

Essay

Seasonal Applicability of Three Plant Constructed Wetlands for Nutrient Removal in Pilot Scale

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Abstract

The main objective of this study was to compare the removal efficiency of nutrients using *Lactuca sativa*, *Medicago sativa* and *Phragmites australis* in subsurface flow constructed wetlands with horizontal flow. In order to test water quality, fabricated reactors designed and the plants cultivated in the soil while their root were inside the wastewater. A long time study carried out from spring till end of autumn (9 months) in order to evaluate the difference in removal rate based on the seasonal changes. The highest removal rate was during summer which followed by spring and autumn. Thus, the effect of plants on the removal efficiency of organic matter (COD, BOD), TSS and nutrient (P and TN) appeared to be dependent on the seasonal growth. *Phragmites australis* the most sensitive species in order the removal of nutrient from wastewater.

Keywords: sub-surface flow constructed wetland; nutrient removal; wastewater treatment; *Lactuca sativa*; *Medicago sativa*; *Phragmites australis*

1. Introduction

Today, constructed wetlands (CWs) are recognized as a reliable wastewater treatment technology and they represent a suitable solution for the treatment of many types of wastewater. Constructed wetlands have been used extensively across the world for treating wastewater due to its low cost and efficiency in removal of pollutants (Vymazal et al, 2010). Wastewater treatment in wetland occurred by a process named phytoremediation that is a moderately late innovation and is seen as practical, proficient, novel, eco-friendly technology, still in its initial improvement stages and full scale applications are still constrained (Rezania et al, 2015). Wide range of wastewaters such as municipal, industrial, agricultural, and storm water can be remediated in CWs. (Pedescoll et al., 2015; Qasaimeh et al., 2015). In addition, CWs is a flexible and effective method for treating and reusing wastewater with less greenhouse gas emission (Chen et al, 2011).

Generally, the major functions of plants in CWs is to create conditions suitable for removal of pollutants and the direct role of plants is limited to uptake of nutrients and heavy metals (Marchand et al, 2010). Brisson, (2009) showed that the some environmental factors like temperature, pH, solar radiation and water salinity can influence plant growth and its performance in phytoremediation. The importance of these parameters are related to size, weight and growth rate of aquatic plants (Lissy et al., 2010).

Based on (Tanner ,2001), wetland plants provide only small improvements in biological oxygen demand (BOD), chemical oxygen demand (COD) and faecal bacterial indicator removal but provide measurable enhancement of nutrient removal, mainly by promoting transformations to gaseous forms and sequestration in accumulating organic matter. As extensively reviewed by Engloner. (2009), considering the worldwide distribution, *Phragmites* dominated wetlands may have a considerable effect on climate change. Because of this issue, the significance of common reed in scientific research will be on-going in the future studies. *Phragmites australis* is the most often used plant in CWs although a large diversity of species can be used and the genus *Typha* and *Scirpus* are commonly used (Vymazal et al, 2011). As described by Engloner. (2004), water availability is an important factor in shoot which is longer in wetter than drier habitats (with maximum water depths 40–0 and –30 cm, respectively).

In the Czech Republic, horizontal subsurface flow CWs are mostly planted with *Phragmites australis* (Common reed) or *Phalaris arundinacea* (Reed canarygrass) or with a combination of these two species. Some factors like : (1) excellent germination from the seeds, (2) easy planting, (3) fast growth, creating full cover of the surface during the first growing season if planted in spring, and (4) provision of good insulation during the winter. (Vymazal , 2013). *P. australis* aboveground biomass in HF CWs varies widely between the values $< 1000 \text{ g m}^{-2}$ to more than 11,000 (g/m^{-2}) on dry matter basis and growing in natural stands also varies greatly within the similar range as in constructed wetlands (Vymazal ,,2016). As the nitrogen and phosphorus are essential elements for plants and living beings, meanwhile domestic and industrial wastewater which is not fully treated can be among the most important factors that threatens the water quality (Chang et al, 2006). There has been a growing evidence that constructed wetlands with emergent vegetation are more efficient as compared to unplanted filters and that some species are more efficient than the other ones (Zhang et al, 2010).

The objective of this study was to determine the effect of nutrient removal by *Medicago Sativa*, *Lactuca sativa*, *Phragmites Australis* and mixture of (*Medicago Sativa* and *Lactuca sativa*) while they grew in municipal wastewater as the first treatment system. Also, the removal efficiency of these plants during 9 months experiments was compared.

2. Materials and methods

2.1 Experimental set-up

A pilot experimental system was established in Ekbatan wastewater treatment plan and the study was carried out from April 2015 to December 2015. In Iran, the spring begin on April while the summer and autumn begin on July and October, respectively. The system was comprised of five horizontal subsurface flow CW units in parallel with a different plant species each: CW1 (unplanted), CW2 (*Medicago Sativa*) CW3 (*Lactuca sativa*), CW4 (*Phragmites Australis*) and CW5 (Mixture of *Medicago Sativa* and *Lactuca sativa*) as shown in Figure 1.

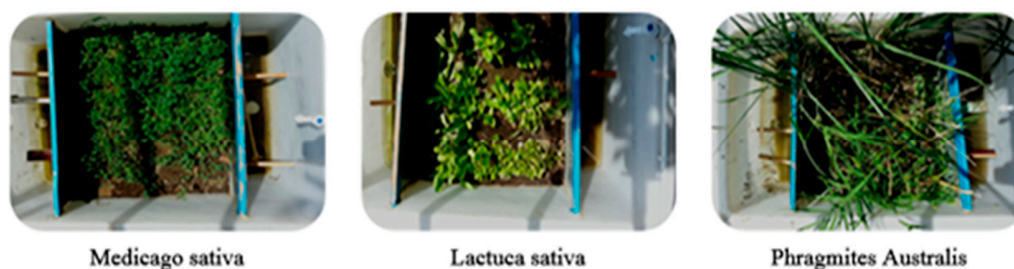


Fig. 1. Plant cultivation in separate reactors

Each CW unit has length of 1.15, width of 0.75 and depth of 0.6 meters. Inside the reactor was completed with stones of various diameters as larger stones (15-32 mm) were placed at the bottom, medium (9.5-15 mm) and small (6-9 mm) placed at the middle and the top. The wastewater was entered with a flow rate of (0.093 L/day) to the system continually. The length of *M. Sativa* root was inside the sand 10 cm while it was 6 cm for *L. sativa* is 6 cm (in a radius way). In the case of *P. Australis*, the bushy root reached to the bottom of the soil. The overall design of pilot study is shown in Figure 2.

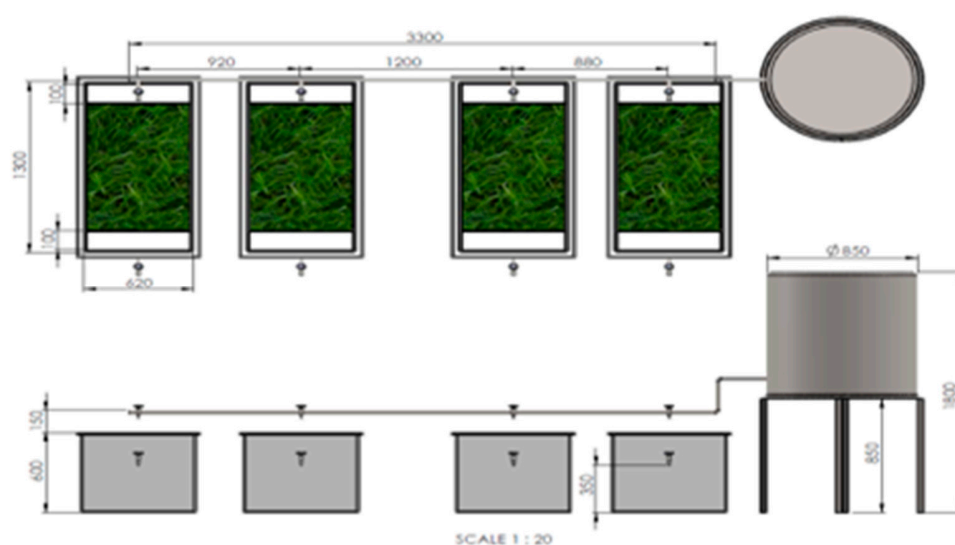


Fig. 2. Design of horizontal subsurface flow constructed wetland in the study

2.2 Water sampling and analysis

The influent comes from raw wastewater as first treatment system which located at Ekbatan township in Tehran. The samples were collected from influent and effluent of each CWs daily for the analyses. The sampling last for 10 days of each month (standard deviation) and each test was conducted in triplicates. All the parameters were investigated in accordance to APHA standards (2005) BOD, COD and TSS were measured by following methods: BOD 5 determined using 5-Day BOD test method (APHA 2005), COD by colorimetric method (5220-D) and TSS by using Method No. 2540D. The total P was measured using the vanado-molybdate colorimetric method by measuring the absorbance at a wavelength of 420 nm (Fiske et al, 1925). Kjeldahl nitrogen was measured using APHA standard 2005.

3. Results and discussion

The removal efficiency of each plant in CWs during 9 months in different seasons was investigated and discussed as shows in Table 1.

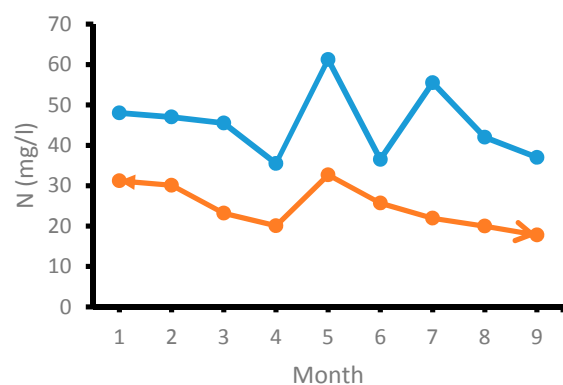
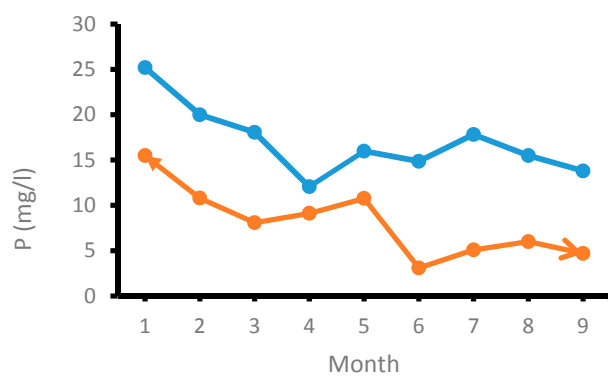
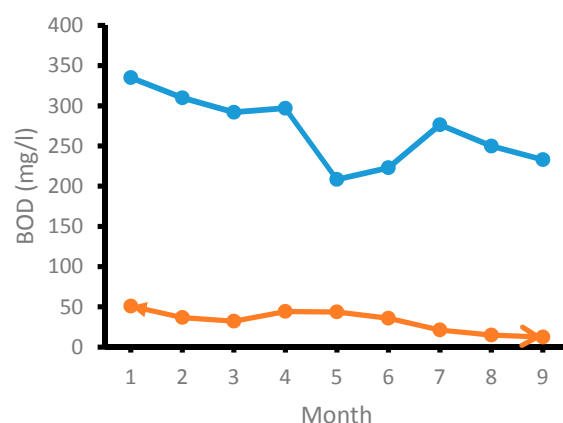
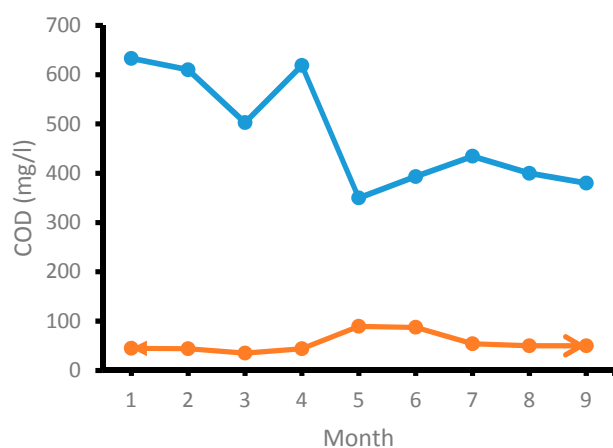
Table 1: Removal efficiency based on different CWs

| CWs | Plant species | Removal efficiency | | |
|-----|---|--------------------|--------|----------|
| | | Spring | Summer | Autumn |
| 1 | <i>Medicago Sativa</i> | low | high | moderate |
| 2 | <i>Lactuca sativa</i> | moderate | high | moderate |
| 3 | <i>Phragmites Australis</i> | moderate | high | moderate |
| 4 | <i>Medicago Sativa & Lactuca sativa</i> | moderate | high | moderate |

3.1 *Medicago Sativa*

As shown in figure 3 during the first months of plant operation, COD decreased gradually which the lowest was 385 on 5 month in the summer. It showed the linear and stable reduction till end of the experiment. The reduction was around 50% using *Medicago Sativa* for the treatment of municipal wastewater. Similarly, BOD showed same reduction while after month 5 (35%), small

increases observed which may related to biomass growth and seasonal changes. In regard to nutrient removal like P and TN, the reduction occurred till 4 month (summer). In summer, the amount of P and TN increased slightly while it was fluctuated for TN. During autumn, P values in water decreased proportionally while TN showed lesser reduction rate by 25%. In regard to TSS, it increased sharply till from spring till end of summer (6 months) which the highest was by 120% on 6 months. Then, it decrease during autumn till end of experiment.



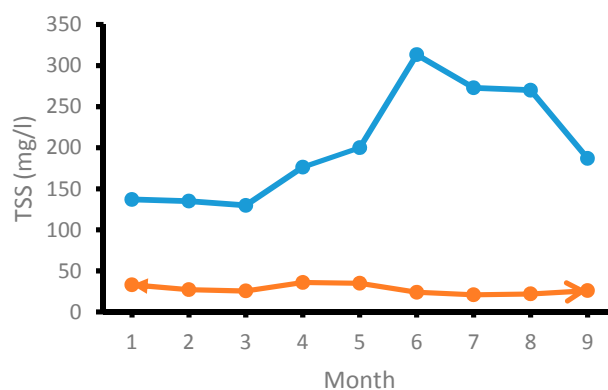
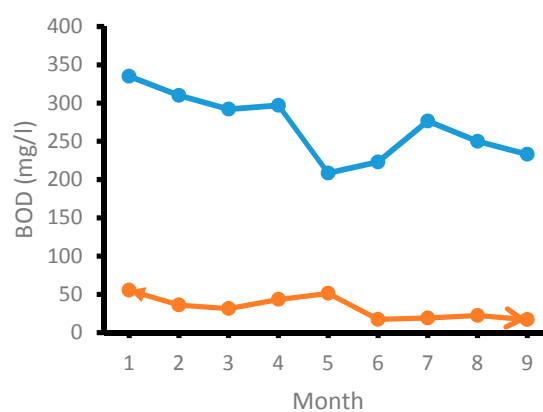
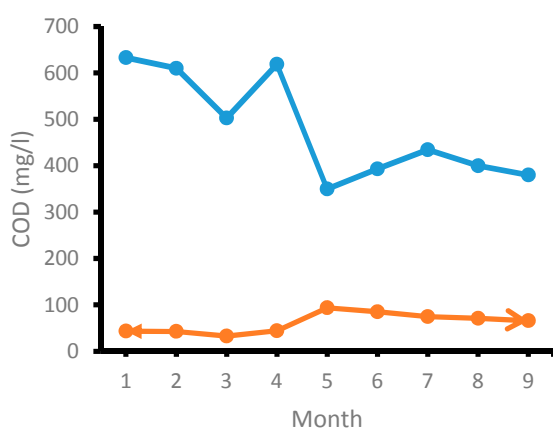


Fig 3: Nutrient removal by *M. sativa*

3.2 *Lactuca sativa*

There is no studies which used *Lactuca sativa* for wastewater treatment. This plant reduced COD by 40% during first five months of the experiment. Then, COD increased during autumn till end of the experiment. In regard to BOD, similar reduction occurred which was highest by 35% on middle of summer after 5 months of the experiment. *L. sativa* had similar removal reduction pattern for T and TN which reduced after 4 months of the experiment. The highest removal was 60% and 30% for P and TN, respectively. By using *Lactuca sativa*, TSS was increased till end of summer by 100% and then decreased till end of autumn (Figure 4).



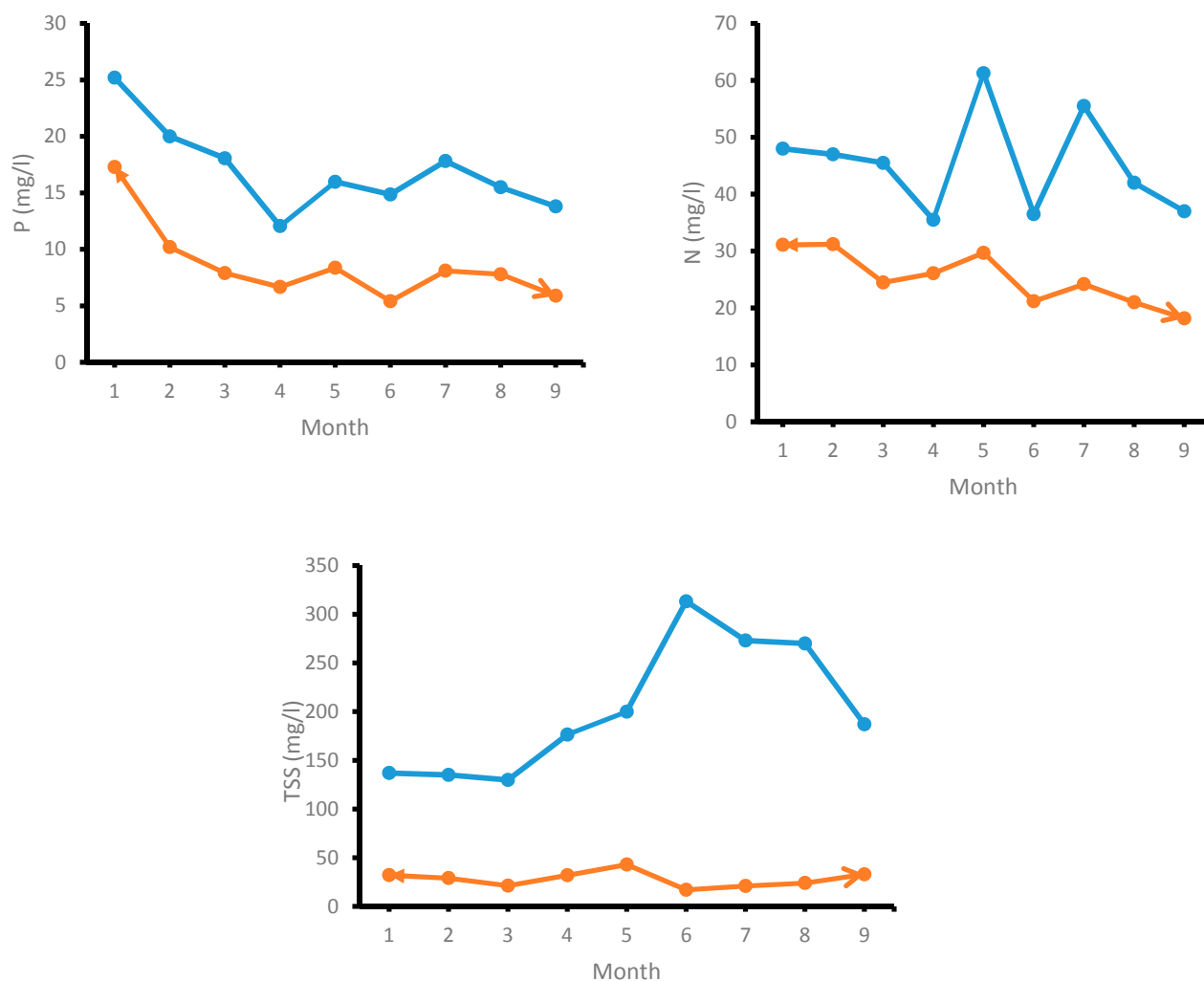


Fig 4: Nutrient removal by *L. sativa*

3.3 *Phragmites Australis*

Many studies showed the efficiency of *P. Australis* in removal of nutrient from different types of wastewater. This plant was effective in removal of BOD and COD over the five years (Březinová and Vymazal, 2014). Although, Carballeira et al. (2016) found that the high increases in TSS by using *P. Australis*. In this study, *P. Australis* removed COD and BOD by 40% and 30% till end of summer, respectively. Similarly, P and TN removed significantly till starting of summer by 65% and 30% respectively. Fuchs et al. (2011) found lesser removal rate of TN and P using *phragmites Australis* which was as 35.6 % and 31% respectively. As indicated by Carballeira et al. (2016), *P.*

australis had an intermediate biomass production rate and an increased nitrogen removal rate by approximately 30% in comparison with the control. As shown in Figure 5, TSS increased till end of summer and was decreased during autumn proportionally.

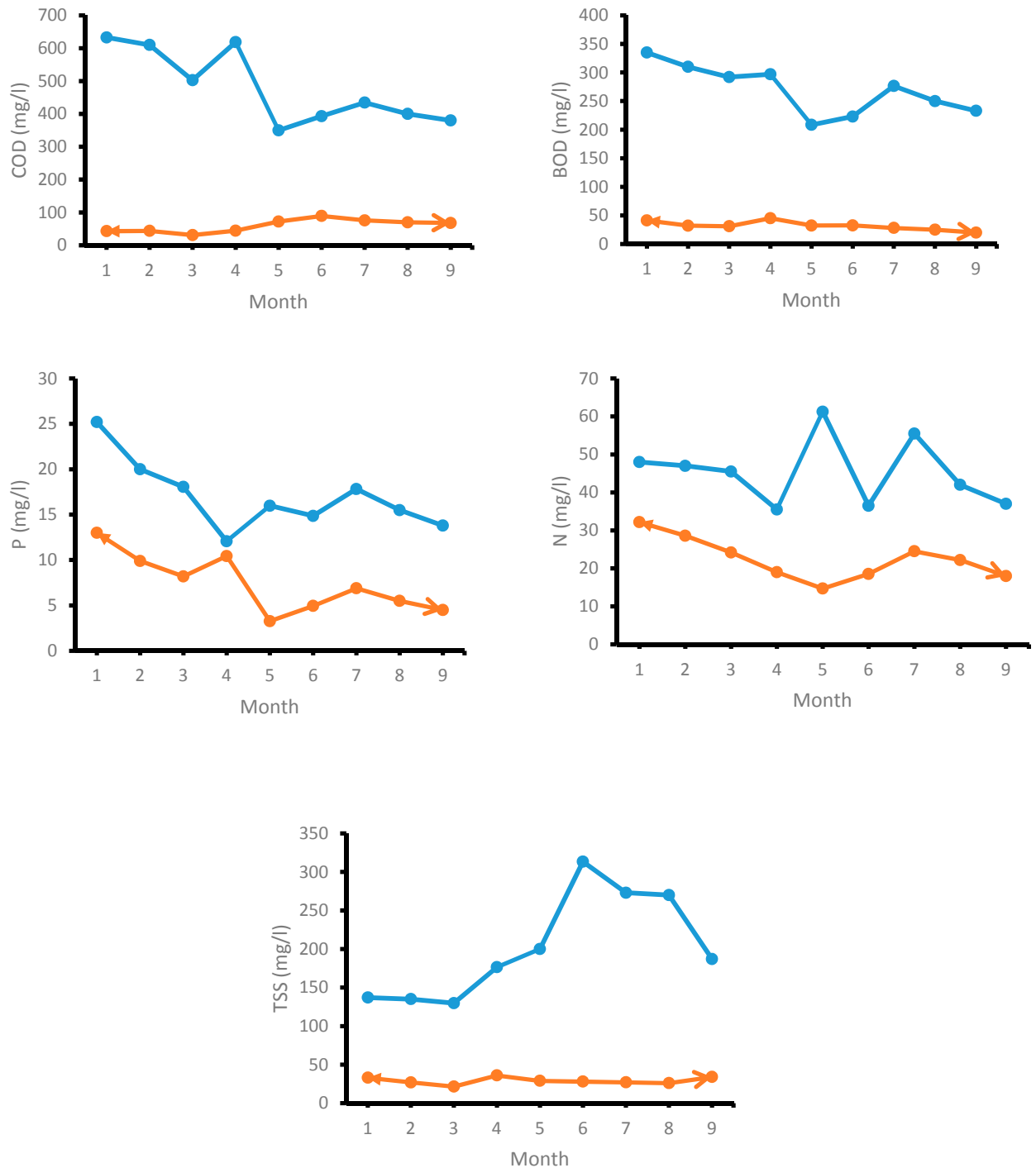
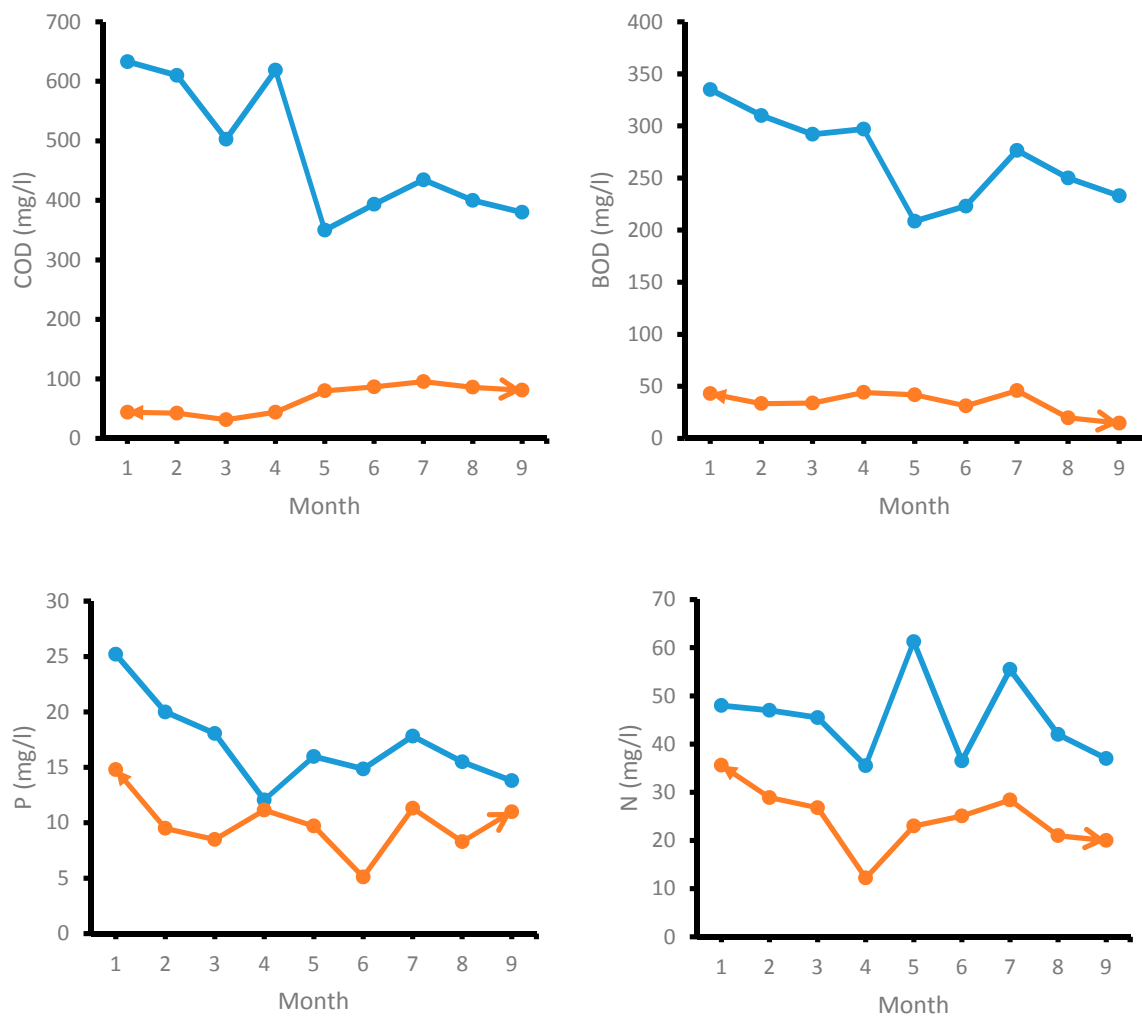


Figure 5: Nutrient removal by *P. Australis*

3.4 Mix of *L. sativa* and *M sativa*

As shown in Figure 6, in the CWs contains mixture of *L. sativa* and *M sativa*, similar observation of reduction was observed. The obtained results showed in was inconsistency with reduction of these plants when they culture in CWs alone. Most of the reduction occurred during summer while it was lesser during autumn. Highest removal of most of the parameters was in summer which followed by autumn and the lowest was in spring (Figure 6). It shows that the duration and season are the important factors which influenced removal efficiency.



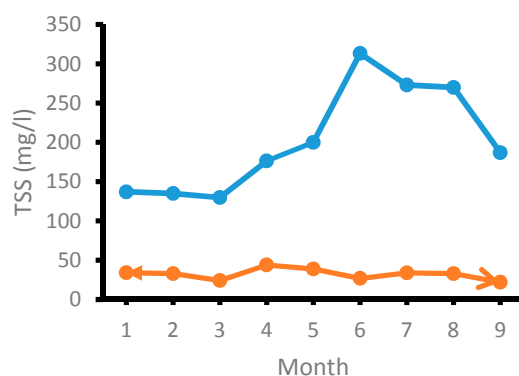


Figure 6: Nutrient removal by mix of *L. sativa* & *M sativa*

4. Conclusion

In this study, the effectiveness of nutrient removal by *Medicago Sativa*, *Lactuca sativa*, *Phragmites Australis* and mixture of (*Medicago Sativa* and *Lactuca sativa*) in farictaed CWs was investigated. Different parameters like COD, BOD, TSS, P and TN measured during 9 months treatment system of municipal wastewater. Similar reduction pattern was observed during experiment while the highest reduction occurred during summer which followed by spring and autumn, respectively. In terms of removal efficiency in CWs, the highest reduction obtained using *Phragmites Australis* which followed by (*Medicago Sativa* and *Lactuca sativa*), *Medicago Sativa* and *Lactuca sativa*. The average of removal rate was for COD (40-65%), BOD (30-50%), TSS (100-120% increase), P (40-60%) and TN (25-35%). This study proved that the horizontal subsurface flow CWs are the effective method for wastewater treatment for initial and secondary treatment.

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