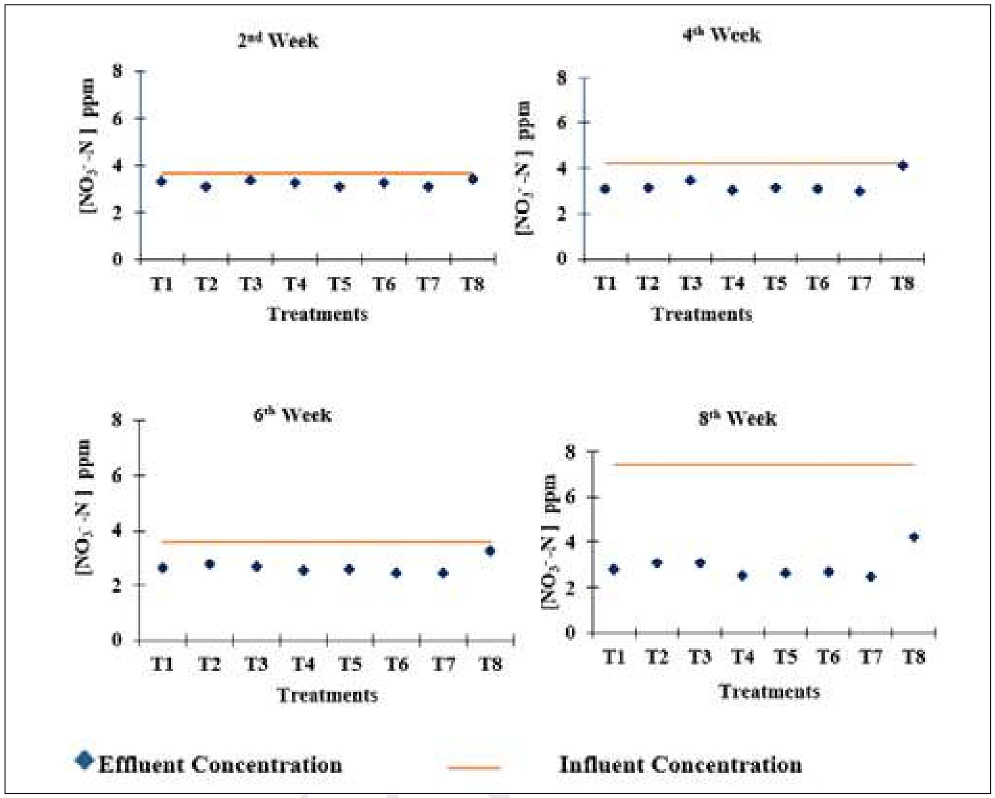
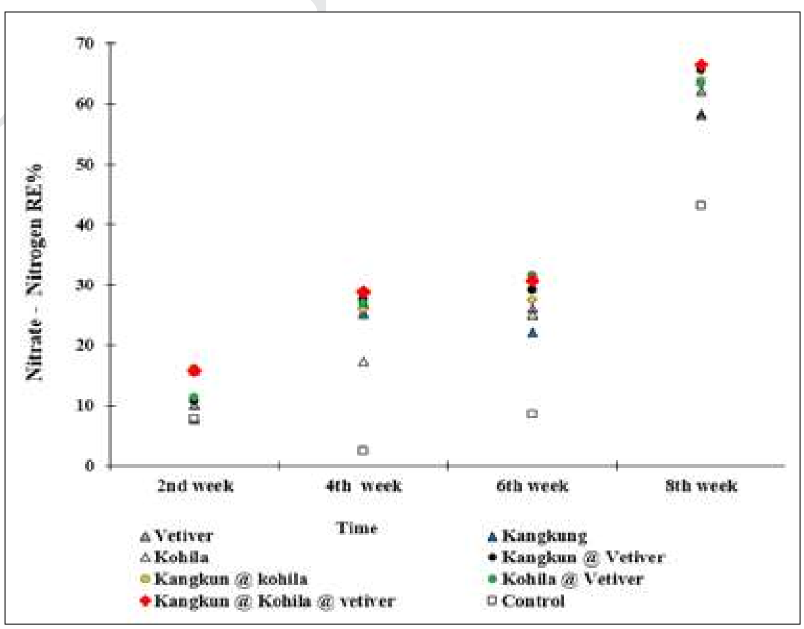


Fig. 6:
Variation of NO_3^- - N concentration of the influents and the effluents in two weeks intervals.



T1	**Vetiver**	**T5**	**Vetiver + Kangkung**
T2	**Kohila**	**T6**	**Kohila+ Kangkung**
T3	**Kangkung**	**T7**	**Vetiver + Kohila + Kangkung**
T4	**Vetiver + Kohila**	**T8**	**Control**

Fig. 7:
Removal Efficiencies of NO_3^- - N with Time (%). (include treatment numbers to the legend)

Total Dissolve Solid(TDS) and pH

The reaction of influents and effluents were not much varied throughout the treatment process. As shown in figure 8, both influents and effluents were ranged between the permissible levels for the irrigation water standards of 6.5pH - 8.5pH. No hazardous effect was recorded in plants or soil when using irrigation water with the aforementioned pH range (Ayers and Wescot, 1985).

Total Dissolved Solids (TDS) indicates the amount of water soluble compouds disssolved in water. During thestudy period, TDS of the effluents were remained in equal or lower level compared to the TDS of the influent (Figure 09). It may be due to the action of filtration by root systems of plants and filtration by soil layer (Gopalan *et al*., 2009). Both influent and effluent TDS values were well below the 2000 mg/l the maximum permissible level for irrigation (National Environmental Regulation, 2008).

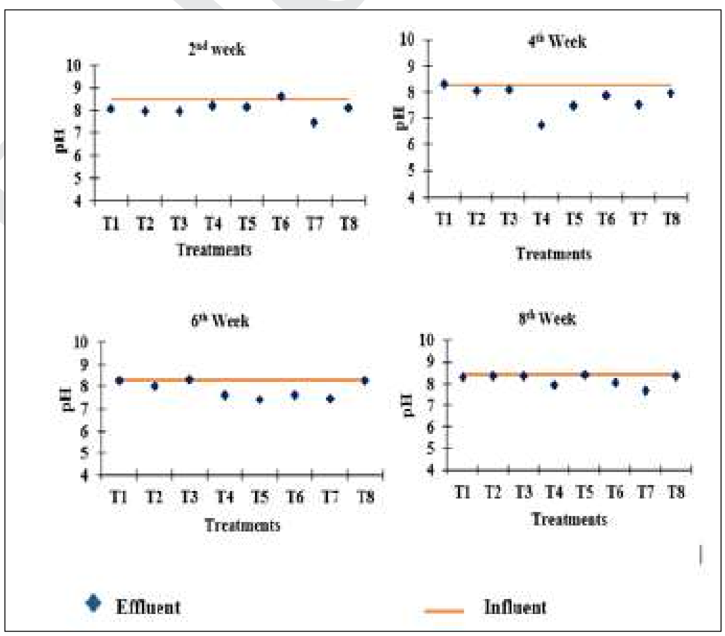


Fig. 8:
Variation of the pH of influents and effluents

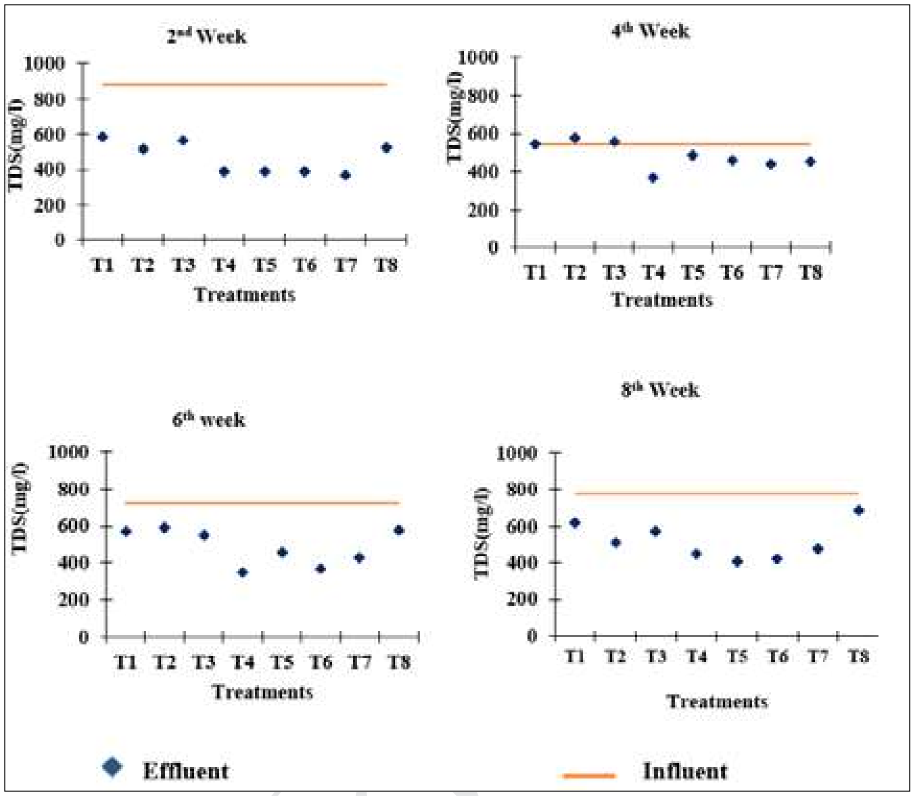


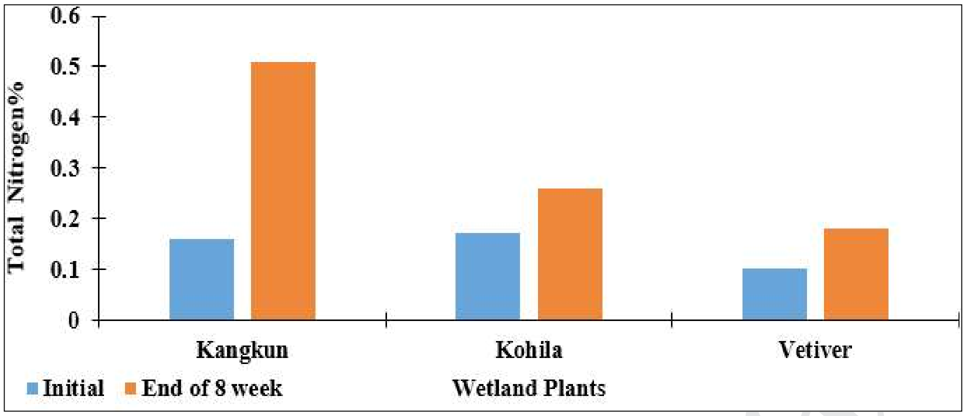
Fig.9:
Variation of TDS of influents and effluents

B. Plant Analysis

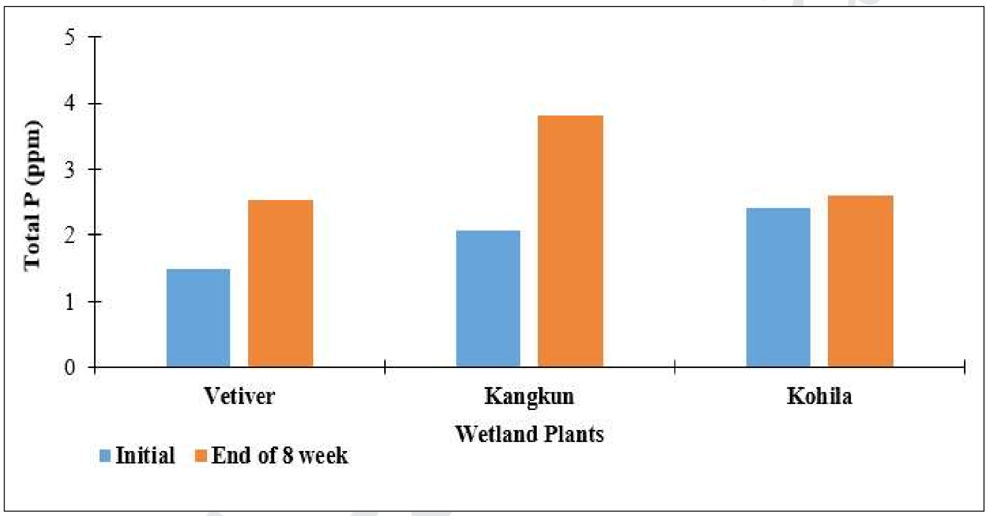
Total N and P contents of Wetland plants

The activity of the roots of the wetland plants is dominant in the phytoremediation process. The root uptake N and converts inorganic N into organic compounds (Vymazal, 2007) during the phytoremediation. Figure 10 illustrates the total N of wetland plants measured before the experiment and at the end (8^{th} weeks) after experiment. It clearly revealed that all the wetland plants used in the experiment significantly contributed to N pollutant removal by accumulating N in plant biomass.

Wetland plants remove aquatic pollutants through a complex variety of biological, physical, and chemical mechanisms, including adsorption, precipitation, sedimentation, and microbial transformation (Cheng *et al.,* 2002). A significant P accumulation in plant tissues was also observed when comparing plant P level at the initial stage and the end of the experiment period (Figure 11).



(a)



(b)

Fig. 10:
Comparison of total N (a) and P (b) contents of the wetland plants before the experiment vs end of the experiment.

4. Conclusions

All the wetland plants recorded increasing pollutant removal efficiencies throughout the monitoring period. Combinations of all three plant species showed higher performance in removal of NH_4^+-N, NO_3^- - N, PO_4^{-3}-P compared to two plants combinations and single plants. It may probably due to the highest root density and variation of root depths in three plant combinations of Kangkung, Kohila, and Vetiver**.** Overall, it can be concluded that small-scale CW units are a viable technology for greywater treatment at the domestic level with the combination of the tree plant species;Kangkung, Kohila, and Vetiver plants.

5. References

Ayers, R.S., and Westcot, D.W. (1985). *Water Quality for Agriculture*, FAO Irrigation and Drainage Paper 174.

Bachand, P.A.M., Horne, A.J. (2000). Denitrification in constructed free-water surface wetlands: II. Effects of vegetation and temperature. *Ecological Engineering* **14**,17-32.

Bremner, J.M., Miller, R.H. and Keeney, D.R. (1982). *Methods of soil analysis. part 2*. American Society of agronomy, Madison, Wisconsin.

Cheng, S,, Grosse, W,, Karrenbrock, F. and Thoennessen, M. (2002). Efficiency of constructed wetlands in decontamination of water polluted by heavy metals. *Ecological Engineering* **18**, 317–325.

Gopalan, B., Thattai, D.V. and Rahman, A. (2009). Treatment of wastewater from kitchen in an Institution Hostel Mess using constructed wetland. *International Journal of Recent Trends in Engineering* **1**, 54-58.

Hemanthika, H. S. (2016). Design and development of Multi – store Constructed, Wetlands for Wastewater Treatment. *Proceeding of Annual Research Symposium, University of Peradeniya, Sri Lanka.*

Jinadasa, K.B.S.N., Tanaka, N., Mowjood, M.I.M. and Werellegama, D.R.I.B. (2006). Free water surface constructed wetlands for domestic wastewater treatment: A tropical case study. *Chemistry and Ecology* **22(3),** 181-191.

Mejare, M. and Bulow, L. (2001). Metal-binding proteins and peptides in bioremediation and phytoremediation of heavy metals. *Trends in Biotechnology* **19**, 67–73.

National Environmental Regulations. (2008). Accessed from https://www.elaw.org/content/sri-lanka-national-environmental-protection-and-quality-regulations-2008 on 22.03.2019.

Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean. L. A. (1954). *Estimation of available phosphorus in soils by extraction with* $NaHCO_3$, USDA Cir.939. U.S. Washington.

Vymazal, J. (2005). Horizontal sub-surface flow and hybrid constructed wetlands systems for wastewater treatment. *Ecological Engineering* **25**,478–490.

Vymazal, J. (2007). Removal of nutrients in various types of constructed wetlands. *Science of the Total Environment* 380, 48–65.

Yang, J., Liang, X., Niu, T., Meng, W., Zhao, Z. and Zhou, G.W.(1998). Crystal structure of the catalytic domain of protein-tyrosine phosphatase SHP-1. *Journal of Biological Chemistry* **273(43)**, 28199-207.

Zhang, D.Q., Gersberg, R.M. and Tan, S.K. (2009). Constructed Wetlands in China. *Ecological Engineering* **35(10),**1367-1378.