Algerian Journal of Environmental Science and Technology
March edition. Vol.8. Nº1. (2022)
ISSN : 2437-1114
www.aljest.org

Removal of nitrogen and phosphorus from domestic wastewater in arid regions by a filter planted with Typha latifolia

N. Guerrouf[1,*], N. Seghairi[2]

[1]Mohamed Kheider University of Biskra, Agronomy Department
[1, 2]Research Laboratory in Civil Engineering, Hydraulics, Development, Sustainability and Environment Med Khider University, BP145, 07000 Biskra, Algeria

*Corresponding author: nguerrouf88@yahoo.com;Tel.: +213 7 90 00 31 80

ARTICLE INFO

Article History :

Received ***: 11/12/2019***
Accepted ***: 22/10/2020***

Key Words :
waste water ;Typha latifolia; Nitrogen ;Phosphorus ; phyto-purification ;Filters.

ABSTRACT/RESUME

Abstract: *Our study focuses on the application of a simple, effective and less expensive treatment method for the retention of nitrogen and phosphorus from domestic wastewater. For these reasons, we have chosen treatment with a filter planted with Typha latifolia. The objective of this study is to evaluate the performance of Typha latifolia in treating nitrogen and phosphorus present in domestic wastewater in an arid climate.*
In order to evaluate their purifying power, a series of water analyses, before and after plant irrigation, were carried out in the laboratory. The results obtained indicate that, during the residence time, the pH decreases and the electrical conductivity increases sharply. It was also found that the average absorption percentage was 96.91% and 97.72% respectively for phosphate and ammonium in the planted filter. All these results confirm the efficiency of using macrophytes in wastewater treatment.

I. Introduction

In many countries, water is becoming an increasingly scarce resource [1]. Algeria is a country with an essentially arid to semi-arid climate, where rainfall is low and irregular, and water resources are very limited. Population growth, frequent drought episodes and economic development have increased water requirements and increased pressure on conventional water resources [2]. Water pollution that affects rivers, seas, water tables and lakes is caused by the discharge of wastewater that has not been treated; this leads to a degradation of the ecosystem [3]. Discharges from domestic and industrial uses of water may contain many substances, in solid or dissolved form, as well as many pathogenic micro-organisms, threatening the quality of the environment as a whole [4].
Considerable attention has recently been allocated to the capacity of natural and artificial marshes to treat municipal and industrial water [5-6-7]. The first experiments using wetland macrophytes for wastewater treatment were conducted in Germany in the early 1950s [8].
This purification procedure relies on the purifying power of aquatic plants where the wastewater is kept in a series of open-air basins populated by these plants. This very simple, effective and affordable technique is reflected in the biological treatment of these effluents [09].
These methods have already been used in developed countries where they have proven successful due to its good retention properties.
The aim of this project is to test the purifying power of the filters planted with *Typha latifolia* and to contribute to the development of an efficient, affordable and ecological technique, which allows for the elimination of phosphorus and nitrogen from

wastewater without causing damage to the natural landscape in dry climate regions.

II. Materials and methods

II.1.Geographical and climatic situation

The experiment was carried out in 2018 at the University of Biskra. The wilaya of Biskra is located in South-Eastern Algeria, particularly in the Southern piedmont of the Saharan Atlas. It extends over an area of 21,671.20 km^2. Its altitude is 128 m at sea level, and it is characterized by high temperatures with an annual average of 21.5 C°, the average temperature of the hottest month is noted in July with 32.2 C°. That of January is the coldest, reaching 10.8 ° C.

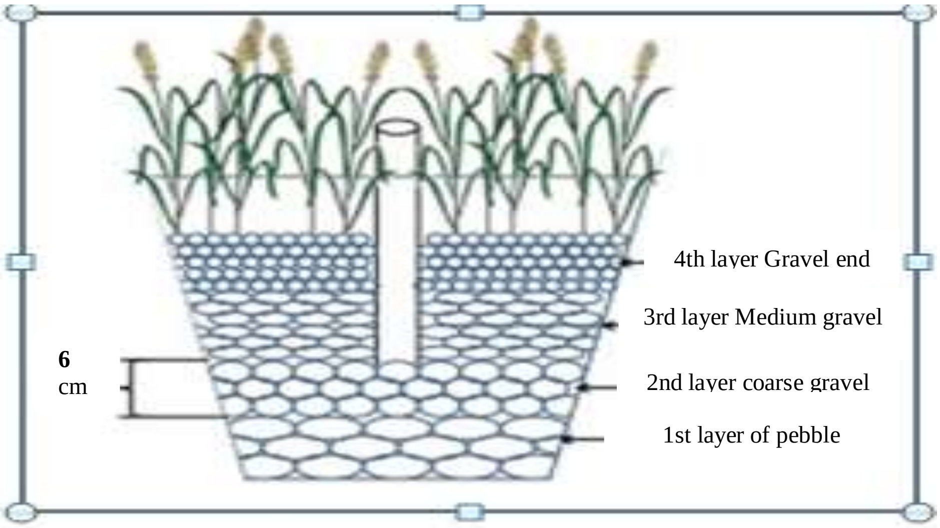

Figure 1. *Arrangement of substrates in filter planted and unplanted filter*

II.2. Preparation of filters planted with Typha latifolia

The choice of the substrate is important in the design of marshes, especially for vertical or horizontal flow systems. This is because it can help obtain effective results in the treatment of urban wastewater and insure an efficient interaction for the removal of pollution parameters.

The experimental pilot consists of two identical plastic pots filled with a substrate made up of alluvial gravel.

The first tank is planted with 10 young*Typha latifolia* plants and the other is considered a control to determine the role of the plant and the substrate. The superimposition of the layers used is made up as follows from bottom to top:

1st layer (Pebbles) Ø =55-75 mm, 2nd layer (Coarse Gravel) Ø =35-45, 3rd layer with a narrow layer (Medium Gravel) Ø = 1.5-2 mm, and finally a 4th layer (Fine Gravel) at a 0.5-1 mm diameter. A layer of water was kept 5cm above the surface of the substrate. (Fig. 1).

Figure 2. *Diagram representing the planted filter of Typha latifolia and unplanted*

Algerian Journal of Environmental Science and Technology
March edition. Vol.8. Nº1. (2022)
ISSN : 2437-1114
www.aljest.org

Table 1.*The physico-chemical characteristics of the wastewater tested*

Parameters	pH	EC (dS/cm)	PO_4^{-3} (mg/l)	NO_3^- (mg/l)	NH_4^+ (mg/l)	NO_2^- (mg/l)
raw water	8.51	3.5	8.75	8.05	43,9	0,502

II.3.Origins and characteristics of wastewater

The wastewater designed to fill the planted and unplanted filters was taken from a domestic discharge from the Mziraa commune, located 65 km away from the province of Biskra. This municipality is generally characterized with mild winters and dry summer seasons.

II.4. Wastewater sampling and analysis

In order to test the effectiveness of the purification after the one-month adaptation period, it is necessary to carry out a physicochemical analysis on these samples; this can take place within a period of 2, 5, 7, 10 or 15 days. This performance will be evaluated after a comparison between the quality of the wastewater at the inlet and outlet of different planted filters and the unplanted control. The samples were collected, stored in washed bottles (0.25 l) and kept in the dark at a temperature of (4 C°). The pH and electrical conductivity were measured immediately after each sampling. The rate of reduction of different pollution parameters is determined by the following relationship:

$$\textbf{Efficiency(\%)} = (X_i - X_f) / X_i * 100$$

Such as:

- **Xi :**Concentration of the parameter under consideration in urban or industrial wastewater applied to the filter bed (mg/l).
- **Xf :**Concentration of the considered parameter in the water recovered from the filters planted with macrophytes]10-11].

The physico-chemical analysis of the wastewater was carried out in the university laboratory. The physiochemical characteristics of these waters are grouped in table 1.

II.5. Statistical analysis

The normality of the distribution was verified using a Shapiro-Wilk test and the equality of variances was verified using a Levene test. An analysis of variance (two-way ANOVA) was used to determine the effect of pH and salinity on the purifying power of *Typha latifolia* for both variables (residence time and filter system). The Mann Witney test was used to determine the significant difference between the type of system applied (Control and *Typha*) for the chemical parameters Phosphate, Ammonium and Nitrate. This test was chosen because the samples did not follow the normal distribution ($p < 0.05$). One-way ANOVA was carried out to identify the significant differences between residence times for Phosphate and Ammonium. The Kruskal-Wallis non-parametric test was used for Nitrate because the assumption of normality is not acceptable. All these statistical tests (one and two-way ANOVA, Mann Witney and Kruskal-Wallis) and post hoc tests were carried out using SPSS Version 25 software.

III. Results and discussion

III.1. Evolution of the pH at the outlet of the filters

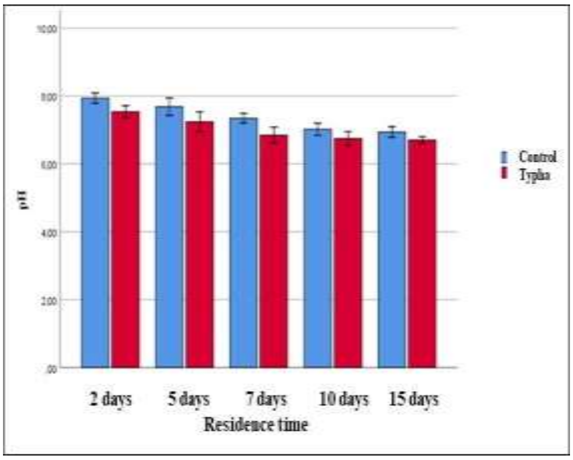

Figure 3. *Evolution of the pH in the water recovered from the planted and not planted filters*

shown in Figure 03, we observed a slight decrease in pH values in the wastewater purified by the planted system of *Typha* and the unplanted system for different chosen residence times. The pH rate in the planted system is slightly lower than in the unplanted system. These results are similar to those found by Zeghdi et al [12], Mancer [11], Pétémanagnan et al [13], Derradji [14], Abissy and Mandi [07], Yahiaoui et al [15]. Statistical analysis showed a significant difference ($p=0.008 <0.05$) between the planted filter and the control for the treatment mode factor, and a significant difference ($p=0.001 <0.05$) for the residence time factor. On the other hand, the interaction between the two factors (treatment mode and residence time) indicated a non-significant difference ($p=0.956 >0.05$).

Tukey's post-hoc test was used to compare averages between residence times. It was a comparison between the following times (two and seven days), (two and ten days), (two and fifteen days). The difference was, respectively, significant ($p=0.029$, 0.003, $0.001 <0.05$). A significant difference was also found between five and fifteen days ($p=0.03 <0.05$). The slight acidification of the environment can be interpreted by several factors:

- The accumulation of H+ as a result of the activity of nitrifying bacteria.
- The accumulation of CO2 due to plant metabolism or the degradation of organic matter by heterotrophic bacteria.
- The production of H^+ ions by the plant to compensate for the removal of certain cations (mineral nutrition).
- The secretion of exudates (organic acids) at the roots [16].

III.2. Evolution de la conductivité à la sortie du filter

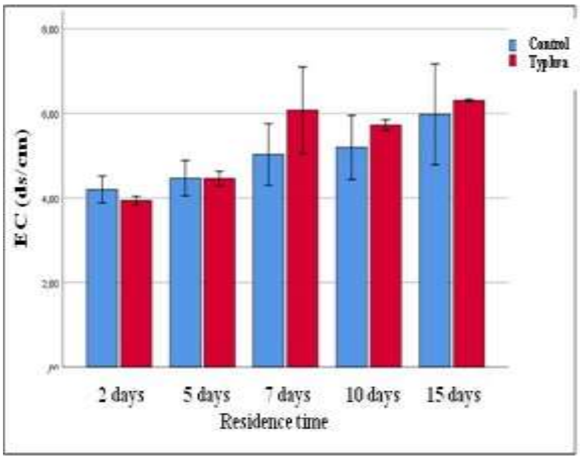

Figure 4. *Evolution of the wastewater EC at the outlet of the planted and non-planted system*

According to figure 04, the electrical conductivity of the water treated by the macrophyte *Typha latifolia* which was recovered at the outlet of the filter, increases exponentially until 15 days at the EC levels of the initial raw water (3.5dS / m). These values increase according to the residence time. The salinity in the planted filter is higher than the salinity of the unplanted filter. The results are identical to those found by Zeghdi; Bebba; Laouini [12], Abissy and Mandi [07], Mancer [11]. The two-way ANOVA test showed that the salinity was not significant between the planted filter (*Typha*) and the unplanted filter ($p= 0.419$ 0.05). Conversely, there is a significant difference between the residence time variable ($p= 0.021$ 0.05). The interaction between the two factors (treatment mode and time) showed that there was no statistically significant difference at a significant level ($p=0.856 >0.05$). This increase could be linked to the accumulation of salts produced by the mineralization of organic matter at the level of the filters and by the decrease in the quantity of water in the bins after the phenomenon of evapotranspiration.

III.3. Evolution of phosphate at the outlet of the filters

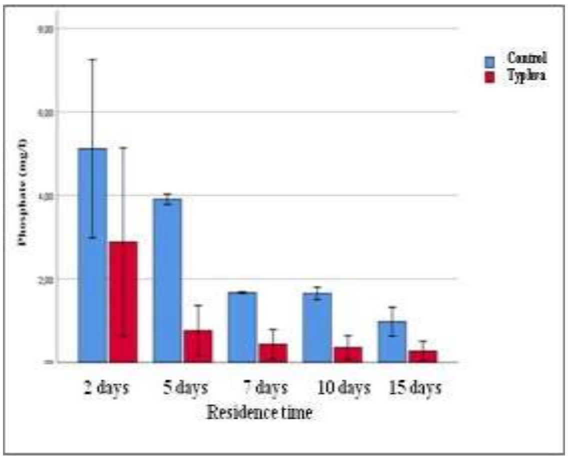

Figure 5. *Variation of phosphate rates as a function of residence time*

Figure 05 above shows the evolution of the phosphate rate after the treatment with the planted filter which was not planted during a residence time. Through the latter we found that the concentration of PO4-3 in the *Typha* planted filtrates is lower than in the raw water. However, it increases in a correlated way with the residence time. Ortho phosphate rate vary between 0.149 mg/l to 0.028 mg/l. The phosphate purification efficiency is higher in planted filters compared to the unplanted system. The abatement reaches 2.88 mg/l, 0.76 mg/l, 0.44 mg/l and 0.27 mg/l respectively for the residence times of two, five, seven, ten and fifteen days. This performance reached the maximum for the filter planted for the fifteenth day 96.91%. Assimilation can be done in different ways, either by bacterial assimilation and/or assimilation by the plant [12]. According to Brix [17], some plants consume a significant amount of phosphorus as they grow. They can be stored in roots and rhizomes, stems and leaves [18], or absorption by the substrate [11].

The obtained results are similar to those of Zeghdi; Bebba; Laouini [12], Mimeche; Debabeche; Seghairi; Benameur [19], Guerrouf; Seghairi; Badaache [20], Mimeche; Debabeche; Seghairi; Benameur [21], Seghairi; Mimeche; Debabeche [22], Guerrouf and Seghairi [23], for the planted filter of *Typha*, *Papyrus*and *Phragmite* respectively, as well as for Corchorus oliterius [24-13].

III.4. Evolution of Ammonium at the outlet of the filters

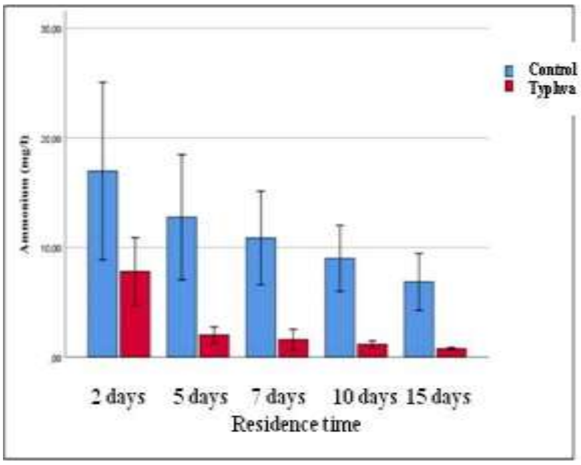

Figure 6. *Variation of Ammonium rates as a Function of Residence Time*

Figure 06 above shows that the amount of ammonium present in raw water is 43.09 mg/l. During the residence time and after the passage through the planted and unplanted filter, we recorded that the concentration of ammonium in the water that has been recovered from the planted filter (*Typha Latifolia*) was lower than the amount found in the wastewater recovered from the control. The residual ammonium concentration in the *Typha* tank varies from 7.80 to 1.6 mg / l for a residence time varying from two to ten days. Whereas we recorded a better elimination after a retention of 15 days with a rate of approximately 98.24%. Ammonium was significant between the planted system (*Typha*) and the non-planted system (Mann-Whitney test, p 0.05), but not significant between residence times (one-way ANOVA, p >0.05). Nitrification is defined as the biological oxidation of ammonium to nitrate with nitrite as an intermediate in the reaction sequence [25]. Nitrification is the primary mechanism for the transformation and removal of ammonia compared to other mechanisms [26-27]. The latter is an aerobic process implemented by a bacterial action nitrifying heterotrophic (Nitrosomonas and Nitrobacter) [27], even if ammonium has the capacity to adsorb on the massif in part [28]. Mimeche; Debabeche; Seghairi; Benameur [21], Seghairi; Mimeche; Debabeche [22], Mimeche; Debabeche; Seghairi; Benameur [19], Kone; Zongo; Bonou; Koulidiati; Joly; Bouvet; Sodre [28] found similar results for the planted filter of Papyrus, Typha, *A.* gayanus and *V. nigritana*, respectively.

III.5. Evolution of Nitrate at the outlet of the filters

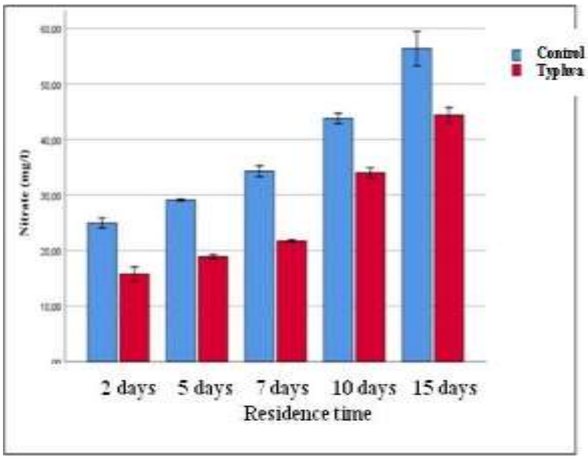

Figure 7. *Evolution of nitrate per planted filter as a function of residence time*

The evolution of wastewater nitrate value at the inlet and outlet of the planted system and over the residence time is shown in Figure 07. An increase in the nitrate substance was recorded after passing by the planted filter of *Typha* and control compared to raw water (8.05 mg / l). The Mann - Whitney test showed that the nitrate was significant $p < 0.05$) between the *Typha* macrophyte comparing it with the control, also between the residence times (Kruskal - Wallis test $p= 0.000 < 0.05$). The high nitrate contents in both filters show that there is good nitrification in both systems [07] (transformation of ammonium into nitrate) [29-26-30-31-32].

IV. Conclusion

Domestic wastewater in the commune of Mziraa, Wilaya of Biskra has high rates of phosphorus and nitrogen, which relatively exceed the limited extreme standards for discharge. This presents a risk for the environment and it is necessary to decontaminate them before disposing them into the natural environment.

The objective of this study was to highlight the purifying potential of an emerging plant (*Typha latifolia*) to treat nitrogen and phosphorus present in domestic wastewater in an arid climate. The results obtained show that this macrophyte provides a substantial removal of inorganic pollutants (NH_4^+, NO_2^-, NO_3^-, PO_4^{-3}) and ensures a good abatement of all the parameters tested during the whole period of the experiment. The efficiency in terms of removal of phosphate (96.91%), Ammonium (97.72%), with a slight decrease in pH value in purified wastewater for different chosen residence times. The electrical conductivity of water treated with the *Typha* macrophyte increases exponentially relative to the unplanted filter. This increase is linked to the accumulation of salts produced by the mineralization of organic matter at the filters. Finally, these results encourage us to exploit these systems in the field of wastewater treatment. The water treated by this system is environmentally friendly and can be reused in restricted irrigation.

V. Références

1. FAO. Wastewater treatment and use in agriculture - FAO Irrigation and Drainage Document (1992) 169.
2. MWR. Algeria's water resources. Synthesis report, Algiers, Algeria (2001) 73.
3. Abouzaid, A. Study of different treatments of textile industry effluents. Doctoral thesis, ChouaibDoukkali University, Morocco (2001).
4. Tamrabet, L .; Bouzerzour, H .; Kribaa, M .; Golea, D. The fate of treated wastewater: Response of two forage grasses, barley and oats, to inputs of treated wastewater. In: Proceedings of the International Oasis, Water and Population Symposium, Mohemed Khider University, Biskra, Algeria (2003).
5. Seghairi, N .; Debabeche, M. Possibilities of retention of copper and zinc on a filter planted with papyrus. 3rd Edition of the International Congress on, Water, Waste and Environment, oral communication, Fez, Morocco, (2011).
6. Benameur, N. Analysis of the microorganisms present in the macrophyte beds during the phyto-purification of wastewater. Magister thesis, University of Biskra (2010).
7. Abissy, M .; Mandi, L. Use of rooted aquatic plants for urban wastewater treatment: the case of the reed. *Journal of Water Sciences* Vol 12 N ° 3 (1999) 285-315.
8. Vymazal, J. Wetlands developed for wastewater treatment water. *Water Journal* 2 (2010) 530-549.
9. Mahdjoub, B. Adsorption of a reactive textile dye on a biosorbent. *Canadian Journal of Chemical Engineering* (2010).
10. Laabassi, A. Wastewater treatment by the Macrophyte lagoon system. Doctoral thesis, Sétif University (2016).
11. Mancer, H. Analysis of the purifying power of some macrophyte plants in arid regions. Magister thesis, Biskra University (2010).
12. Zeghdi, S .; Bebba, A .; Laouini, S. Chemical treatment of wastewater in the city of El-Oued (south-eastern Algeria) using Typha Latifolia. *Oriental Journal of Chemistry* Vol 32 N ° 6 (2016) 10.
13. Pétémanagnan, O. J .; Coulibaly, L .; Niamien, M. P .; Gourene, G. Treatment of Urban Wastewater by an Artificial Vertical Drainage Marsh Planted with Maximum Panicum under Tropical Climate. *European Journal of Scientific Research* Vol 23 N ° 1 (2008) 25-40.
14. Derradji, M. Contribution to the study of tolerance of purification plants in wastewater treatment: strategy and application. Doctorate thesis, Annaba University (2015).
15. Yahiaoui, K .; Zoubeidi, A .; Rouahna, N .; Ouakouak, A. Study of the treatment of domestic wastewater by a macrophyte plant in the arid region of Southeast Algeria (case of the Oued Oued region). *Journal of Basic and Applied Sciences* Vol 10 N ° 2 (2018) 265-276.
16. Kone, D. Wastewater treatment by microphyte and macrophyte lagooning in West and Central Africa: inventory, purification performance and sizing criteria. Doctoral thesis, Luxembourg University, Belgium (2002).
17. Brix, H. Functions of macrophytes in constructed wetlands. *Journal of Water Science and Technology* Vol 29 N ° 4 (1994) 71-78.
18. Kucuk, O.S .; Sengul, F .; Kapdan, I.K. Ammonium removal from tannery effluent in a reed swamp. *Water Science and Technology Review* 48 (11–12) (2003) 179-186.
19. Mimeche, L .; Debabeche, M .; Seghairi, N .; Benameur, N. Capacity of macrophyte plant filters for wastewater treatment in semi-arid climates. *Courier of Knowledge* 17 (2013) 33-37.
20. Guerrouf, N .; Seghairi, N .; Badaache, S. Removal of ammonium and phosphorus present in domestic wastewater by a filter planted with Typha latifolia. International Water-Environment-Climate conference, oral communication, Hammamet, Tunisia. (2018).
21. Mimeche, L .; Debabeche, M .; Seghairi, N .; Benameur, N. Possibility of eliminating pollutants from urban wastewater in arid climates by plant filter of Cyperus papyrus. *Courier of Knowledge* 21 review (2016) 61-66.
22. Seghairi, N .; Mimeche, L .; Debabeche, M .; Khider, S. Possibilities for removing phosphates and nitrogen from domestic wastewater using a filter planted with papyrus. The 4th International Congress Water, Waste & Environment (EDE4), oral communication, Agadir, Morocco. (2013).
23. Guerrouf, N .; Seghairi, N. Removal of phosphate from domestic wastewater on a filter planted with Phragmite communis. 5th International Conference on Green Energy and Environmental Engineering, oral communication, Sousse, Tunisia. (2018).
24. Lacina, C .; Issiaka, S .; Germain, G. Treatment of domestic wastewater with a wetland constructed on a pilot scale and fully drained vertically, with Corchorus oliterius. *African Journal of Agricultural Research* Vol 3 N ° 9 (2008) 587-596.
25. Norio, T .; WunJern, N.G .; Jinadas, K.B.S.N. Wetland for tropical applications treatment of wastewater by constructed wetlands. Ed Imperial College Press (2011) 150.
26. Alexandros, S .; Christos, S.A .; Vassilios, A.T. Eco-engineering systems for the treatment of wastewater and sewage sludge (2014) 378.

27. Mar-yam, S. Treatment of industrial and agro-industrial wastewater using managed wetlands. Doctoral thesis, Patras University (2014).
28. Kone, M .; Zongo, I .; Bonou, L .; Koulidiati, J .; Joly, P .; Bouvet, Y .; Sodre, S. Treatment of urban wastewater by planted filters with vertical flow in a Sudano-Sahelian climate. *International Journal of Biological and Chemical Sciences.* Vol 5 N ° 1 (2011) 217-231.
29. Vymazal, J. Wetlands developed for wastewater treatment: proceedings of Taal 2007: 12th World Lakes Conference (2008) 965-980.
30. Okurut, T.O. Pilot study on municipal wastewater treatment using a constructed wetland in Uganda. Ed A .A .B alkema. Rotterdam (2000) 170.
31. Vymazal, J. Nutrient removal in various 'types of managed wetlands. Total *Environmental Science Journal* 380 (2006) 48–65.
32. Brian, S. Use of constructed wetlands for wastewater treatment. Ed Wetlands International - Malaysia Office (2003) 24.

Please cite this Article as:
Guerrouf N., Seghairi N., Removal of nitrogen and phosphorus from domestic wastewater in arid regions by a filter planted with *Typha latifolia*, ***Algerian J. Env. Sc. Technology**, **8*:1 (2022) 2322-2328**