Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 29, issue 2, 2019, pp. 70-81
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THE USE OF MACROPHYTE *TYPHA LATIFOLIA* FILTERS IN THE TREATMENT OF WASTEWATERS OF MEDJERDA RIVER, IN SOUK-AHRAS CITY (NORTH-EAST ALGERIA)

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Abstract: The present study was aimed to test the purifier capacities of a helophyte plant, and herein the cattail (*Typha latifolia*) has been used to purify the raw wastewaters through monitoring the contamination physico-chemical and parasitological indicators following various stay periods. The experimental pilot scheme is composed of three planted trays of young *Typha* stem. Each one was retained, respectively a treatment period of 7, 14 and 21 days. The supply of planted systems are exclusively occurred through the release of wastewaters in Medjerda river (discharge of river).The results have shown that these helophytes lead to the neutralization of pH, along with decrease in electrical conductivity of raw wastewaters. The monitoring of the purifying performances of the three systems shows that the third planted tray ensure an important elimination of the total suspended matter (TSS) at 97.6 % and the turbidity (92.4 %), which showed to be efficient in removing the organic charge with a reduction in BOD_5 (90.1 %), COD (92.66 %) and the nutrients (NH_4^+: 88.54 % and PO_4^{3-}: 91.9 %). Moreover, the concentrations of these chemicals do not exceed the national (J.O.R.A) and international (WHO, FAO) standards for the irrigation water. Regarding the parasite load, the three planted trays lead to the elimination of the total parasitic helminth eggs.

Keywords: wastewaters, irrigation, contamination, treatment, *Typha latifolia*

INTRODUCTION

In nowadays, the most developing countries are faced huge environmental problems, in particular those related to the treatment of raw wastewaters. These effluent wastes found on the water surface with no adequate treatment is basically resulted from their breakdown process (eutrophication, biodiversity disappearance and pathogenic microorganism pools), and the inappropriate turn in the human consumption (Tfeila *et al*.,2016; Fagrouch *et al.*, 2011; Youbi *et al*., 2018). Although the efforts provided in the realization of the classical purifying systems (activated sludge, bacterial beds), the raw wastewaters usually leads to damages to environment and populations of these countries. The region of Souk-Ahras (north-east Algeria) is agricultural vocation and surface water resources, mainly is formed in the Medjerda river , known as one of the high important rivers in the eastern Algeria (Athmani, 2008). This city exhibits an increased serious environmental problems for the health of Souk-Ahras population, due principally to the presence of the pathogenic agents (e.g. helminths) in waters (El Ouali Lalami *et al*., 2014), since the agricultural reuse of their wastewaters makes appealing contributions for agriculture (Keffala *et al*., 2012).

Hence, this region gets worse due to the multiplicity of the temporary urban installations, often unaccomplished and to the lack of the appropriate sanitation structures of wastewaters (Fonkou *et al*., 2010). Thus, it is necessary to explore new purification technologies of real wastewaters and adapted wastewaters to the actual development of countries. The phyto-purification of wastewaters as known as the alternative technique of wastewater treatments (Ouatrra *et al*., 2008), and thus it is considered in nowadays as the high suitable technique, with respect to the diversity of plant species that can be used, the real fees of installation and the best performances (Czudar *et al*., 2011). The studied aquatic plants are as well free or floating, such as *Lemna minor* (Bokhari *et al*., 2016) compared to those rooted or halophyte plant like *Typha latifolia* (Rana and Maiti, 2018). Noteworthy, the wastewater treatment using these rooted halophytes is basically focused on the fact of using the most plants of horizontal and vertical rhizomes making a support for bacterial growth, in addition to the filtration of particulate substances (Gesberg *et al*., 1986). Additionally, the rhizome contributes with roots a high soil permeability and a large contact surface between soil and wastewaters (Radoux and Kemp, 1988), and hence they become able to concentrate heavy metals, to absorb higher nutrients than their needs and to neutralize the extreme pH (Hadad *et al*., 2006). The plant systems ensure several advantages, including the fact that are cheap to be made and exploited, might be easily built on the production site of wastewaters, require less mechanized equipments and are found to be less sensible to pollutant load variations (Achak *et al*., 2011).

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The present study, was therefore designed to test the purification ability of the macrophyte (*Typha latifolia*) filters in purifying the wastewaters of Souk Ahras city (discharge of river of Medjerda) through the determination of the contamination physico-chemical and parasitological indicators following various stay periods subjected to the same experimental conditions, and subsequently to try discussing the quality of the effluents within sight of an agricultural reuse.

MATERIALS AND METHODS

Description of the study site

The urban municipal of Souk-Ahras is the main place of Souk-Ahras city located in north-east Algeria, and characterized by sub-humid climate and important agricultural activities. Also, it contains a large variety of crops, including cereals, vegetables and arboriculture (Amani, 2008).

The wastewaters discharged from the urban conurbations of this region are transported, at the raw state into the Medjerda river downstream through the urban secondary collectors. The raw effluent of Medjerda river was the aim of the present study (Fig.1), with respect that the selection of this site focuses on the importance of wastewaters released into the natural environment by the secondary collectors crossing the urban zones, and interestingly the wastewaters selection is not related to the purification station of the Souk-Ahras region. This river constitutes, however, an important source of irrigation water in this region, exhibiting an agricultural vocation (Gausmi *et al*., 2006).

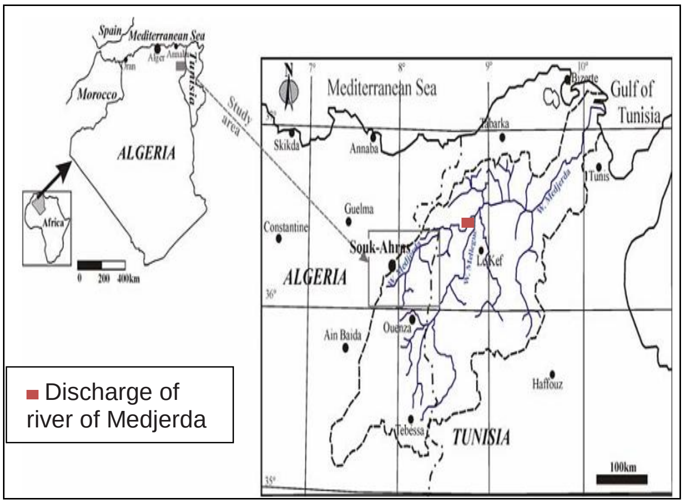

Fig. 1. Location of studied site (Gausmi *et al*., 2010)

Plant material

In this study, the monocotyledonous angiosperm (order: *Typhales*; family: *Typhaceae*) was used as a plant material. It is a cattail: Typha *latifolia* (Ingrid and Uwe, 1989), vertical and horizontal rhizome plant growing spontaneously in humid environments and forming monospecific fields. In addition, it has a height ranging from 1.5 to 3 m, and large leaves (2-4 cm), making it as a helpful plant for human and an important nutrient for semi-aquatic mammals (Julve, 1998). As well as a very productive species easy adapts to adverse environment conditions (Zaimoglu, 2006).

Experimental system and water supply

The experimental design (fields) includes three serial systems (Fig. 2): In brief, the three trays of 50 litres and 50cm high, filled successively from top to bottom by three layers. The two first layers are composed of gravel of decreasing diameter (4-25 mm) on thickness of 8cm and the third layer has the highest thickness and is composed of 18cm thick sand. Each tray has a slope of 10% toward the downstream, and equipped with an outlet valve to evacuate the percolation water (treated water). Also, the three trays were planted with young stems of *Typha latifolia* (with a density of 9 plants /m²) and then all retained for a 7 day treatment period, 14 days and 21 days respectively. The water supply system was exclusively through the discharge of Medjerda river reused in irrigation of the uncontrolled horticulture of Souk-Ahras city.

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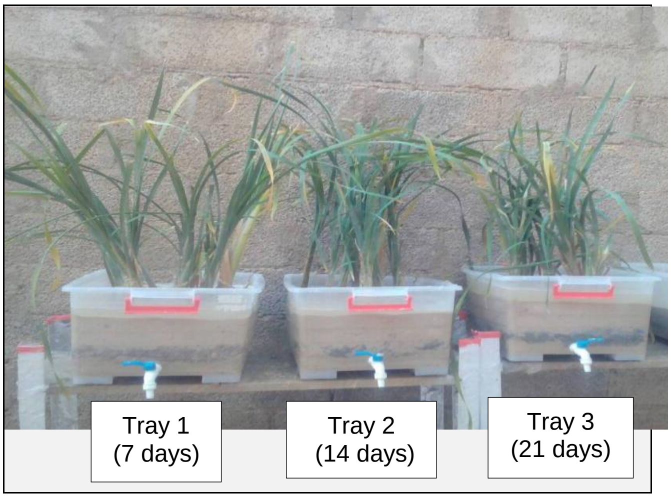

Fig. 2. Overview of the experimental design (Mamine, 2017)

Sampling

The wastewaters to be treated mainly come from an emissary of Souk-Ahras city in the residential neighbourhood. At the exit of this outfall, the wastewaters are discharged into the Medjerda river downstream without any prior treatment. The experiment was conducted for 4 months from March to June, 2017, during which the experimental pilot scheme was monitored by measuring physico-chemical and parasitological parameters. Additionally, the sampling was conducted on raw wastewater samples applied to the planted trays and at their three exits. These samples were taken under strict aseptic conditions to avoid any accidental contamination during handling, collected into sterilized flasks carefully labelled, and kept in a lab cooler at low temperature (4ºC) until the day of analysis (Rodier, 2009).

Analysis Methods

Determination of physico-chemical indicators

The physico-chemical indicators (pH, electrical conductivity, turbidity, suspended matters (TSS), ammonium, orthophosphate, biochemical oxygen demand for 5 days (BOD_5), chemical oxygen demand (COD)) were determined following various analytical methods, as indicated in table 1.

Table 1.

Methods of physico-chemical analyses

Parameters	Determination Methods	References
pH **Electrical conductivity**	Multi parameter probe	HQ40d multi /NACH
Turbidity	Turbidity meter	NF EN ISO 7027
TSS	Spectrometric (HACH : DR5000)	NF, T 90-105
BOD_5	Manometric method	NF, T90-103
COD	Oxydation of potassium dichromate	NF, T90-101
NH_4^+	Spectrometric method	ISO 7150/1-1984
PO_4^{3-}	Spectrometric method	ISO 6878/1-1998

Determination of parasitological indicators

The parasitological analyses of wastewaters include, principally the research for helminth eggs. Here, we have performed the centrifugal flotation technique of Faust *et al*. (1938). Briefly, direct dilution of the pallet resulted from centrifugation in solution of zinc sulfate (33% & density 1.18) at 1500 rpm for 1 to 2 minutes (El Ouali Lalami *et al*., 2014). We have afterwards collected by pipette the superficial layer of the supernatant, in which the found parasites were spread on a Malassez chamber for the identification and then the counting (Rodier, 1996). The total number of helminth eggs per litter (N) of the wastewater samples is determined according to the following formula:

$$N = X/P *$$

Where N, is the number of total eggs per litter, X is the number of counted eggs, P is the volume of suspension involved in cell counting in ml, V is the total volume of the suspension in ml, and S is the volume of the wastewater sample.

Purification yields

The yields of purification of physico-chemical and parasitological parameters are calculated according to the following equation:

Yield (%) = $(X_{RW} - X_f / X_{RW}) * 100$

X_{RW} = Concentration of the parameter selected in the raw wastewater applied on the tray.

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X_f = Concentration of the parameter selected in the filtrate.

Statistical analysis

The collected data were treated by using Statistica (version 7.1) software, providing arithmetic means and standard deviations. Also, the performance difference between the three planted trays was tested at significance level of 0.05, after the normality check by the Kolmogorov-Smirnov test, since the analysis of variance (ANOVA) tested to compare the mean leads to the determination of the significant difference between planted trays. XLSTAT version 2014.5.03 has been used for this analysis.

RESULTS AND DISCUSSION

Variations of water contamination physico-chemical indicators

The obtained results of the measured parameters of raw wastewater are shown in table 2.

Table 2.

Raw wastewater physico-chemical indicators

Parametrs	Min-Max (Mean ± SD)	Parametrs	Min-Max (Mean ± SD)
pH	7.81- 8.2 (8±0.1)	**BOD_5 (mg /l of O_2)**	100 - 160 (117.7±87.2)
Conductivity (µs/cm)	1548 -1855 (1684±21.54)	**COD (mg /l of O_2)**	150 - 277 (264.75±67.12)
		COD/ BOD_5	1.27 - 2.89 2.24±0.5
TSS (mg/l)	360.98 - 422 (397.3±15.74)	**NH_4^+ (mg/l)**	6.41-9.8 (8.73±1.84)
Turbidity (NTU)	96 -102 (98±7.14)	**PO_4^{3-} (mg/l)**	7.89 -10.1 (7.42±0.56)
SD : Standard deviation ; Min : minimum ; Max : maximum			

Evolution of the potential of hydrogen

The pH is used to quantify the concentration of H^+ ions in the water, which gives it its acidic or basic character. This measure provides information on the water quality (Franck, 2002). The extreme pH values of raw wastewaters are slightly alkaline (7.81 to 8.2) (Table 2), and this is in line with those Algerian standards regarding the quality of wastewaters used for irrigation (J.O.R.A, 2012), as well as they are in the interval recommended by Food and Agriculture Organisation (FAO) (6.5-8.4).

As seen in figure 3, the pH at the exit of the three planted trays of *Typha latifolia* following various stay periods was decreased by one unit compared to that of raw wastewater. This pH value is expressed as mean± standard deviation and ranged from 8±0.1 (raw wastewater) to 7.5±0.3, 7.2±0.1 and 7.1±0.2 respectively for a stay period of 7, 14 and 21 days. These values are included within the recommended intervals provided by FAO (6.5 – 8.4) regarding the quality of wastewaters used for irrigation. In addition, the low pH value leads to an acidification of the medium. As reported by Ouattara *et al.* (2008), this acidification may be resulted in oxidation of chemical oxygen demand (COD) and NH_4^+. Indeed, the increase in the stay period exhibits a good ability of COD oxidation producing carbon dioxide by the planted system of *Typha latifolia*, similarly to the nitrification reaction (oxidation de NH_4^+) inducing an acidification of filtrates. These results are in line with those reported by Kipasika *et al.* (2016) for the planted system of *Typha latifolia* . The difference in the equality mean is highly significant (p = 0.000) between the planted trays as compared with the raw wastewater.

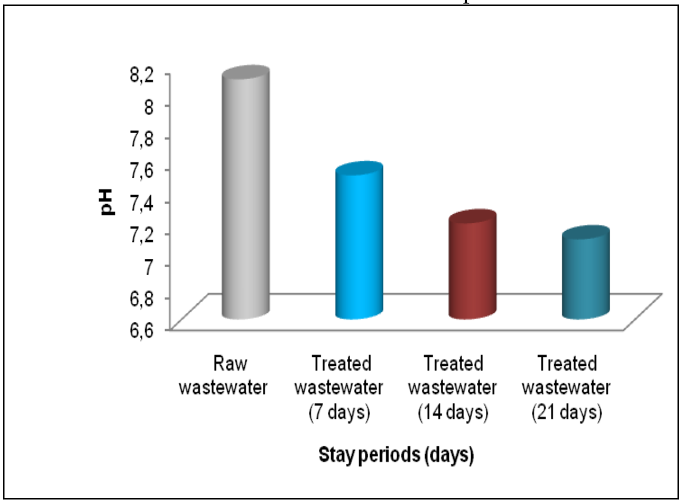

Fig. 3. Variation of pH of raw and treated wastewater following various stay periods

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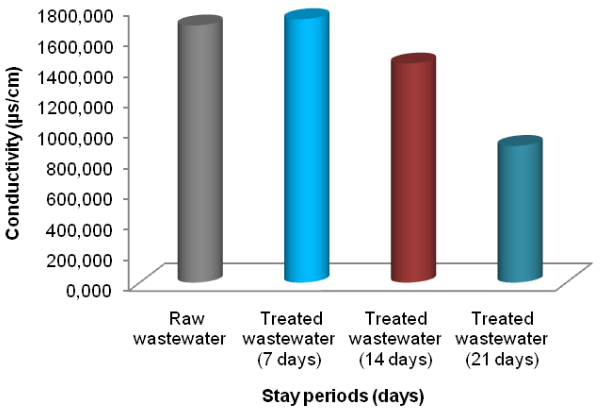
Evolution of the electrical conductivity

The electrical conductivity reflects the rate of global mineralization and provides information on the salinity (Lakhili *et al.*, 2015).The extreme values of raw wastewaters are comprised between 1548 and 1855 µs/cm (Table 2), and thus the water becomes saline and highly mineralized, alike to what have been reported by Rodier (2009), proving that the conductivity ranged from 1000 to 3000 µs/cm makes the water saline in nature. Hence, the high salinity of irrigation water induces undesirable effects on the physical properties of soil and the agriculture yields (Ayers and Wastcot, 1994).The figure 4 indicates that the electrical conductivity of the first tray filtrate (1725.2±66.3 µs/cm) was found to be higher than that found in the raw wastewater (1684 ±21.54 µs/cm). This elevation is likely explained by the early adaptation of development of plants (Achak *et al*., 2011).

In regard, Finlayson and Chick (1983) has reported the same observation for the planted bed of *Arundo* at vertical flow for a short-term stay. According to Rajani *et al*. (1896), the increase in the electrical conductivity is due to the leaching of soil minerals and the mineralization of organic substances. Nevertheless, the electrical conductivity of planted filtrates decreases after 14 days (1434.7±24.2 µs/cm) and 21 days (895±41.6 µs/cm) of treatment. These values are found within the ranges of admissible values recommended by the FAO which are 3000 µs/cm (FAO, 2003), and to that of the Algerian standards which stipulates an electrical conductivity lower than 2000 µs/cm (J.O.R.A, 2006). Our data showed that the electrical conductivity decreases at 46.85% in the third planted tray, against those found in the first (-24 %) and the second (14.8 %) planted trays. Achak *et al*. (2011) have proved that the aquatic rooted plants have tendency in accumulating the dissolved salts in wastewaters along with increased stay period in association with the phyto-extraction process leading to extract the pollutants of soil and, then to concentrate them in the aerial and root parts which would be afterwards, harvested. These results concord with those found by Xu *et al*. (2018). The difference in the equality means is very highly significant (p = 0.00) between the planted trays compared with those seen for raw wastewater.



Treatment	Tray 1 (7 days)	Tray 2 (14 days)	Tray 3 (21 days)
Abatement rate (%)	- 24	14.8	46.85

Fig. 4. Variation of the conductivity of raw and treated wastewaters after various stay periods

Evolution of turbidity

The turbidity of a water is due to the presence of suspended finely divided matters, e.g. clay, silt, silica grains and organic matters, etc. The assessment of the abundance of these materials measures its degree of turbidity (Idrissi *et al*., 2015). The extreme of turbidity values of raw wastewaters range from 96 NTU to 102 NTU (Table 2), and hence they exceed the standard of the discharges appointed by the Official Journal of the Algerian Republic (50 NTU), suggesting consequently that wastewater discharged into Medjerda river is highly turbid (J.O.R.A, 2006).

Moreover, the evolution during the study period of the turbidity of raw and treated wastewater after various stay periods is displayed in figure 5. The wastewater treated at the exit of the three planted trays following various stay periods (7, 14 and 21 days) show a significant decrease compared to that of raw wastewater. On top of that, the mean value of the turbidity before purification is found to be 98 ±7.14 NTU, while the average values recorded at the exit of the three filtrates are respectively, 17.44±4.53 NTU, 11.22±1.85 NTU and 7.48±1.52 NTU for planted trays selected for stay periods of 7; 14 and 21 days. These values are lower than the standard of direct discharges into the receiving milieu given by the J.O.R.A (2006) (50 NTU). The reduction in the turbidity of the wastewater from the three planted trays is mainly affected by the effect of sand (filtration and adsorption)

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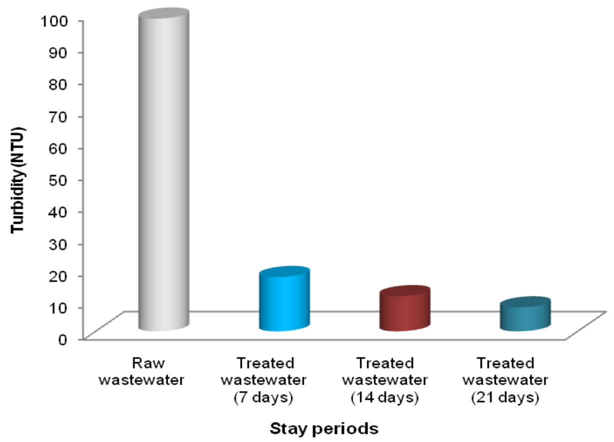
and the presence of *Typha latifolia* (Kaverugu *et al*., 2016) due to the mechanical effect of these horizontal and vertical rhizomes attributing with the roots to a high permeability of the sand and a large contact surface between sand-wastewater (Radoux and Kemp, 1988). Our results show the reduction rate of turbidity in the third planted tray is about 92.4 % with the longer stay period (21 days). Also, the improvement in turbidity reduction performance is influenced by the chosen experimental conditions. This can be explained by the increase of the stay period and the use of a nutrient-less rich substrate (sand). These results are in agreement with those reported by Kadaverugu *et al*. (2016). The difference in the equality means is highly significant (p = 0.004) between planted trays compared to raw wastewater.



Treatment	Tray 1 (7 days)	Tray 2 (14 days)	Tray 3 (21 days)
Abatement rate (%)	82.8	88.5	92.4

Fig. 5. Variation of turbidity of raw and treated wastewaters after various stay periods

Evolution of suspended matters

The suspended matter represents all the mineral and organic particles in the water. It depends on the nature of the lands crossed, the season, the rainfall, the flow regime, the nature of the effluents, etc. (Ould Mohamedou, 2006).Also, the quantity of suspended solids in the raw wastewater varies between 360.98 and 422 mg/l (Table 2) which proved to be higher than the standard values of the direct discharges given by the World Organization Health (WHO) (30 mg/l), may result in soil clogging, with damaging effects on the agriculture (Abouelouafa *et al*., 2002).

The evolution of the suspended matter concentrations in the raw wastewater and the filtrates of the three planted trays are shown in figure 6, showing a decrease in the concentration of suspended solids in all planted trays for different stay periods as compared with that found for raw wastewaters. This concentration was noticed to be ranged from 397.3±15.74 mg/l to 30.6±11.41 mg/l (7 days), 16.01±5.63 mg/l (14 days) and 9.37±4.78 mg/l (21 days). Moreover, the values recorded for the suspended matter filtrates after the stay period (14 and 21 days) do not exceed the standard of discharges in the aquatic receiving environment recommended by the WHO (30 mg/l). The reduction of suspended matters can be explained mainly by physical processes (sedimentation and filtration) (Achak *et al*., 2011), in addition to the biological processes associated with bacterial flora and adsorption by vegetation (Ouattara *et al*., 2008). Furthermore, the third planted tray provides a better reduction yield of suspended matter (97.6%) compared to the first and second planted trays, and thus this system provides highly pure waters compared to that of raw wastewater. This result is somehow related to the influence of these plants and the increase in stay period, making favourable physico-chemical conditions to the oxidation of pollutants by the microbial flora (Abissy and Mandi, 1999). These plants supply oxygen to the filter bed via the roots and rhizomes (Brix, 1994). The best rate of the removal efficiency of suspended matters obtained at the third level (97.6 %) is significantly higher than that obtained by Chandanshive *et al*. (2017) (35 %) for a bed planted of *Typha angustifolia*. This difference would possibly be related to the type of used plant, and also the difference in the equality of the means is highly significant (p = 0.002) between the trays compared to the raw wastewater.

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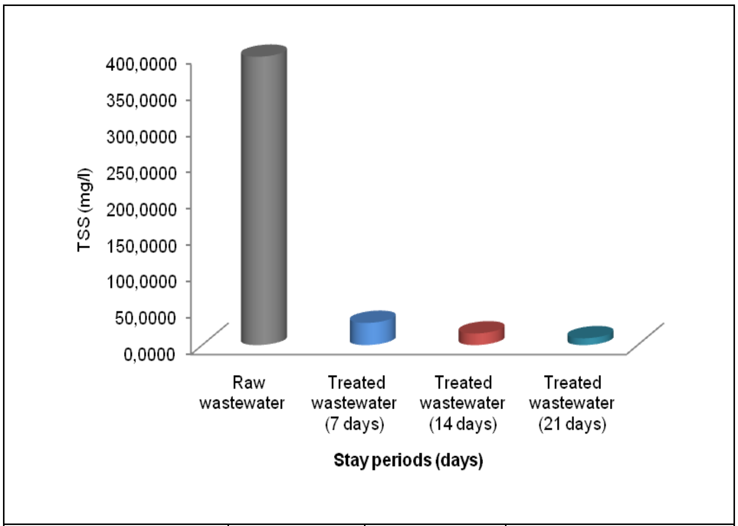


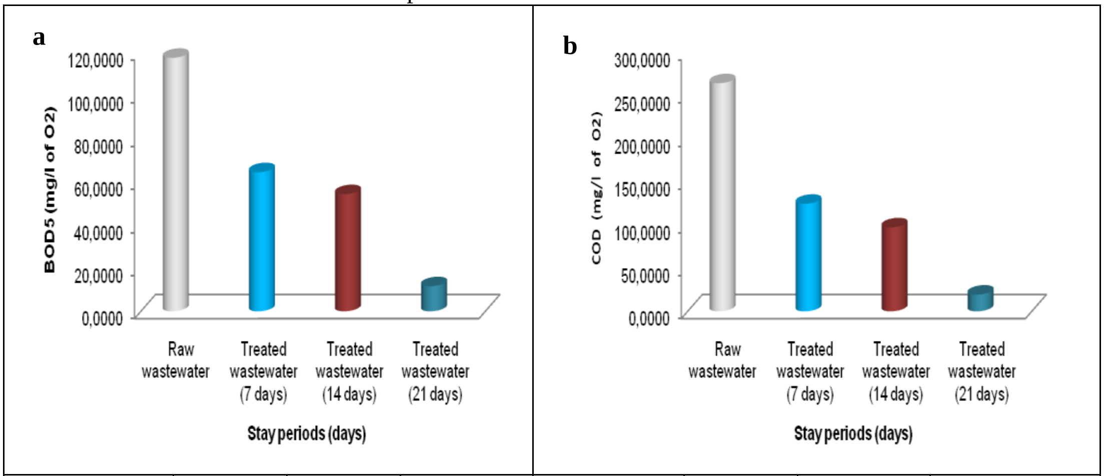
Treatment	Tray 1 (7 days)	Tray 2 (14 days)	Tray 3 (21 days)
Abatement rate (%)	92.3	95.9	97.6

Fig. 6. Variation of suspended matter in raw and treated wastewaters after various stay periods

Evolution of organic carbonaceous load

The parameters BOD_5 and COD allow evaluating the quantity of organic matter present in water (Lamhasni *et al.*, 2013). As shown in Table 2, the extreme values of BOD_5 (100 to 160 mg/l of O_2) and COD (150 to 277 mg/l of O_2) of raw wastewaters ranging from are higher than the standards values of waters intended for irrigation (30 mg/l O_2) and (90 mg/l O_2) respectively (J.O.R.A, 2012). These waters are of very poor quality (Idrissi *et al.*, 2015). For a better appreciation of the pollution source in Souk-Ahras city, the determination of COD/BOD_5 ratio makes an effective tool to screen the pollution degree due to the raw effluents, in addition to propose a proper treatment. The extreme values of the ratio COD/BOD_5 ranged between 1.27 and 2.89 proves that the waters of Medjerda river receive domestic wastewater whose ratio COD/BOD_5 is less than 3 (Rodier, 2009), and hence wastewater of these urban discharges has a high biodegradable organic load.

The evolution of the BOD_5 and COD contents of the raw wastewater and filtrates of the three planted trays is presented in the figure 7 .The results show also, that the carbonaceous organic load of the raw wastewater (COD = 264.75±67.12mg/l of O_2 and BOD_5 = 117.7±87.2mg/l of O_2) decreases after passing through the three trays planted with *Typha latifolia*. At the exit of the planted systems, high concentrations of COD (124.80±22.56 mg/l of O_2) and BOD_5 (64.6±13.9 mg/l of O_2) were noticed at the level of the planted tray chosen for 7 days with a small reduction in COD (52.84 %) and BOD_5 (45.11 %), in addition to the low concentration averages of COD (19.44±6.4 mg/l of O_2) and BOD_5 (11.66±1.87 mg/l of O_2) recorded at the level of the plant filter retained for a duration of 21 days with a better reduced rate for the BOD_5 (90.1 %) (Fig.7a) and for COD (92.66 %) (Fig.7b). The average in COD and BOD_5 values obtained after 21 stay days are below the standard limited to the irrigation water (90 mg/l of O_2) and to a limit value (30 mg/l of O_2) recommended by the JORA (2012) respectively.



Treatment	Tray 1 (7 days)	Tray 2 (14 days)	Tray 3 (21 days)	Treatment	Tray 1 (7 days)	Tray 2 (14 days)	Tray 3 (21 days)

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Abatement rate (%)	**45.11**	**53.8**	**90.1**	**Abatement rate (%)**	**52.8**	**63.17**	**92.66**

Fig. 7. Variation of BOD_5 (**a**) and COD (**b**) raw and treated wastewaters after various stay

In addition, the biodegradability ratio in the three filtrates was very significantly ($p = 0.00$) deceased with increasing of stay period as compared to raw wastewaters. This variation ranges from 2.24 ± 0.5 to 1. 93 ± 0.4, 1.8± 0.8 and 1.66 ± 0.1 respectively for planted trays selected within 7, 14 and 21 days (Fig.8).

Importantly, this reduction is referred to a better oxygenation of the substrate in this planted tray by the plant *Typha latifolia*, promoting the aerobic bacteria to proliferate and to ensure better mineralization or oxidation of organic matter (Kaverugu *et al*., 2016). The rate of abatement of COD and BOD_5 obtained with the third planted tray is higher than that found by Abou-Elela *et al*. (2017) for a bed planted with *Cyprus* papyrus (COD =87 %, and BOD_5 =80 %). The difference in the equality of averages is very highly significant ($p = 0.00$) between planted trays compared to raw wastewater.

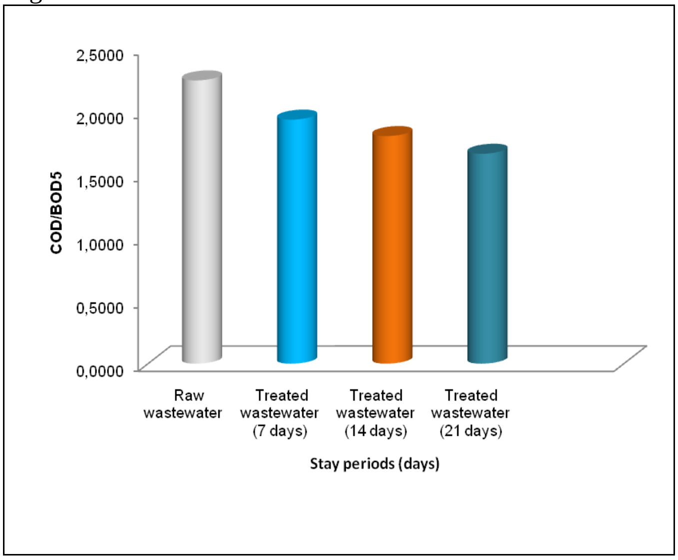

Fig. 8. Variation of COD/BOD_5 ratio of raw and treated wastewaters after various stay periods

Evolution of nutrients

Ammonium

The ammonium is the product of the final reduction of nitrogenous organic substances and inorganic matter, in water and soil. It also comes from the excretion of living organisms and the reduction and biodegradation of the dung, without neglecting the inputs from domestic, industrial and agricultural sources (Dimane *et al*., 2017).

The extreme values of ammonium consumption of raw wastewaters range from 6.41 to 9.8 mg/l (Table 2). Additionally, the concentration of ammonium in the filtrates after various stay periods is lower than that of the raw wastes, and thus the average of NH_4^+ concentration of the raw water is found as 8.73±1.84 mg/l, since the ammonium concentrations of the treated wastewater are found as 3.47±0.75; 2.54±0.41 and 1±0.22 mg/l, respectively for the retained trays at 7, 14 and 21 days (Fig.9). The rate of abatement of the third planted tray of about 88.54 % is significantly higher than that observed for the first (60.25 %) and second (70.9 %) trays. The mean value noted in the third tray does not exceed the standard value for irrigation water as reported by FAO and WHO (<2 mg/l) (FAO, 1985; WHO, 1989). These results are explained by the biological oxidation of NH_4^+ by nitrifying bacteria found in the roots and rhizomes of these plants (Derradji, 2014).

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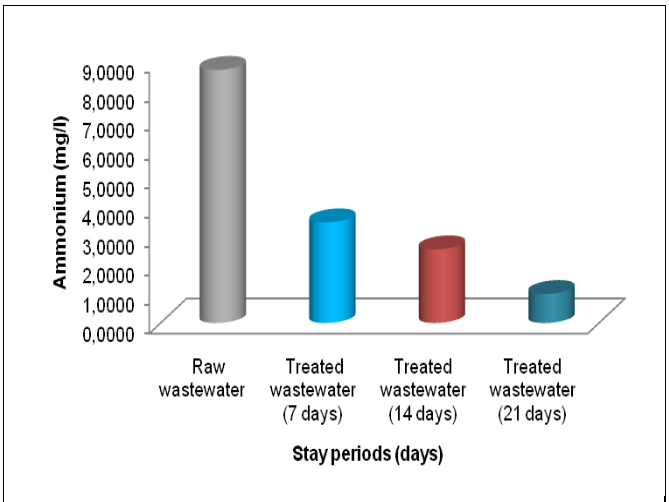
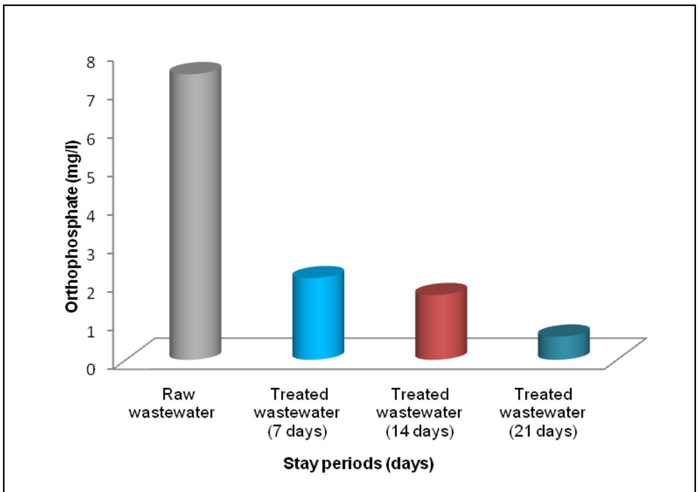


Treatment	Tray 1 (7 days)	Tray 2 (14 days)	Tray 3 (21 days)
Abatement rate (%)	60.25	70.9	88.54

Fig. 9. Variation of ammonium in raw and treated wastewaters after various stay periods

Orthophosphate

The evolution of the orthophosphate concentration in raw wastewaters shows that these waters are highly concentrated and exhibits extreme values range between 7.89 and 10.1 mg/l (Table 2), which are higher than the threshold of the standard of discharges prescribed by JORA (2006)) (2 mg/l), and are notably superior to those recommended by FAO for irrigation water (FAO, 1985). In addition, the concentration of orthophosphate in the three filtrates was very significantly ($p = 0.00$) deceased with increasing of stay period as compared to raw wastewaters. This variation ranges from 7.42 ± 0.56 mg/l to 2.12 ± 0.59, 1.68 ± 0.77 and 0.6 ± 0.3 mg/l respectively for planted trays selected within 7, 14 and 21 days (Fig.10). This decrease would be due to the taking of (PO_4^{3-}) by *Typha latifolia* for ensuring its physiological needs (Kadaverugu *et al*., 2016), which in turn increases the removal of PO_4^{3-} in the third planted tray with an abatement rate found as 91.9 %. Also, the reduction rate of orthophosphate obtained in the third planted tray is higher than those reported by Du *et al*. (2017) for a planted bed with *Canna generalis* (77 %).



Treatment	Tray 1 (7 days)	Tray 2 (14 days)	Tray 3 (21 days)
Abatement rate (%)	71.42	77.35	91.9

Fig. 10. Variation of orthophosphate concentration in raw and treated wastewaters after various stay periods

Parasitic evolution

Parasitic searching in raw wastewaters has evidenced the presence of helminth eggs (Table 3), since the quantitative analysis led to identify two classes of helminths in the wastewater samples, namely the nematodes (*Ascaris sp*, *Enterobius vermicularis*)

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and the cestodes (*Taenia sp*). The presence of these helminths reveals faecal contamination transported by raw wastewater (Keffala *et al*., 2012). These concentrations for wastewater intended for irrigation are higher than the standard values provided by WHO (2006). Noteworthy, the most frequently encountered species in the studied wastewater are *Ascaris sp* (21±4.6 egg/l)). The presence of intestinal nematodes, in particular the genus *Ascaris* in reusable wastewaters for irrigation (forage or market gardening crops) could increase the number of intestinal flora in humans, leading consequently to metabolic imbalance and serious health hazards (El Ouali Lalami *et al*., 2014).

Table 3.

Analysis results of raw wastewater parasitic contamination

Helminths		Concentration (egg /l) Mean ± SD	Threshold value (WHO, 2006)
Nematodes	***Ascaris sp***	21±4.6	< or =1 egg/l
	Enterobius vermicularis	10±3.2	
Cestodes	***Tænia sp***	1.22±0.4	
SD : Standard deviation			

Elimination parasitic load

Parasitological analysis of treated wastewater basically focuses on the absence of parasitic helminth eggs in treated wastewater (Table 4). The three planted systems resulted in allowance of 100% of helminth eggs according to the standards recommended by WHO (2006) (<1 of eggs in liter of analyzed water). Moreover, helminth eggs were found to have larger size in comparison with other pathogens (Feachem *et al*., 1983). The absence of helminth eggs in treated wastewater is likely related to mechanisms involving the attachment by the root and rhizomatous system of these macrophytes, in addition to adsorption and sedimentation by sand. These findings are in concordance with those reported by Shingare *et al*. (2017).

Table 4.

Mean concentrations and abatement rates obtained for treated wastewater after various stay periods

	Helminths	
	Concentration (egg/l)	**Abatement rate (%)**
TWW (7 days)	0	100
TWW (14 days)	0	100
TWW (21 days)	0	100
TWW: Treated Waste Water ; 0: not detected		

CONCLUSIONS

The characterization of the physico-chemical and parasitological quality of raw wastewaters of Souk-Ahras city (discharge of river of Medjerda) prior the treatment by plant *Typha latifolia* have shown that these waters may cause problems for the receiving environments which are rich with organic matters and nutrients. Furthermore, the presence of helminth eggs lead to serious health problems when they are reused in irrigation of agriculture. The cattail *Typha latifolia* is very resistant plant to the urban wastewaters, however its potentiality in purifying raw wastewaters is influenced by the periods of stay. The results show that the retained *Typha latifolia* plants at 21 stay period are robust purification systems of raw wastewaters of Souk-Ahras city accordingly to the national standards provided by J.O.R.A (2006 and 2012) and the international standards given by WHO (1989 and 2006) and FAO (1985 and 2003) for the irrigation waters. Additionally, they ensure an obvious improvement was noticed either for the organic load or nutrients, as well as pure purified waters with no parasitic helminth eggs.

CONFLICT OF INTEREST

The authors reports no conflict of interest.

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