Carpathian Journal of Earth and Environmental Sciences, November 2015, Vol. 10, No 4, p. 65 - 74

PERFORMANCES OF A CONSTRUCTED WETLAND TREATING PLANTED WITH EMERGENT AND FLOATING MACROPHYTES UNDER ALGERIAN SEMI-ARID CLIMATE

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Abstract: Constructed wetlands (CWs) have been successfully used to remove pollutants from wastewater. This research uses two aquatic plant species, *Phragmites australis* an emergent macrophyte (EM) and *Salvinia natans* a floating macrophyte (FM) in separate or mixed culture to investigate whether the CW systems using EM and FM are effective for the treatment of domestic wastewater. In order to evaluate the water purification performance several chemical and biochemical parameters were measured. Mixed plant culture recorded the highest and significant removal potential with 97.3% of biochemical oxygen demand (BOD_5), 95% of chemical oxygen demand (COD), 93% of total Kjeldahl nitrogen (TKN), 87.9% of ammonium-nitrogen (NH_4-N), 52.8% of nitrite-nitrogen (NO_2-N) and 40% of phosphate-phosphorus (PO_4-P). Our results suggest that the mixed culture of *P. australis* and *S. natans* is a simple and low-cost technique for effective removal of organic (BOD_5 and COD) and inorganic (TKN, NH_4-N and PO_4-P) pollutants from domestic wastewater.

Keywords: Wastewater treatment, Nutrient removal, *Phragmites australis*, *Salvinia natans*, semi-arid climate.

1. INTRODUCTION

In most countries of the world, there has been growing and irreversible interest of the public for the protection of the environment. In Algeria, for instance, the water pollution problem is quite serious and therefore, purification techniques including constructed wetlands (CWs) using macrophytes are currently widely used for treatment of wastewater. CWs become an interesting alternative for the treatment of wastewater, seen the great benefits that they exhibit, they are less expensive to build and operate, are constructed directly on the wastewater discharge site, require little mechanized equipment and ultimately are less sensitive to changes in pollutant loads (Brix, 1997).

The main functions of CWs include surface water storage, holding and recycling nutrients, providing wildlife habitats, stabilizing shorelines, controlling and buffering storm related flooding, recharging groundwater, providing treatment for pollutants in water (Jing et al., 2001). Furthermore, CWs can effectively remove organic matter, suspended solids, metals, and excess nutrients (such as nitrogen, phosphorus, etc.) through various processes including filtration, sedimentation, biological and microbiological adsorption, and assimilation (Dortch, 1996; Delaune et al., 1996; Josimov-Dunđerski et al., 2012).

Macrophyte-based wetland systems (MBWS) are reported to be effective for the treatment of primary, secondary and tertiary urban wastewater, domestic, stormwater, agricultural and industrial wastewater (Galfati et al., 2011; Jing et al., 2001; Khan et al., 2014), however, the challenge is to maximize efficiency the lowest possible cost (Zimmels et al., 2008). The choice of plants is an important issue in the filters planted with macrophytes because they have to survive the potential toxic effects of sewage and their variability. The use of local plants with economic and environmental interests in the sewage system, such as *Phragmites australis*, makes them more exciting (Calheiros et al., 2007).

Aquatic plants, emergent or free floating, acquire more and more importance in the world especially in countries with hot climates where the photosynthetic efficiency is important. The produced biomass is valued using biomethanation or by incorporation in animal nutrition (Sooknah & Wilkie, 2004). Floating or emergent aquatic plants, such as water hyacinth (*Eichhornia crassipes* (Mart) Solms), water lettuce (*Pistia stratiotes L.*), *Salvinianatans* (L.), cattail (*Typha latifolia L.*), bulrush (*Scirpus validu .L.*),are able to treat wastewater with high purification yields(Reddy et al., 1982; Jampeetong & Brix, 2009b; Vymazal, 2005).

Since the innovation of the CWs system, several studies performed using either EM or FM. However, little attention has paid to the combination of EM and FM (Kumari & Tripathi, 2014).

In this study, we developed a macrophyte-based wetland system using two aquatic plants namely *P. australis* as EM and *S. natans* as FM to evaluate the efficiency and treatment performance of mixed culture for filtration of domestic wastewater.

2. MATERIALS AND METHODS

2.1. Experimental device and methods

The experiment was carried out under semi-arid conditions at the town of Merouana (35°37'43''N, 05°54'42'E) located 500 km East of Algiers (Fig. 1), which has a semi-arid to arid Mediterranean climate with an average rainfall of about 240mm per year and an average temperature of about 5 to 38°C. The experimental device used for the present study depicted in figure 2.

Three biofiltration units, where each unit comprised two tanks of 75 liters capacity (50 cm(L) x 50 cm(W) x 60 cm(H)).

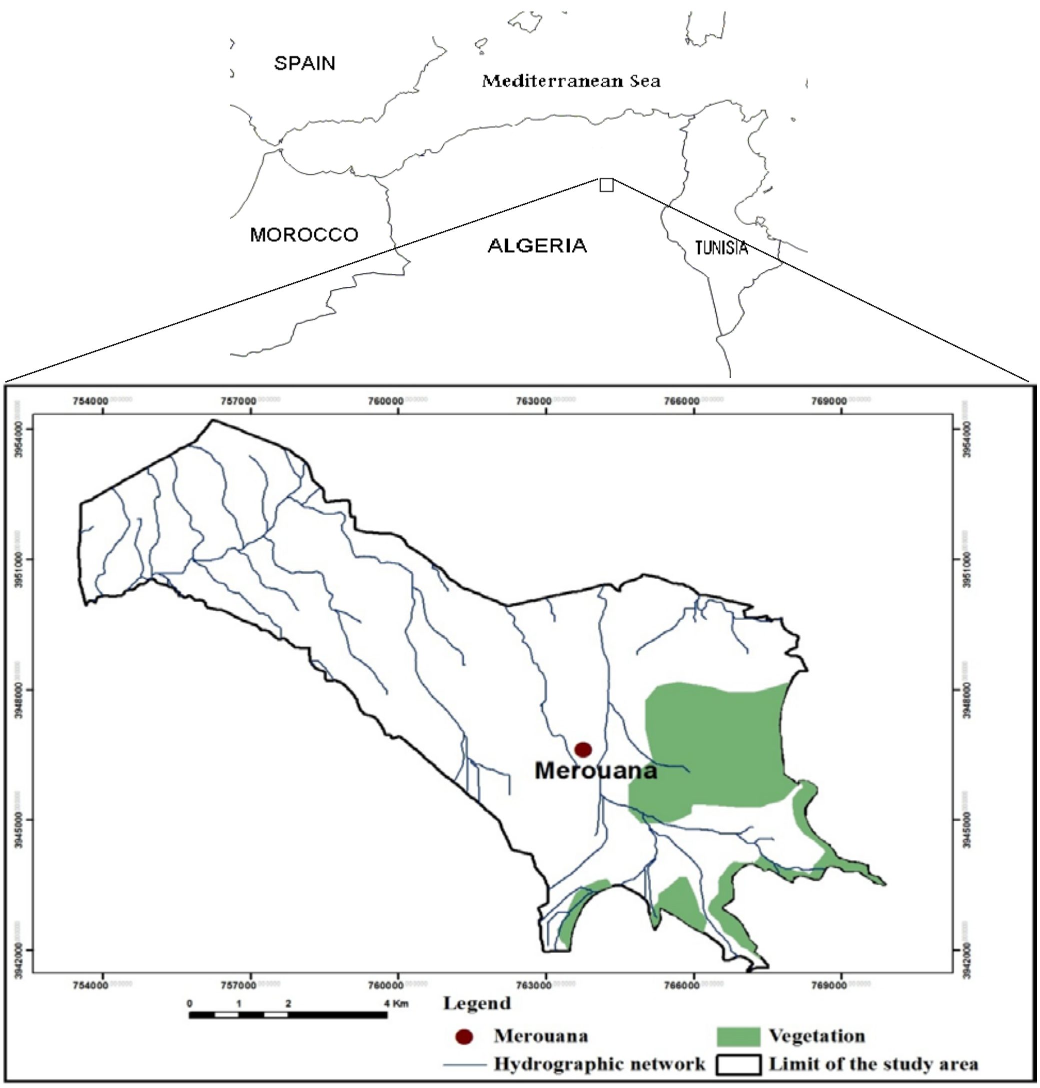

Figure 1. Location map of analyzed area

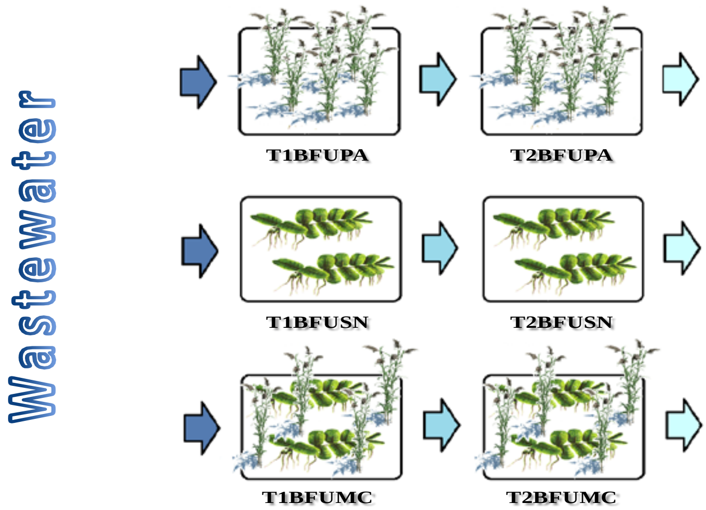

Figure 2. Macrophyte-biofiltration systems used for wastewater treatment. T1 BFUPA, T2 BFUPA N (Tanks 1and 2 of first biofiltration unit planted with *Phragmites australis*); T1 BFUSN, T2 BFUSN (Tanks 1and 2 of second biofiltration unit planted with *Salvinia natans*); T1 BFUMC, T2 BFUMC (Tanks 1and 2 of third biofiltration unit planted with mixed culture of both species).

The tanks are filled to 5 cm in depth and 30 cm with respectively gravel (5-10mm) and soil with silty clay-sandy texture (31% clay, 20% silt and 49% sand). In the tanks of the first unit (BFUPA), young shoots of *P.australis* (36 stems/m^2) were planted.The tanks of the second unit (BFUSN) were planted with *S. natans* (36.5 g per tank), whereas in the third unit or mixed culture, tanks were planted with *P.australis* and *S.natans* (BFUMC) at a density of 05 stems/m^2 and 18.25 g per tank, respectively.

The systems supplied by raw domestic wastewater (25 liters/day) acquired from Merouana municipal sewage treatment works, and Table 1 summarizes its physicochemical characteristics. Tanks inclined at 10° to the surface such that water can be directly downstream, and fitted with a drain at the bottom for percolating water collection (effluent). Wastewater passes from a tank to another through a 4-cm (outside diameter) perforated PVC pipe. The experiment lasted eight months from April to November 2014.

2.2. Operating conditions

Early in March, we collected the young plants (*P. australis* and *S. natans*) around the lake of Garaet Hadj-Tahar in northeast Algeria (36°51’50’’N, 07°15’57’’E), and washed them properly with distilled water to remove soil and dead plant tissues and in order to get them free from microalgae. Healthy plants were then acclimated in tanks using fresh water at 20cm above the ground for three weeks prior to treatment with wastewater. The biofiltration units kept under natural conditions of sunshine throughout the experiment.

2.3. Wastewater quality monitoring and statistical analyses

The CWs placed in operation in April 2014.Theirremoval efficiency and treatment performance evaluated in eight sampling campaigns, which took place in the eight-month period from April to November 2014. Wastewater samples (influent and effluent) were collected and stored in glass bottles, transported to the laboratory and analyzed immediately for biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), ammonium-nitrogen (NH_4-N) and phosphate–phosphorus (PO_4-P) according to French standard methods (AFNOR, 2008). In addition, measurement of temperature (T) and pH had done using a portable instrument (ProfiLine pH 3110, WTW). We used at least five repetitions of each sample to achieve sufficient accuracy.

Treatment efficiency of chemical parameters was calculated as the percentage of removal for N and P as follows: *Removal efficiency (%)=* $\left(\frac{Ci-Ce}{Ci}\right)$ *x 100*, where Ci and Ce are the influent and effluent concentrations in mg/L.

Data analyzed using one-way ANOVA and least significant difference tests (LSD at alpha = 0.05) to find differences among means of the different physicochemical parameters of wastewater before and after treatment. Statistical analyses carried out using STATGRAPHICS Centurion XV (Manugistics, Rockville, MD, USA).

3. RESULTS

3.1. Mean physicochemical parameter variation

Table 1 summarizes results of the measured physicochemical proprieties of wastewater before and after biofiltration treatment. Figure 3, however, displays the seasonal variation of all these parameters throughout the eight-month period of experience. In contrast to the mean values of the wastewater temperature, which showed only slight spatial variations along the biofiltration units and generally ranged from 18.2 to 24.6ºC depending on the season (Fig.3a), all the studied parameters were showed a significant variation after wastewater biofiltration (Table 1).

As revealed by figure 3b, the mean pH value of input water used in this study was 7.2 and ranged from 7 to 7.5. However, at the outlet of biofiltration units, the pH values were ranging from 7.1 to 8.3.

This decrease in pH values was statistically significant (P<0.01). In addition, it appears from the same figure that the concentration of the main forms of nitrogen (NH_4-N, NO_3-N and TKN) and PO_4-P as well as BOD_5 and COD in wastewater showed highly significant decreases (P<0.001) after biofiltration, particularly by using mixed culture (Table 1 and Fig. 3).

Table 1. Physicochemical parameter and pollutant concentration statistics

		INLET	OUTLET			F	LSD5 %
			BFUPA	BFUSN	BFUMC		
pH	Mean	7.18 (c)	7.55 (ab)	7.41 (bc)	7.70 (a)	5.50**	0.29
	SD	0.17	0.20	0.23	0.37		
	Min	7.0	7.25	7.1	7.25		
	Max	7.5	7.9	7.75	8.25		
T °C	Mean	21.13 (a)	20.16 (ab)	19.94 (ab)	18.56 (b)	1.63 n.s	n.s
	SD	2.25	2.40	2.10	2.01		
	Min	18.2	16.65	17.3	15.75		
	Max	24.6	23.45	23.3	21.6		
NH_4-N	Mean	64.36 (a)	10.02 (b)	13.38 (bc)	8.08 (c)	264.3***	5.51
	SD	8.46	2.79	2.29	1.96		
	Min	51.84	6.14	10.42	5.02		
	Max	76.18	10.65	16.46	10.14		
NO_3-N	Mean	2.43 (b)	13.73 (a)	3.61 (b)	3.34 (b)	25.77***	10.11
	SD	0.93	4.24	2.32	3.31		
	Min	1.4	6.2	1.0	1.2		
	Max	3.9	20.1	6.9	11.2		
NO_2-N	Mean	0.128 (a)	0.116 (a)	0.083 (ab)	0.06 (b)	3.73*	0.056
	SD	0.05	0.04	0.06	0.02		
	Min	0.08	0.07	0.02	0.03		
	Max	0.20	0.18	0.22	0.09		
TKN	Mean	102.4 (a)	10.31 (b)	15.84 (b)	7.15 (b)	97.43***	86.52
	SD	22.81	5.93	11.01	3.36		
	Min	69.6	2.20	6.40	3.10		
	Max	131.3	17.8	40.1	12.3		
PO_4-P	Mean	10.95 (a)	6.56 (b)	6.86 (b)	7.10 (b)	10.66***	3.85
	SD	1.47	2.26	1.90	1.38		
	Min	8.9	3.0	5.1	5.1		
	Max	13.2	9.3	11.1	9.0		
BOD_5	Mean	311.3 (a)	9.20 (b)	8.31 (b)	5.94 (b)	43.7***	302.07
	SD	129.7	5.12	3.65	1.98		
	Min	112.4	4.9	4.2	3.5		
	Max	466.1	19.8	15.5	9.8		
COD	Mean	981.7 (a)	46.09 (b)	40.56 (b)	28.68 (b)	209.08***	935.64
	SD	171.4	18.98	4.47	5.79		
	Min	683.5	20.2	33.2	20.5		
	Max	1230.1	75.5	47.1	39.2		

*, **, *** indicate significant differences at P<0.05, P<0.01 and P<0.001 respectively. n.s, not significant.SD, standard deviation. Different small letters mean significant differences (P<0.05) among treatments.

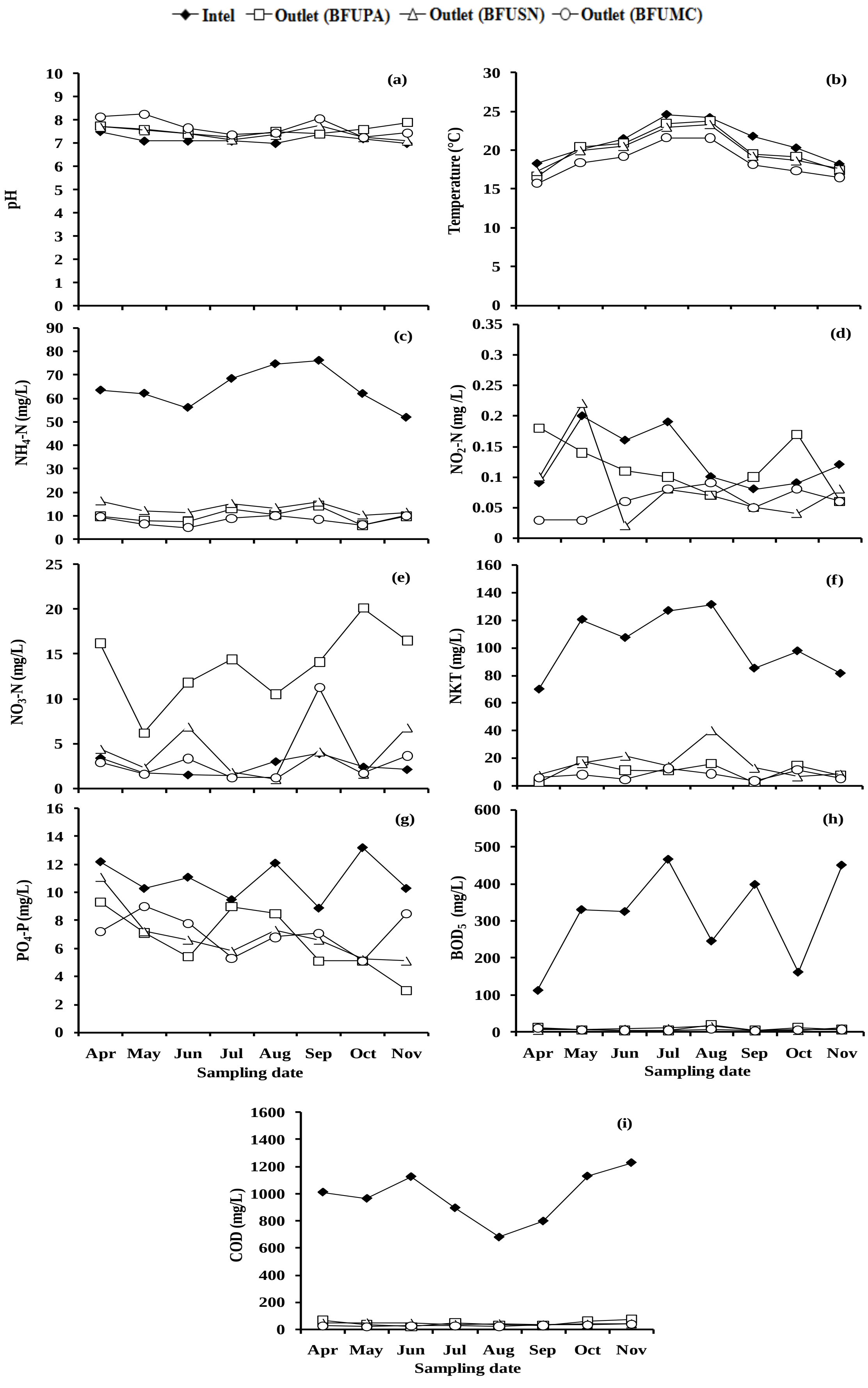

Figure 3. Time-course of change in Temperature (a), pH (b), NH_4-N (c), NO_2-N (d), NO_3-N (e), TKN (f), PO_4-P (g), BOD_5 (h), COD (i) throughout the period of study(Mean ± SD).

3.2. Pollutant removal efficiency

3.2.1. Removal of nitrogen

Table 2 presents the variation of mean removal efficiency along the various biofiltration units for all the pollutants. Overall, we calculate the removal for each constituent based on its concentrations at the inlet and outlet of the biofiltration units. As displayed by table 2, with the exception of nitrate (NO_3-N), the three-biofiltration systems exhibited high percentages of removal efficiency of nitrogen from wastewater namely in term of NO_2-N, NH_4-N, and TKN. However, both species (cultivated in separate or mixed culture) showed statistically significant variability in the removal efficiency ofNH_4-N and TKN with $P<0.001$ and $P<0.05$ respectively.

3.2.2. Removal of orthophosphate

Table 2 also showed the variation in removal of orthophosphate from the wastewater in the various experimental devices. Overall, there is no significant difference in the removal efficiency of PO_4-P among the three-biofiltration units. The efficiencies of removal in BFUPA increase by 5.2–70.8% with an overall average of 39.4%. The second and the third biofiltration units (BFUSN, BFUMC) achieved the removal efficiencies of 09-60.6% and 12.6-61.3% respectively. While the overall average seems to have moderately decreased overall up to 36.9% and 33.8% respectively in relation to the first unit, it is worth noting that even though PO_4-P concentrations increased in the outlet waters on some individual occasions.

3.2.3. Removal of BOD_5

The average concentrations and overall efficiency elimination of BOD_5 in the influent and effluent throughout the study period displayed in Figure 3h and Table 2 respectively. The removal of BOD_5 found higher in the three unit's biofiltration with very close averages in each unit: 95.7 % for BFUPA, 96.9 % for BFUSN and 97.5 % for BFUMC.

3.2.4. Removal of COD

The load of domestic wastewater chemical oxygen demand (COD) fluctuates greatly between 683.5 mg/L and 1230.1 mg/L with a mean value of 981.7 mg/L. Thus, at the outlet of the three units follows fluctuations in domestic wastewater with significant picks (Fig. 3i). Overall, compared to domestic wastewater, the treated wastewater quality is significantly better. The removal rates of COD displayed higher in each unit (Table 2).

3.3 Correlation analysis

Multiple correlation analysis of our data revealed the existence of several strong relationships between almost all the studied parameters (Table 3). Interestingly, we found strong positive relationships between NH_4-N and almost all the studied variables. In contrast, negative relationships between pH values and almost all the others variables namely TKN, BOD_5, NH_4-N and COD with r = -0.58***, -0.52**, -0.51** and -0.51**, respectively. On the other hand, both BOD_5 and COD showed high positive correlation between them (r = 0.89**) and almost all the other variables.

4. DISCUSSION

Constructed wetlands (CWs) using macrophytes are currently widely used for treatment of wastewater. In order to investigate whether the CWs using emergent macrophyes (EM) and floating macrophytes (FM) were effective for the treatment of domestic wastewater, we carried out the present study using two aquatic plant species, namely *P. australis* an EM and *S. natans* a FM in separate or mixed culture.

Table 2. Removal efficiency (%) of different nutriments for the three units

		BFUPA	BFUSN	BFUMC	F	LSD5%
NH_4-N	Mean	84.4 (b)	79.0 (a)	87.9 (c)	18.18***	3.45
NO_3-N	Mean	0.0 (a)	17.1 (a)	15.5 (a)	n.s	n.s
NO_2-N	Mean	23.5 (a)	40.0 (a)	52.8 (a	n.s	n.s
TKN	Mean	90.4 (ab)	85.2 (a)	93.0 (b)	4.32*	7.75
PO_4-N	Mean	39.4 (a)	36.9 (a)	33.8 (a)	n.s	n.s
BOD_5	Mean	95.7 (a)	96.9 (a)	97.3 (a)	n.s	n.s
COD	Mean	95.3 (a)	95.7 (a)	97.0 (b)	5.04*	1.25

*, **, *** indicate significant differences at P<0.05, 0.01 and 0.001 respectively. n.s, not significant. Different small letters mean significant differences (P < 0.05) among treatments.

Table 3. Correlation analysis (n = 8x4 = 32)

	NH_4-N	NO_2-N	NO_3-N	TKN	PO_4-P	BOD_5	COD	TEM
NO_2-N	0.3340							
	0.0617							
NO_3-N	**-0.3538**†	0.1099						
	0.0470‡	0.5492						
TKN	**0.9499**	**0.4190**	**-0.3869**					
	0.0000	0.0170	0.0287					
PO_4-P	**0.7157**	0.2546	-0.3475	**0.6824**				
	0.0000	0.1597	0.0513	0.0000				
BOD_5	**0.8858**	**0.4209**	-0.3359	**0.8927**	**0.5579**			
	0.0000	0.0165	0.0602	0.0000	0.0009			
COD	**0.9265**	**0.3731**	-0.3438	**0.9065**	**0.7203**	**0.8873**		
	0.0000	0.0354	0.0540	0.0000	0.0000	0.0000		
TEM	**0.3550**	0.2028	-0.1506	**0.4519**	0.1776	0.3260	0.2054	
	0.0462	0.2657	0.4106	0.0094	0.3309	0.0686	0.2595	
pH	**-0.5147**	-0.3483	0.2871	**-0.5768**	-0.2234	**-0.5204**	**-0.5076**	**-0.5156**
	0.0026	0.0508	0.1111	0.0005	0.2189	0.0023	0.0030	0.0025

†Correlation: Pearson product-moment correlation coefficients (r) between each pair of variables. ‡P-Value: tests the statistical significance of the estimated correlations.

Overall, our results indicate that all the three-biofiltration systems (EM, FM or EM+FM) are highly effective in the treatment of domestic wastewater (Tables 1, 2 and Fig.3a-i).

In contrast to the slight decrease observed in the mean values of wastewater temperature at the outlet of all the biofiltration units, especially BFUMC, which can be explained by the fact that water surface was fully hedged by floating and emergent plants (Fig.3a and Table 1),the mean values of pH were significantly increased (Table 1). Similar results observed in previous studies (Lin et al., 2002; Coleman et al., 2001). Both decrease in temperature and increase in pH can be explained by the algal growth observed at the surface of each tank since foliar cover may preserves the tank surface against summer drying and offer shade to bacteria and the fact that algae can absorb CO_2 faster than it can be replaced by bacterial respiration (Lin et al., 2002).

Regarding nitrogen pollution, our results indicate high average removal efficiencies of the three-biofiltration systems, particularly for ammonium (NH_4-N) and TKN. Consistent with this, in aquatic ecosystems, the decrease in NH_4-N content was usually explained by the transformation of NH_4-N into NO_3-N (the so-called nitrification), which is favored by aerobic conditions, plus a subsequent denitrification (Kadlec & Knight, 1996). Another possible way is volatilization as NH_3, which is inducible by the increase of pH (Reddy & Sutton, 1984). Under natural growth conditions, NH_4-N is probably the main N source preferred for most aquatic macrophytes as revealed by results of numerous studies which used submerged, emergent, and free-floating species (Jampeetong & Brix, 2009a; Fang et al., 2007) and corroborate the high linear correlation found between NH_4-N and TKN ($r = 0.95^{***}$).

Numerous studies have shown that the alkaline pH values is conducive to the growth and the development of *S. natans* and *P. australis* reflected by excessive uptake of NH_4-N (Zutshi & Vass, 1971; Duke, 1979**)**, which corroborate the negative linear correlation found between NH_4-N vs. pH ($r = -0.52^{**}$). Regarding the levels of NH_4-N, our data showed that the mixed culture (BFUMC) has obtained the maximum removal. Similar result reported by previous works (Sooknah & Wilkie, 2004; Gikas & Tsihrintzis, 2012), suggesting the greater removal capacity of the selected plant species. Like pH, low temperature also affects the removing of NH_4-N probably because below15^{o}C the bacteria that are responsible for nitrogen removal do not work efficiently (Gikas et al., 2007; Kuschk et al., 2003). In this study, the recorded temperature values are ranged between 15.7 to 23.9 °C, which however explain the positive linear relationship observed between temperature and NH_4-N ($r = 0.36^{*}$). In addition, clay particles or organic matter in the soil can readily absorb the NH_4-N (Horne & Goldman, 1994).

The high level of NO_3-N in the outlet water from the BFUPA compared to wastewater (5.5-fold), bear witness to the great nitrifying activity. In agreement, aquatic macrophytes such as *P. australis* have well-developed internal air spaces (aerenchyma) throughout the plant tissues that ensures the transfer of oxygen to the roots and rhizomes (Brix, 1994; Abissy & Mandi, 1999). The oxygen that diffuses through the roots stimulates growth of nitrifying bacteria in the rhizosphere (Armstrong & Armstrong, 1988; Brix et al., 2002; Tanner et al., 2002; Zhang et al., 2009). This assumption would explain the negative removal efficiencies obtained in particular with the BFUPA (Fig.3e) and support the negative linear correlations found among NO_3-N vs. NH_4-N and NO_3-N vs. TKN (Table 3). In contrast, the positive removal efficiencies of BFUSN and BFUMC can probably due to macrophytes uptake (Imaoka & Teranishi, 1988; Matheson et al., 2002) and/or the process of denitrification (Faulkner & Richardson, 1989; Reddy et al., 1989).

Nitrite concentrations of the inflow and the outflow are of secondary importance for the evaluation of the overall annual nitrogen removal of the wetland (Kuschk et al., 2003). In general, the low outflow concentrations (< 1mg/L) been brought about by nitrification of NH_4-N to NO_3-N and NO_2-N at aerobic plant roots, with subsequent rapid denitrification to the atmosphere in the anaerobic parts of the substrate or is immobilized by plant uptake, adsorption, and precipitation (Kuschk et al., 2003; Jetten et al., 1997; Shalla et al., 2000). Our results support the suggestion that the removal efficiencies change in correlation with the temperature and seasonal changes, the increase of the mean nitrite removal rates in summer was outstanding in relation to the rates in autumn and spring, which is related to the decrease of the outdoor temperatures in this season (Fig. 3a,c-e).

The high levels of TKN removal efficiencies in all the treatments are probably due to macrophytes that play a major role in eliminating TKN through nitrification, metabolism, and storage processes (Wanget al., 2009; Maltais-Landry et al., 2007; García et al., 2003). TKN removal efficiency increases with increase in pH (Olguín et al., 2003; Mishra et al., 2013). Our results confirm those of previous studies (Sellami et al., 2009; Su & Ouyang, 1996) suggesting that the removal efficiency of TKN and NH_4-N reached maximum levels when NO_3-N yield are very low (Fig.3c,e-f), which also reflect the significant negatives relationships achieved (Table 3).In other words, the detection of NO_3-N in excess in the outlet water indicates that nitrification occurred in these treatments, whereby ammonium seem to oxidize to NO_3-N by nitrifying bacteria (Sooknah & Wilkie, 2004).

The high removal efficiency of phosphorus monitored as orthophosphate (PO_4-P) achieved by BFUPA, could be due to direct use of PO_4-P by plants (Urbanc-Berčič & Gaberščik, 2004) or attributed to adsorption on the soil particles and precipitation reactions (Reed et al., 1995). At the same time, microbial populations residing in the submerged roots may uptake orthophosphate that were in contact with wastewater for a longer period of time (Lantzke et al., 1998). However, in the second biofiltration unit (BFUSN), our result showed quite lower removal of PO_4-P as compared to the result previously reported by Lance et al., (1980). However, it also added that release of orthophosphate and clogging of the system could explain this low average reduction.

Otherwise, the higher reduction of BOD_5 by *P.australis* can be attributed to several mechanisms (physical and biological processes) including sedimentation and filtration associated with settleable solids or filterable material (Pride et al., 1990), in addition to oxidation mainly by aerobic bacteria (protozoa, rotifers, etc.) attached to plant roots (Reddy et al., 1985; Reddy & DeBusk, 1987). Bacteria suspended in the water column also can remove BOD_5 metabolically (Pride et al., 1990). On the other hand, as shown by Reddy et al., (1985), wastewater treatment with water hyacinth (floating macrophytes) can result in a significant reduction of BOD_5 (90%).In our study, *S. natans* exhibited high performance in removal of BOD_5 (96.9 %). Moreover, the maximum reduction (97.3%) of BOD_5 achieved by mixed culture can be attributed to the double root systems, which not only provide larger area for decomposers, it help absorption of nutrient and other elemental resulted from accelerated microbial degradation of organic pollutants. This assumption was in good agreement with significant positive correlations found among BOD_5 vs. TKN (0.89***), BOD_5 vs. NH_4-N (0.88***) and BOD_5 vs. PO_4-P (0.56***).

Like BOD_5, COD reduction is almost entirely due to physical processes such as filtration and adsorption rather than biological processes associated with the microbial community or with the plants (Ciria, et al., 2005). These findings are in agreement with some studies reported in the literature, which found better COD removal whether using emergent or floating macrophytes (Kumari & Tripathi, 2014; Mishra et al., 2013).

5. CONCLUSIONS

This work provides an opportunity to highlight the potential of emergent plants (*P. australis*) and floating plants (*S. natans*) as well as their mixed culture to treat the domestic wastewater under semi-arid conditions. Overall, our result indicates that the three units provide a significant removal of the organic (BOD_5, COD) and inorganic (TKN, NH_4-N and PO_4-P) pollutants from domestic wastewater. However, the mixed culture (BFUMC) showed the highest removal of nutrients as compared to their individual cultures. The effluent quality from the three units especially BFUMC was lower than the Algerian standards related to effluent quality for agricultural reuse purposes, therefore, it is possible to reuse the treated wastewater for restricted irrigation and can be environmentally friendly. The good results given by *S. natans* (rare plant) involve its use in wastewater treatment in order to preserve this kind of plants. Finally, the use of this kind of biofiltration systems for the treatment of other types of water pollution (e.g. microorganisms and heavy-metal pollution) is required.

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Received at: 10. 03. 2015
Revised at: 13. 05. 2015
Accepted for publication at: 31. 08. 2015
Published online at: 14. 08. 2015