Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

PHYTOREMEDIATION PERFORMANCE OF URBAN WASTEWATER BY THE *PAPYRUS ALTERNIOFOLIUS* IN EL-OUED REGION (SOUTHEAST OF ALGERIA)

S. Zaghdi[1], S. E. Laouini[2], A. A. Bebba[1]

[1]Laboratory of recovery and promotion of Saharan resources, University Kasdi Merbah, Ouargla, 30000, Algeria

[2]Department of process engineering and petrochemical, faculty of technology, Hamma Lakhdar University, El-Oued, 39000, Algeria

Received: 23 May 2018 / Accepted: 30 August 2018 / Published online: 01 September 2018

ABSTRACT

The aim of this study is to highlight the ability of plants to purify wastewater with a horizontal flow system under a dry and hot climate. The process consists of circular beds with a capacity of 30 L filled with superimposed layers of gravel (25/15) mm, sand, 45 cm and 10 cm deep respectively. The first bed was planted with freshly collected stems of the plant *Papyrus alterniofolius* (40 stems/m^2) and an unplanted bed was taken as a witness. The results revealed important removal fractions of the main pollutants namely: chemical oxygen demand COD (70,59%), biochemical oxygen demand BOD_5(97,25%) total suspended solids TSS (97.16%), nitrite NO_2^- (65.55%), nitrate NO_3^-(86.16 %), E. coli (99.41%), total coliforms (99.97 %) and total streptococcus (99.90 %). The considerable decrease of pollutants content and harmful organisms enables the reuse of the treated water in agriculture and industry.

Keywords: Phytopurification, *Papyrus alterniofolius*, Wastewater, horizontal flow biomass, EL Oued.

Author Correspondence, e-mail: zaghdisaad39@yahoo.com

doi: http://dx.doi.org/10.4314/jfas.v10i3.30

1. INTRODUCTION

Water is one of the most important elements involved in the creation and development of healthy life. The exponential growth of population and industrialization will cause a huge lack of water if we don't start to use it in a sustainable way. To achieve this, a high level of responsibility towards water usage is required, and it must be recycled according to its pollution content in order to maintain water quality and protect our environment. Many methods of water treatment have been researched and employed by responsible nations around the globe. There are various parameters that must be considered when a wastewater treatment choice is made, including the level of pollution and the amount of water, to be recycled at a certain time. The use of plants for wastewater treatment is appropriate in smaller communities and agglomerations because they are easily constructed, inexpensive to maintain and very efficient. Constructed wetlands use plants which are able to cope with different concentrated pollutants in water and help bacteria's to break down these substances have design pilot station using surface flow systems and floating aquatics.

2. RESULTS AND DISCUSSION

2.1. Purification efficiency

The yield of purification is calculated according to the formula: R % = (Xi-Xf) x100 /Xi

Xi = concentration of the parameters inside the bed (mg/L).

Xf = concentration of the parameters at the output of the bed (mg/L).

Features effluent to be treated. The water to be treated are urban wastewater from the city of El-Oued, they are collected at the entrance of the treatment plant Kouinine. The characteristics of the effluent are indicated in Table 1.

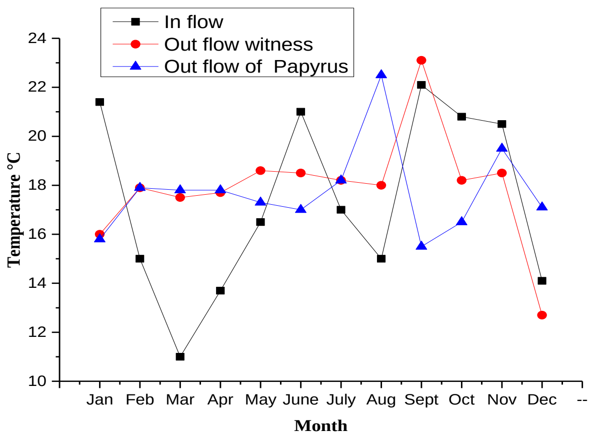

Fig.1. Temporal evolution of the T °C at the input and output of both planted and unplanted bed

Table 1. Physicochemical characteristics of the effluent to be treated

Parameters	**Sample numbers**	**Inflow**	
		Cold	Hot
Conductivity Electronic (ms/c)	48	6,05	5,99
COD Chemical Oxygen Demand: COD (mg/l)	48	428	354
BOD_5 Biochemical Oxygen Demand: BOD_5(mg/l)	48	211	247
TSS Total suspended solids (mg/l)	48	253	245
Ammonium NH_4^+(mg/l)	48	52,1	54,6
Nitrates NO_3^- (mg/l)	48	0,51	0,43
Nitrites NO_2^- (mg/l)	48	0,307	0,263
Nt	48	83	70
Orthophosphate (mg/l) PO_4^{3-} (mg / L)	48	10,2	8,5
Dissolved Oxygen(mg/l)	48	1,99	0,59
Turbidity (NTU)	48	329	247
pH	48	7,93	7,8
T C°	48	19 ,14	27 ;00

In Figure 1, indicated that the temperature of the inflow water decrease at the beginning the constant when they pass from February till August, it decreases to 17 °C in the three months October until December. This decreasing can be caused by the fact that climate it remains colder all these stocks are linked to the temperature of the season.

2.2. Evolution of pH

The evolution of pH values of wastewater at the inflow and outflow of planted and unplanted systems, during the period from January 2016 to December 2016, are given in Figure 2.

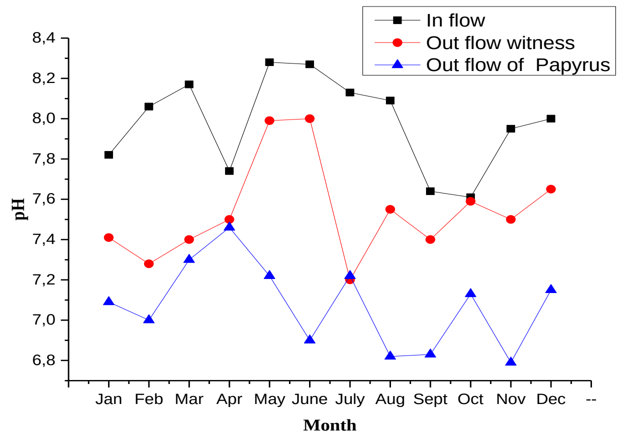

Fig.2.Temporal evolution of the pH at the input and output of both planted and unplanted

Throughout the year of study, for planted or unplanted beds slight acidification of the water is observed. Acidification of the planted bed is more important. This slight acidification of the medium may be performed by oxidation of the COD and NH_4^+ [25], carbon dioxide (CO_2) of the oxidation of the COD acidifies the medium, nitrification (oxidation of NH_4^+) results in acidification of filtrates, indicates the possibility that the plants release root exudates (tannic acid and gallic), which cause acidification of the medium.

2.3. Evolution of Electrical conductivity

The evolution of the conductivity values of wastewater at the inflow and outflow of planted and unplanted systems, during the period from January 2016 to December 2016, are given in Figure 3.

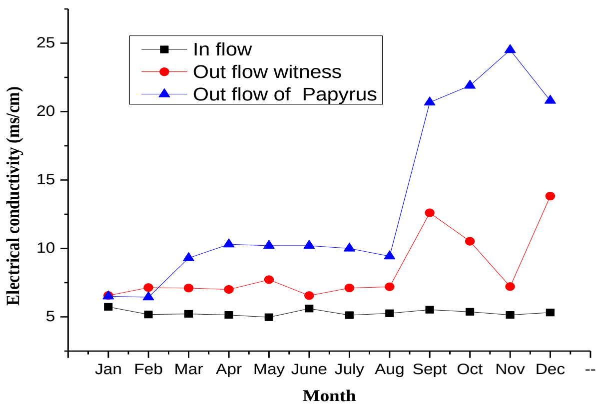

Fig.3. Temporal evolution of the EC at the input and output of both planted and unplanted

The conductivity increases with the output of the witness and planted bed, this increase may be related to the mineralization of the organic material. Our results are similar to those found Finlayson for planting (*Papyrus alterniofolius*) who interpret this phenomenon by a vegetation evapotranspiration which tends to further concentrate the effluent. According to the previous study, the increase in conductivity is rather related to the leaching of minerals from the soil and mineralization of organic matter, reported no change in the electrical conductivity.

2.4. Evolution of total suspended solids TSS

The evolution of the values of TSS wastewater at the inflow and outflow of planted and unplanted systems, during the period from January 2016 to December 2016, are given in (Figure 6).

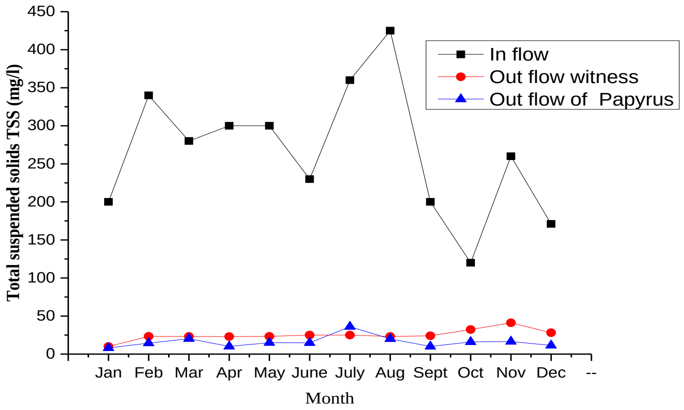

Fig.4. Temporal evolution of the TSS at the input and output of both planted and unplanted

In general as shown by the results, the reduction of yields are obtained very satisfactory suspended matter which in all cases exceed 81.58%. For the witness, yields oscillate between 83.58% (January) and 95.00% (December). The hurdle for the planting bed is 87.75% (January) and yield reached 95.34% during the month of (November). There has been a slight improvement in the retention of suspended solids when moving from non planted bed because the most important part of the suspended matter is retained by filtration through gravel, plant roots contribute to retention another part of the suspended solids. Our results are superior to those obtained in the previous study, in the case of a vertical drainage constructed wetland planted with Panicum maximum in a tropical climate. For the planted bed, the best performance was observed in summer.

2.5. Evolution of Turbidity (NTU)

During the period from January 2016 to December 2016, urban of wastewaters were collected from the EL Oued station every 7 days analyses were made, in holding measurements of turbidity in the inflow (untreated water), outflow (treated water) and urban wastewater the turbidity level vary between 82,20 NTU to 93,22 NTU.

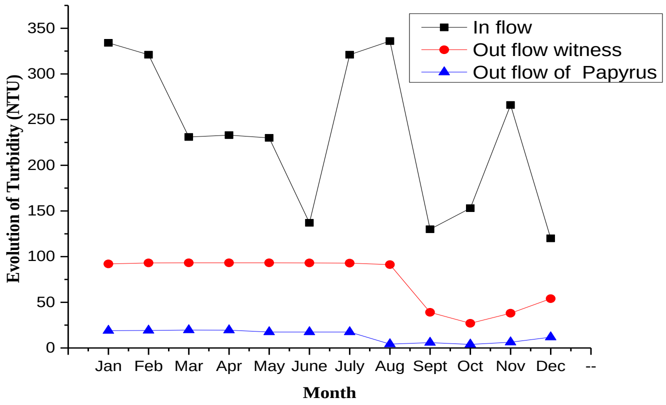

Fig.5. Temporal evolution of the Turbidity (NTU) at the input and output of both planted and unplanted

2.6. Evolution of Chemical Oxygen Demand: COD (mg/l).

The evolution of the COD value of wastewater at the inflow and outflow of planted and unplanted systems, during the period from January 2016 to December 2016, are given in Figure 6.

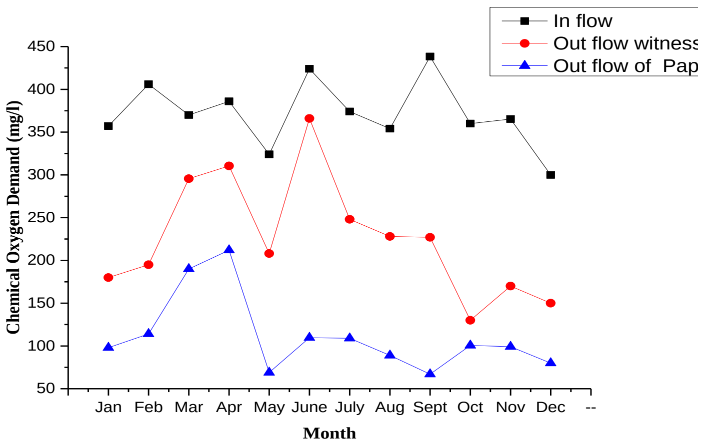

Fig.6. Temporal evolution of the COD at the input and output of both planted and unplanted

For the witness, the yields in terms of COD oscillate between 35.80 % (May) and 53.46% month of November, the minimum yield for the planting bed is 50.62% (November) and yield reached 83.33% during the month of(October). The COD reduction obtained is similar to that found in another study. A marked improvement in the reduction of COD is observed when passing the witness planted bed. Biological degradation by the action of bacteria added to physical phenomena, filtration is probably causing the lowering of the organic matter. Plants create physicochemical conditions favourable to the oxidation of organic matter by microbial flora. These bring oxygen into the solid filtering mass via the roots and rhizomes, which thing allows aerobic bacteria to proliferate is to ensure oxidation of the organic matter. Sedimentation of solids and their filtration by gravel and plant roots have certainly contributed to the removal of carbonaceous pollution. The best performance is obtained in the spring.

2.7. Evolution of Biological Oxygen Demand: BOD_5(mg/l)

The changing values of BOD_5 wastewater at the inflow and outflow of planted and unplanted systems, during the period from January 2016 to December 2016, are given in Figure 7.

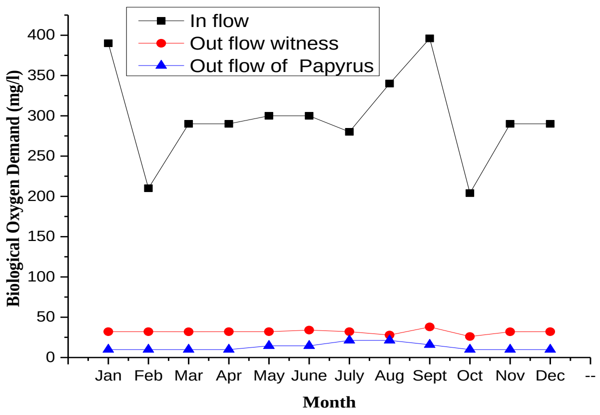

Fig.7. The Temporal evolution of the BOD_5 at the input and output of both planted and unplanted systems

For the witness, the yields in terms of BOD_5 range from 87,20% (October) and 91.79% (month of August). The hurdle for bed planted by (*Papyrus alterniofolius*) plant is 96.99%% (October) and yield reached 97.63% during the month of May. The same phenomena for the reduction of COD involved in the retention of COD.

2.8. Evolution of Dissolved Oxygen (mg/l)

Changes in dissolved oxygen values of wastewater at the entrance and exit of planted and unplanted systems, during the period from January 2016 to December 2016, are given in Figure 8. A significant improvement in the amount of dissolved oxygen is observed in the planted and unplanted bed. In the beds, we pass values maximum of 3.30 mg/L to 6.10 mg/L for the witness, for the planted bed (*Papyrus alterniofolius*) the values were changed from 4.70 mg/L to 7.80 mg/L. The best performance is obtained in the spring. Degradation of organic matter that the water becomes less charged and therefore the oxygen concentration becomes higher.

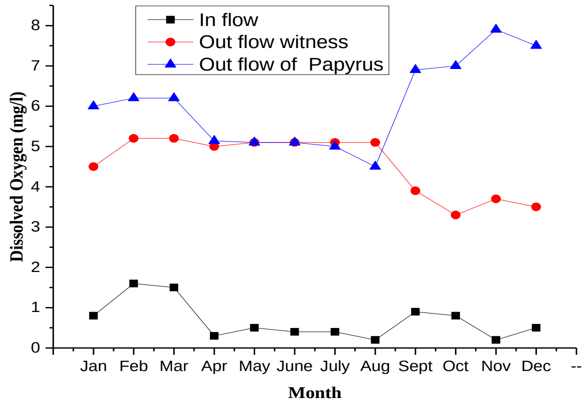

Fig.8. The Temporal evolution of the dissolved oxygen at the input and output of both planted and unplanted systems

2.9. Evolution of nitrites NO_2^- (mg/l)

The evolution of nitrite values of wastewater at the entrance and exit of planted and unplanted systems, during the period from January 2016 to December 2016, are given in Figure 9.

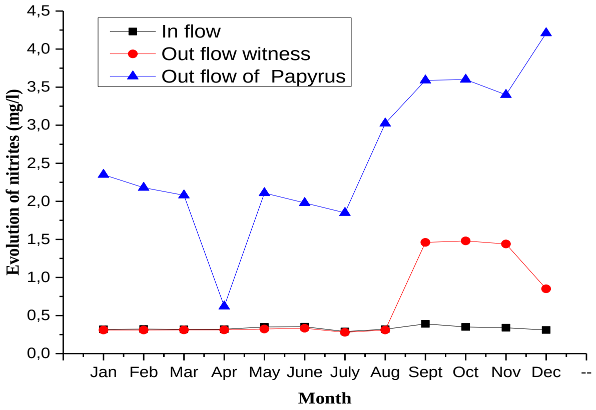

Fig.9. The Temporal evolution of the nitrite at the input and output of both planted and unplanted systems

For the witness, nitrite yields range from 58,28% (August) and 65,54% (month of January). The hurdle for the planting bed is 58,28% (August) and yield reached 73,81% during the month of November. The elimination of nitrite is quite significant in beds planted and unplanted in the bed. The best performance is obtained in winter. Nitrites are oxidized to nitrates (nitration) according to the reaction by Nitrobacter bacteria and some are absorbed by plants.

$$2\,NO_2^- + O_2 \xrightarrow{Nitrobacter} 2\,NO_3^-$$

2.10. Evolution of nitrates NO_3^- (mg/l)

The changing values of wastewater nitrate at the inflow and outflow of planted and unplanted systems, during the period from January 2016 to December 2016, are given in Figure 10.

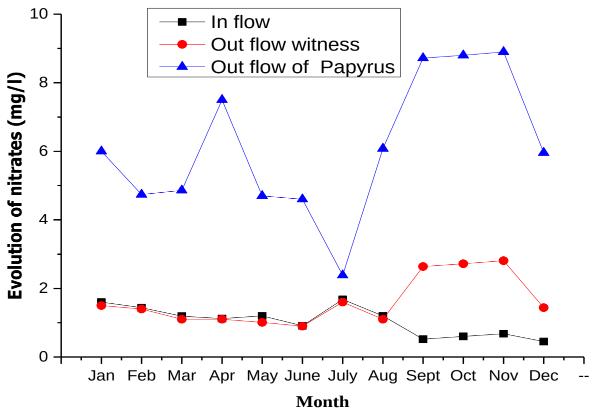

Fig.10. The Temporal evolution of the nitrate at the input and output of both planted and unplanted systems

For the witness, nitrates oscillate yields between 94.62% (December) and 80.95 (January). The hurdle for the planting bed is 75,37% (Jul) and yield reached 80,80% during the month of August. The nitrate removal is quite significant in beds planted and unplanted in the bed, a yield of 80.00 % for the witness, we go to 94.62% for (*Papyrus alterniofolius)*. Better yield is obtained for the end of the summer planted bed. Nitrates are absorbed by plants in the presence of light for photosynthesis.

2.11. Evolution of the ammonium (mg/ml)

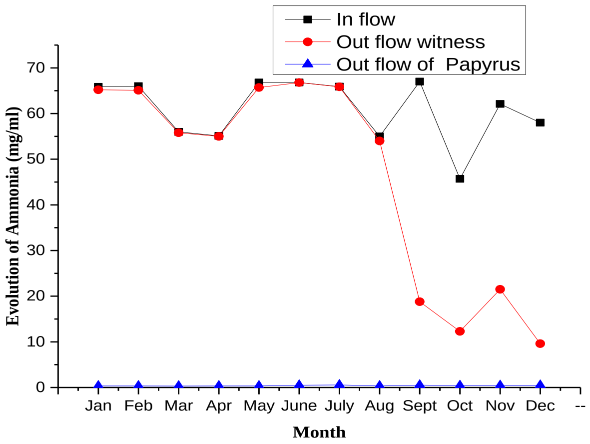

Fig.11. The Temporal evolution of the ammonia at the input and output of both planted and unplanted systems

Ammonia is a widely used indicator of the efficacy of wastewater treatment systems. The production of ammonium is the first step in mineralization of organic nitrogen. In terms of wastewater quality, elevated ammonia-nitrogen concentrations may indicate high organic compound contamination associated with the aerobic and anaerobic processing of dead and dying cells and tissues. Therefore, the reduction of ammonia concentrations in constructed wetland effluent implies that organic nitrogen is being converted, through microorganism facilitated transformation, to various species of inorganic nitrogen, such as ammonium ion, nitrite, and nitrate. The CW units achieved excellent removal efficiencies of ammonia-nitrogen, with overall concentrations decreasing by 99.81% during treatment. The value of ammonium was obtained for the untreated water (wastewater) vary between (45.70 mg/l and 66.81 mg/l). However the ammonium average values for the treated water (*Papyrus alterniofolius)* the amount is less than vary between (0.12 mg/l and 0.32 mg/l). These results give us yield range between (99.81 % 99.30%), can be interpreted by the fact that part of ammonium is assimilated by the plant (*Papyrus alterniofolius)* while the other part is converted to nitrite and then to nitrate by biological oxidation by nitrifying bacteria. According, aquatic macrophytes are equipped with an internal airspace well developed through plant tissues which ensure the transfer of oxygen to the plants (roots) and rhizomes. The oxygen diffuses through the roots stimulates the growth of nitrifying bacteria in the rhizosphere.

$$NH_4^+ + 3/2\ O_2 \text{ — Nitrosomonas } \rightarrow NO_2^- + 2H^+ + H_2O$$

$$NO_2^- + 1/2\ O_2 \xrightarrow{Nitrobacter} NO_3^-$$

2.12. Evolution of Orthophosphate (mg/l)

Changing values of orthophosphates wastewater at the entrance and exit of planted and unplanted systems, during the period from January 2016 to December 2016, are given in Figure 12.

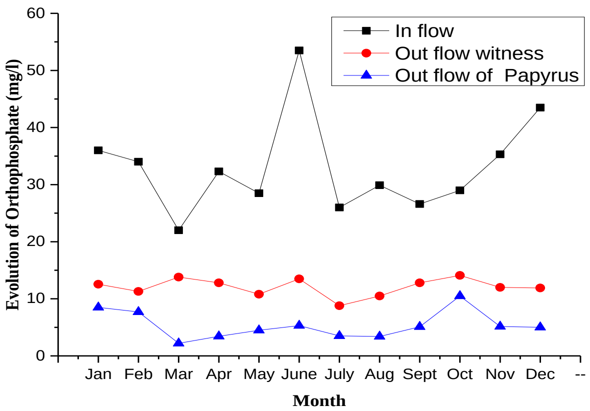

Fig.12. The temporal evolution of the orthophosphate at the input and output of both planted and unplanted systems

For the witness, yields oscillate between 52.62 orthophosphate (Nov) and 69.63 (Jul) The minimum return for the planting bed is 65.58% (October) and yield reached 89.09% during the month of Mai. For the planted bed, the best performance is obtained in the spring. Assimilation can be done in different ways either by bacterial assimilation and/or assimilation by the plant: the plant to assimilate these growing tissues, phosphorus through its rhizome and the roots or by adsorption by gravel.

2.13. Total Coliform Bacteria

Total Coliform Bacteria removal efficiency of hydrilla and witness units were found to be nearly 100 % while in the *Typhaunit* it fluctuated and was lower than 40 %. The high removal of total coliform bacteria in *Papyrus alterniofolius* and control unit could form their receiving direct sunlight and their high pH. Prolonged exposure to ultraviolet (UV) radiation and toxic chemicals from roots of the *Papyrus alterniofolius* are the result of being away from the suitable host for microorganisms natural death with organic matter degradation.

3. EXPERIMENTAL

3.1. Presentation of the study area

The city of El Oued is located in the southeast of Algeria, in the northern reaches of the Erg Oriental (33° to 34° North and 6° to 8° East). It is characterized by an arid climate the annual average temperature is around 22.66 °C, the warmest month is July with 34.43 °C, and the coldest month is January with 10.76 ° C. The cold period lasts from November to April, with an average of 14.99 °C and the warm period from May to October, with an average of 29.98 °C (ONJ), Rainfall is low and erratic in winter. The average annual rainfall (1999-2008) is on the order of 5.47 mm. Rainfed time of year is very short (2-3 months) against the dry period lasts almost all year round. The average annual humidity is around 47.39% (1999-2008). The value of the average maximum humidity in the Souf region is recorded in the month of December with 67.7% and the value of the minimum average humidity in this area is recorded for the month of July, with 30.9 % (Table I) (ONM, 2009). During the warm period, there is significant evaporation, the maximum value is 33.44 mm in July, and the minimum value is 7,67mm in January. The annual total is in the range of 228.44 mm (Table I) (ONM, 2009). Solar radiation is important; the peak of isolation is marked for June, with an hourly volume of 344 hours. The average annual insolation is 273.40 hours/month. (O.N.M, 2009). The region is also characterized in the spring and summer by hot dry winds causing the Sirocco or "Chihili" appear during the summer and sandstorms.

3.2. Choice of plant

Various studies reported the using of plants in treatment and purification of wastewater. The *Pistia stratiotes* [1], *water* hyacinth [2], *Imperata cylindrical* [3], *Phragmites Australis* [4-10], *Typha latifolia* [11-15], *Scipus validus*, *Juncus effuses*[16], *Papyrus alterniofolius* [17] *Typhadomingensis* [18], *Amaranthus* [19] and *Chorcourus* [19], *Arundo Donax*[20],*Tilapia* [21], *Panicum maximum* [22]. Taylor [23] has tested 19 plants for the elimination of the organic load: 18 species at the beginning of the experience have not resisted to the conditions of the local climate.

Our choice is focused on a plant *Cyperus alternifolius*, better known as the Umbrella Plant is a very popular house plant and commonly grown as a marginal pond plant. Growing to a height of 60 cm, the bracts are symmetrically arranged in an umbrella formation and held atop elegant stems that sway with the breeze, giving a tropical touch to the garden. This lovely and versatile plant is easily grown and makes an excellent ornamental waterside or marginal plant for water gardens. Plant as an indoor pot plant they are useful for homes and conservatory, or as an interior plant for commercial offices, hotels, and malls, ideally in containers stood in water. Its fascinating shape makes it a great for landscaping, and as an accent plant or informal screen.

3.3. The Protocol Overview

The experimental pilot consists of four plastic drums with a capacity of 30 litters, filled from bottom to top on gravel (25/15) mm thickness of 45 cm and 10 cm of sand (Figure13). An overflow is 5 cm below the sand to avoid water overflow. The barrel is planted saplings at 36 stems/ m^2. The drums are fed by water tarpaulin 30 L once a week. The waters are from sewage after primary treatment at the sewage plant Kouinine (north of the city of El-Oued). The percolation flow is through the substrate. The percolating water is récupéréeau means of a drain at the base of each drum (Figure 14). The water residence time is 5 days. The treated water is collected by a valve placed at the bottom of the barrel.

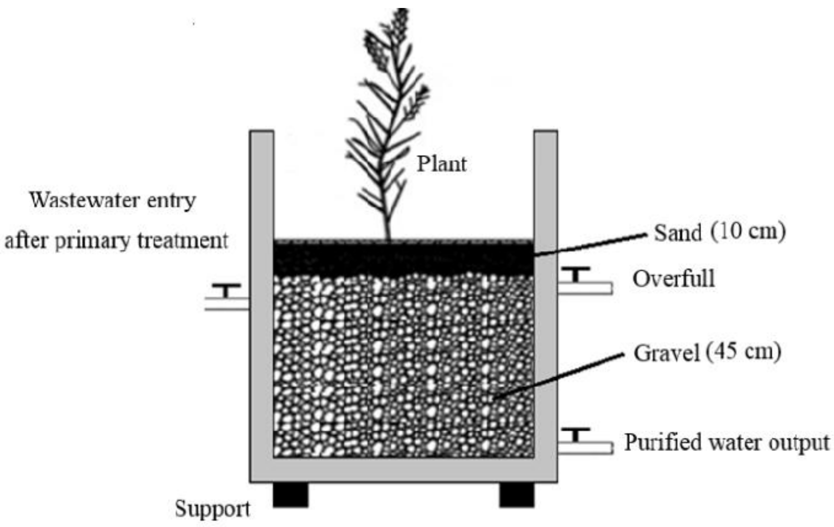

Fig.13. The experimental pilot station

Fig.14. The experimental pilot station

3.4. Analyzes

Water samples are taken after primary treatment at the wastewater treatment plant located Kouinine (north exit of the city). The analyses were performed at the laboratory of Valuation and Promotion for Saharan Resources of the University of Ouargla, in the laboratory of the treatment plant wastewater Kouinine. Our measurements were carried out ten parameters: pH, electrical conductivity (E C), total suspended solids (TSS),chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), dissolved oxygen, nitrite (NO_2^-), nitrate (NO_3^-) and ammonium (NH_4^+), orthophosphate (PO_4^{3-}). For the determination of pH, we used a pH meter HANNA pH 213. The conductivity was determined using a multi-parameter HACH HQ40d. For the TSS and depending on a number of suspended solids two methods were used: filtration method fiberglass according to DIN EN 872: 1996 and centrifugation according to standard NF T 90-105-2. Dissolved oxygen is determined by an Oximeter WTW pH/Oxi 340i. The BOD_5 BOD meter -WTW-OxiTop. COD, nitrite, nitrate, and orthophosphate were determined by colorimetry using a colorimeter HACH DR / 890.

4. CONCLUSIONS

Today phytopurification technology that resorts to the use of natural purification procedures for treating civil waste represents a widespread and consolidated choice worldwide. The present study was aimed to develop an artificial Phyto-Purification station of subsurface hybrid flow to treated urban wastewater using the plant *Papyrus alterniofolius* The change in the physic-chemical and bacteriological parameters reflect the ability of this natural purification process to act as an eco-filter and hence may be used in a large scale to combat the raising pollution problem. More the obtained results have consolidated the capacity of such procedure to achieve the desired specifications for the wastewater through the removal of contaminants and pathogens and access to the allowable limits for water used in agriculture (watering the trees, fruits, and grains that have the ability to withstand salinity) without the use of chemicals. Following conclusion are drawn by using the pilot station as a model on different plants substrate condition and using with and without plant species with the same detention time. The raw wastewater characteristics of EL Oued was determined and that wastewater is moderate in strength and needs treatment. Using *Papyrus alterniofolius* is found that BOD_5, TSS removal (97.25%) and (91.16%) for planted constructed wetland whereas for unplanted constructed wetland it was less than. It was found that the overall percentage removal of all pollutants was better for the detention time of 5 days as compared to the other detention time. Planted wetland Papyrus alterniofolius (97.25%). It is because of the oxygen diffusion from roots of the Papyrus alterniofolius and the nutrient uptake and insulation of the bed surface.

REFERENCES

[1] Ndzomo GT, Ndoumou DO, Awah MT. Effect of Fe^{2+}, Mn^{2+}, Zn^{2+} and Pb^{2+} on H^+/K^+ fluxes in excised Pistia stratiotes roots. *Biologia plantarum*., 1994, 36(4):591-597 (1994).

[2] Mandi L. Marrakesh wastewater purification experiment using vascular aquatic plants Eichhornia crassipes and Lemna gibba. *Water Sci Techno*., 1994, 29(4), 283-287.

[3] Badri A. Contribution to the study bioremediation of ammonium and nitrate by *imprata cylindrica*. First international seminar on the water resource in the Sahara, 2011

[4] Benslimane M, Mostephaoui T, Hamimed A, Cerif Z. Performance épuratoires and interest of the process of phytotraitement of wastewater by macrophytes plants, Mail of knowledge., 2013, 17: 47-51.

[5] Dong HY, Qiang ZM, Wang WD, Jin H. Evaluation of rural wastewater treatment processes in a county of eastern China, *J Environ Monit*., 2012, 14(7), 1906- 1913.

[6] Brix H. Treatment of wastewater in the rhizosphere of wetland plants–the root-zone method. *Water Sci Technol*, 1987, 19(1-2), 107-118.

[7] Brix H, Schierup HH. Soil oxygenation in constructed reed beds: the role of macrophyte and soil-atmosphere interface oxygen transport. *Cons wetlands water poll control*., 1990, 53, 57-66.

[8] Bnsmina-Mimeche L, Debabeche M, Seghairi N, Benameur N. Capacité de filtres plantes de macrophytes pour l'epuration des eaux usees dans le climat semi-aride, *J Int Envir Confl Manag*., 2010., 1(1), 10-15.

[9] Coleman J, Hench K, Garbutt K, Sexstone A, Bissonnette G, Skousen J, Treatment of domestic wastewater by three plant species in constructed wetlands. *Water, Air, & Soil Pollution.,* 2001, 128(3) :283-295.

[10] Tiglyene S, Mandi L, Jaouad A. Enlèvement du chrome par infiltration verticale sur lits de Phragmites australis (Cav.) Steudel. *J Water Sci*., 2005 18(2): 177-198.

[11] Oertzen IV. Wastewater Treatment with Aquatic Plants: ecotypic differentiation of Typha domingensis seedlings. Envir Pollution (Series A)., 1984, 35:259-269.

[12] Solano M L, Soriano P, Ciria MP. Constructed wetlands as a sustainable solution for wastewater treatment in small villages. *Biosystems Engineering*., 2004, 87(1):109-118.

[13] Seidl Mr. The system "lens of water - Tilapia" an ecological solution promising for the treatment of wastewater in West Africa. Gallery of the water, *Gallery of the water*., 2005, 3(635):11-17.

[14] Ouattara JMP. Treatment of urban wastewater by artificial marshes to Vertical drainage planted with Panicum maximum subtropical climate, Eur J Sci Res., 2008, 23(1):25-40.

[15] Taylor C R, Hook P B, Stein OR, Zabinski CA. Seasonal effects of 19 plant species on COD removal in subsurface treatment wetland microcosms. *Ecol Eng*., 2011, 37(5) :703-710.

[16] Münch C, Kuschk P, Röske I. La stimulation racinaire de l'élimination de l'azote concerne-t-elle des zones limitées ou l'ensemble d'un marais artificiel. *Ingénierie Nspécial*., 2004, 5-11.

[17] Finlayson CM, Chick AJ. Testing the potential of aquatic plants to treat slaughterhouse effluent. *Waters Res*., 1983, 17(4):415-422.

[18] Belkaçem H, Abdelhafidh DBA, Zineb H, Saad Z. Gardens planted with macrophytes filters, purification performance in an arid climate. Pilot station of Témacine, Ouargla (Algeria). *International Letters of Chemistry, Physics and Astronomy*, 2013, 8(3): 259-268.

[19] Ouattara P J M, Coulibaly L, Manizan P N, Gourene G. Traitement des eaux résiduaires urbaines par un marais artificiel à drainage vertical planté avec *Panicum maximum* sous climat tropical. *Eur. J. Sci. Res*, 2008, 23(1): 25-40.

[20] Achak M, Ouazzani N, Mandi L. Elimination des polluants organiques des effluents de l'industrie oléicole par combinaison d'un filtre à sable et un lit planté. *J Water Sci*., 2011, 24(1): 35-51.

[21] Rivera F, Warren A, Curds C R, Robles E, Gutierrez A, Gallegos E, Calderón A. The application of the root zone method for the treatment and reuse of high-strength abattoir waste in Mexico. *Water Sci and Technol*., 1997, 35(5): 271-27.

[22] Fonkou T, Nguetsop VF, Pinta J Y, Dekoum V M, Lekeufack M, Amougou, A. Macrophyte diversity in polluted and non-polluted wetlands in Cameroon. *Cameroon J Exper Biol*., 2005, 1(1): 26-3.

[23] Al-Omari A, Fayyad M. Treatment of domestic wastewater by subsurface flow constructed wetlands in Jordan. *Desalination*., 2003, 55(1): 27-39.

[24] Grismer M, Shepherd H. Plants in constructed wetlands help to treat agricultural processing wastewater. *California Agriculture*, 2001, 65(2): 73-79.

[25] Nelson M. living off the land: resource efficiency of wetland wastewater treatment, *Adv. Space Res*., 2001, 27(9): 1547-1556.

How to cite this article:
Zaghdi S, Laouini SE, Bebba AA. Phytoremediation performance of urban wastewater by the *papyrus alterniofolius* in El-Oued region (southeast of Algeria). J. Fundam. Appl. Sci., 2018, *10(3), 448-464.*