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Phytoremediation Performance of Urban Wastewater by the Plant *Juncus effusus* in an Arid Climate.

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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. This study involves a comparison between a planted bed and an unplanted bed (used as witness) focusing on the plant's ability to filter wastewater. The study was carried out through an experimental pilot scale in the area of urban wastewater treatment (ONA Touggourt, Algeria). The process consists of circular beds with a capacity of 130 L filled with superimposed layers of gravel (25/15) mm and sand, 45cm and 10 cm deep respectively. The first bed was planted with freshly collected stems of the plant *Juncus effusus* (36 stems/m^2) and an unplanted bed taken as a witness. The procedure consists of providing the bed with urban wastewater (feed) after primary treatment (physical treatment) with a flow rate of 30 L per day over regular intervals once every week. The water obtained after staying 5 days in the bed is collected in a vase. After analysis the results revealed important removal fractions of the main pollutants namely: chemical oxygen demand (COD) (82.21%), biochemical oxygen demand (BOD_5) (85%), total suspended solids (TSS) (94.41%) nitrite NO_2^- (82.32%), orthophosphate PO_4^{-3} (82.92%), E. coli (99.41%), total coliforms (99.97 %) and total streptococcus (99.90 %). The presence of the plant stems in the unplanted bed leads to the creation a crossing water channel so as to avoid plugging.The considerable decrease of pollutants content and harmful organisms enables the reuse of the treated water in agriculture and industry.

Keywords: Phytoremediation, wastewater, *Juncus effusus*

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INTRODUCTION

Nowadays most of the developing countries face several environment problems, especially those related to the treatment of urban waste water. The release of this water affects the surface water if untreated and may cause the proliferation of bacteria and organisms and give an unpleasant odor and becomes unusable by the human in spite of the efforts made in the building of wastewater treatment plants using classical methods [1-3]. These methods are complex and require high operating and maintenance cost. In recent years most of the world countries are more and more interested in protecting the environment using modern techniques and methods of processing plants, including phytopurification which has proven competencies in the ability to achieve the desired specifications for the wastewater by decreasing the percentage of contaminants and pathogens, and access to the allowable limits for the use of the treated wastewater in agriculture without the addition of chemicals.

Water phytopurification treatment depends on the plant rhizomes and roots which form an incubator for the growth of bacteria and a filter of suspended solids [4]. Rhizomes and roots form a large area of contact between soil and water and hence enable water to flow into the soil [5]. Plants allow the oxygen to access to the roots through the leaves and stems [6,7]. This oxygen contributes to the growth of bacteria which destroy the organic material in the water. Rhizomes and roots may produce a toxic substance (antibiotics) to kill harmful bacteria.

A comparison between the classical treatment methods and phytopurification reveals that this later is cost effective and easy to handle since it requires a few possibilities and has less effect in the change in water quality. The objective of our work is to assess the efficiency of the plant in the purification of urban wastewaters. The choice of this plant is mainly due its abundance and spontaneity [8-10].

MATERIAL AND METHODS

The study was conducted through an experimental model in the area of urban wastewater treatment near the city of Touggourt, Algeria. This region is characterized by a dry weather with a rainfall rate of 18 mm / year and an average temperature ranging between -1.6 to 48.4 °C. This experimental model consists of a circular bed with a capacity of 130 filled from the bottom with the gravel (15/25) 45 cm thick and 10 cm of sand.

Two beds planted with young plant stems (density 36 stem/m^2) [11, 12] and two unplanted beds taken as standard witnesses were prepared. The Process consists of providing the beds with urban wastewater (feed) after primary treatment (Physical treatment) at a flow rate of 30 l a day through a regular subsurface horizontal flow once every week . The water obtained after a 5 days treatment inside the bed is collected in a Multi bottom vase of the tub

Figure 1: Experimental device

Physico-chemical characteristics of the filling materials

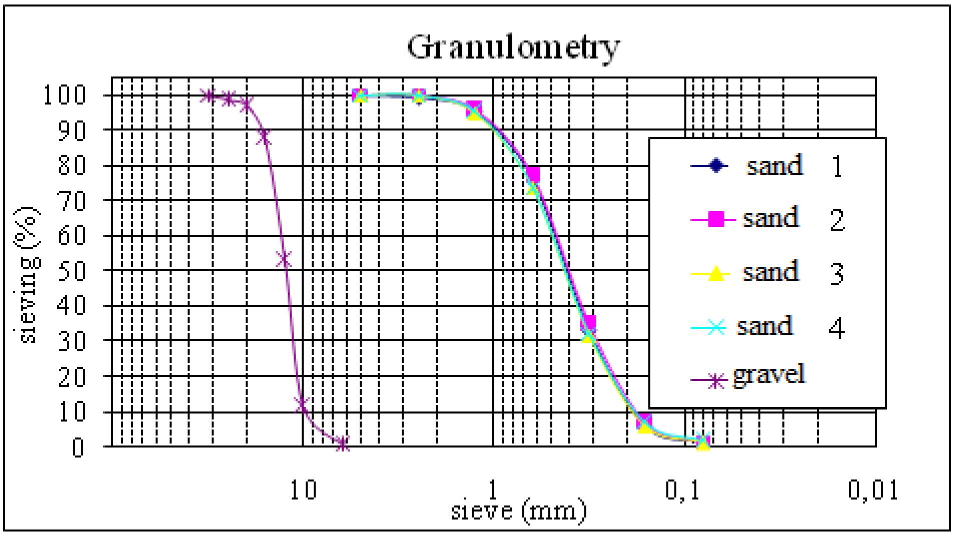

Figure 2: Granulometric analysis curve

From the granulometric analysis curve we can deduce that:
The graduation of size is limited to Cu=1.4
The grains are well distributed Cc=1.02
Permeability 0.18Cm/S
Capillarity 37.36
Gravity 1.66

Plant used

The plant species belongs to the genus *Juncus* of the family Juncaceae, known in the region under the popular name of "SEMMAR" [8-10].

This plant is collected from the typical bed for wastewater treatment (WWG), located under the old palace in Tamassine Touggourt and is aimed to treat wastewater and urban sewage and reuse it for watering. The study has been carried out throughout the whole year from January 2012 until December 2012. During the period of study the physiochemical analyses were conducted in ONA laboratory and in food and water analysis laboratory in Touggourt hospital.

As far as the physicochemical properties of the packaging materials are concerned, the experiments were conducted in the VPRS laboratory at Ouargla University including Weekly physicochemical properties tests at input and output and twice a month (every 15 days) for bacteriological analysis

Physicochemical and bacteriological parameter

- pH was measured with a an ORION pH-meter
- Electrical Conductivity was measured with TACUSSEL conductimeter
- The temperature was measured in situ using multiparameter analyser.
- the total suspended solids (TSS) was measured using the filtration on a paper (GF/C) and dried at 105°C
- COD was measured using potassium dichromate in 50% sulfuric acid solution and heating for two hours in the presence $AgSO_4$ and $HgSO_4$
- BOD_5 was measured using DBO-meter
- NO_2 was measured by *Diazotization* method using colorimeter DR/890
- The orthoposphates were determined by forming a complex porosphomolybdique and measured using a colorimeter
- Total Coliforms, Total Streptococci, E. coli were determined using the culture media

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Purification efficiency

The yield of purification is calculated according to the formula

$$R\ \% = (X_i - X_f)\ x100\ /X_i$$

X_i= concentration of the parameters inside the bed (mg/L)
.X_f= concentration of the parameters at the output of the bed (mg/L)
-The table below shows the values of the measured parameters of the urban wastewater used to feed the beds during the phase of purification

Table 1: physicochemical and bacteriological properties of wastewater.

Parameter	Sample numbers	Minimal Value	Maximal Value	Average Values ± Standard deviation
pH	48	7.31	8.16	7.8 ± 0.22
Electrical Conductivity	48	3.59	9.05	(6.81± 1.50)ms/cn
TSS	48	236	236	(402 .50 ± 135.22)mg/l
COD	48	180	346	(280.58± 56.54) mg/l
BOD_5	48	110	295	(211.17± 59.55) mg/l
No_2	48	0.1	0.58	(0.212±0.146)) mg/l
Po_4^{-3}	48	55.9	23.17	(33.07± 8.83) mg/l
Total Coliforms	24	5700000	450000	(1862500.00± 1577847.35)UFC/100ml
Total streptococcus	24	4600000	140000	(1116666.67± 1012487.81) UFC/100ml
E. Coli	24	760000	12000	(236666.67± 221727.61)UFC/100ml

RESULTS AND DISCUSSIONS

pH measurement

Figure 03 reveals that the average pH value decreases in treated water in different beds compared to the untreated water. Actually the pH is reduced from 7.8 to 6.7 in the planted bed and to 7.3 in the unplanted bed (the witness). These results are similar to those reported by Vincent et al [13]. In fact, the acidity of the medium is caused by the oxidation of nitrites and COD [14], and the CO_2 produced increases the acidity of the medium. Moreover the oxidation of nitrites produces nitrates which in turn increase the acidity.

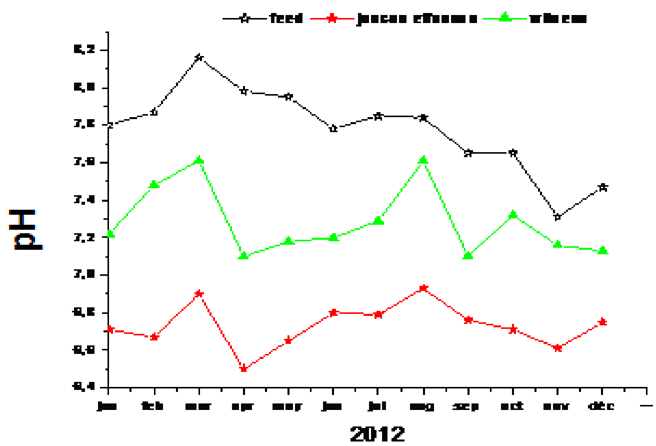

Figure 3: Temporal Evolution of pH at the input and at the output of both planted and unplanted systems

Electrical conductivity

Electrical conductivity of the water after treatment in planted bed is higher than that of the water in the unplanted bed (the witness) and the untreated water (feed) (Figure 04). This difference is found to be further higher during spring and summer. Electrical conductivity is 6.81± 1.50 for the untreated water, and 18.39±7.12, 8.21±0.82 ms/cm in planted and unplanted beds respectively. The statistical analysis shows a big difference in Electrical conductivity between planted and unplanted bed similarly to what was reported by Finlayson and Chick [15] who used the plant Typha to treat the wastewater.

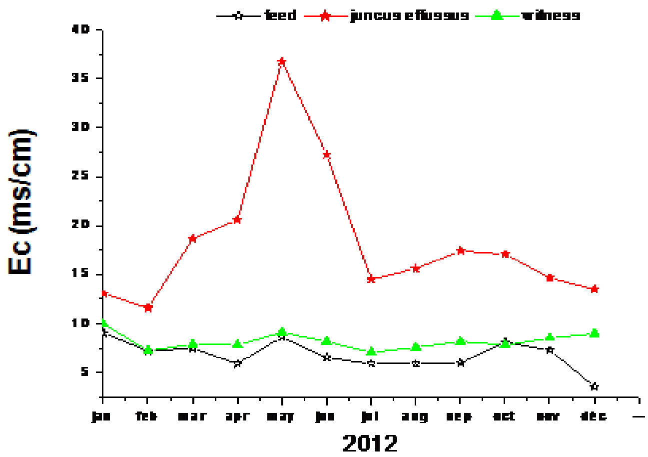

Figure 4: Temporal evolution of the electrical conductivity at the input and output of both planted and unplanted systems.

Total suspended solids (TSS)

The figure 5 shows the evolution of suspended solids between the minimum value of 236 mg /L and the maximum value of 613 mg / L in urban wastewater at a rate of 402.5 ± 135.22. However for the treated water the amount is more or less constant (the rate is 23.84 ± 5.92 mg/L in the planted bed and 27.94 ± 6.41 mg / l in the unplanted bed). The Decrease of the TSS concentration in treated water is due mainly to physical and chemical adsorption on the surface of the plant material. It seems that the water in the planted bed is more turbid than that in the unplanted bed owing to the presence of plant roots and rhizomes. The TSS in the planted bed is found to be 94.41%.

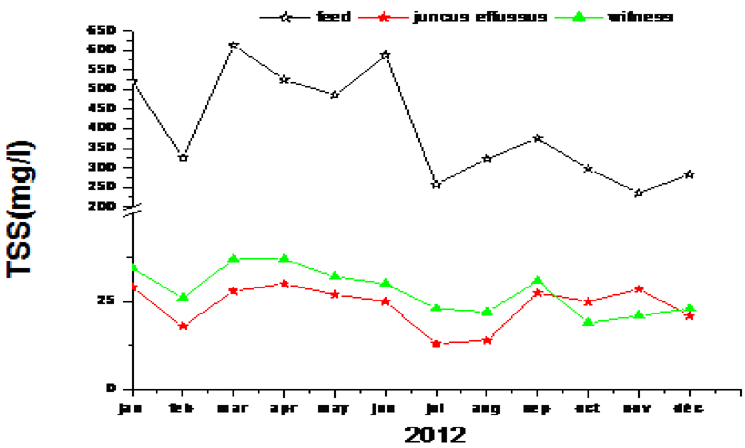

Figure 5: Temporal evolution TSS at the input and output of both planted and unplanted systems.

Chemical oxygen demand: COD

As far as the COD is concerned Figure 6 shows a concentration decrease in the treated water compared to the wastewater where the value in wastewater is 280.58 ± 8.74 mg of O_2/L, however it is 50.33±7.99 and 77.67±8.74 in the planted and unplanted beds respectively.
The removal rate of COD in the planted bed (82.21%) is higher than that in the unplanted bed (76.61%). The result is better than that reported by ABBISSY and MANDI which was 72% [11] . This difference is attributable to the type of the plant used and the quality of wastewater.

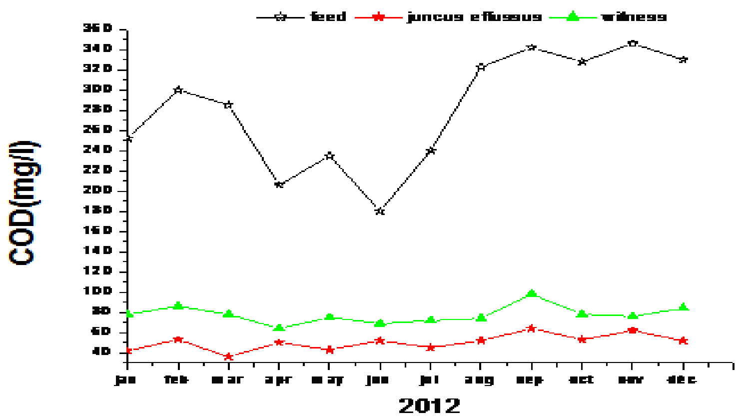

Figure 6: Temporal evolution COD at the input and output of both planted and unplanted systems.

Biochemical oxygen demand: BOD_5

Figure 7 shows the evolution of BOD_5 in the urban wastewater and the treated water in both the planted and unplanted beds. Generally BOD_5 value in urban wastewater is greater than in the treated water. The BOD_5 average value is 211.17 ± 59.55 mg/L in the wastewater but only 31.58 ± 4.96 and 50.42 ± 8.28 in treated water in planted and unplanted beds respectively. The difference between the planted and unplanted basins may be due to the fact that aquatic plants are able to absorb oxygen through leaves and stems which enhances the oxidation of organic matter by bacteria.

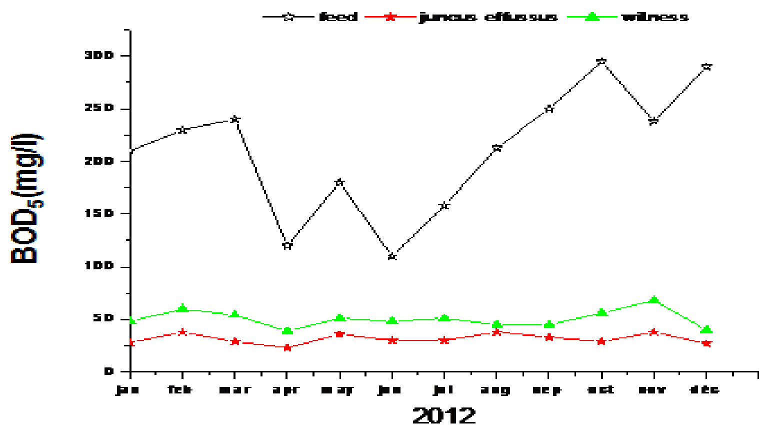

Figure 7: Temporal evolution of BOD_5 at the input and output of both planted and unplanted systems

Figure 8 shows the evolution of NO_2^{--} in the wastewater (feed) compared to the treated water in both planted and unplanted beds. The concentration of nitrite NO_2^{--} in wastewater changes with time and is greater than in both treated waters where its average value is 0.212 ± 0.146 mg /L in wastewater but only 0.037 ± 0.027 and 0.073 ± 0.038) in treated water in planted and unplanted beds respectively.

Therefore the performance of the method in both planted and unplanted beds is 82.32 % and 65.61 %, respectively.

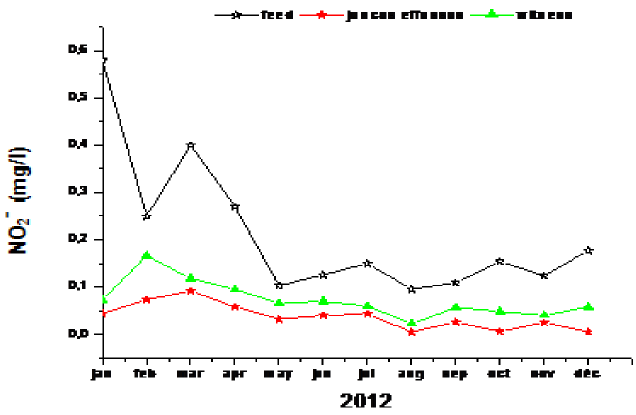

Figure 8: Temporal evolution of NO_2 at the input and the output of both planted and unplanted systems

Orthophosphates PO_4^{3-}

Figure 9 reveals that PO_4^{3-} concentration in wastewater changes with time and is greater than that in the treated water where it is reduced from 34.26 ± 10.59 to 5.86 ± 2.84 in the planted bed and to 11.62 ± 2.75 in the unplanted bed (the witness). The purification yield in the planted bed (83%) is higher than that in the unplanted bed (66.08 %). This value is higher than that reported by [16] using the plant *Panicum maximum.*

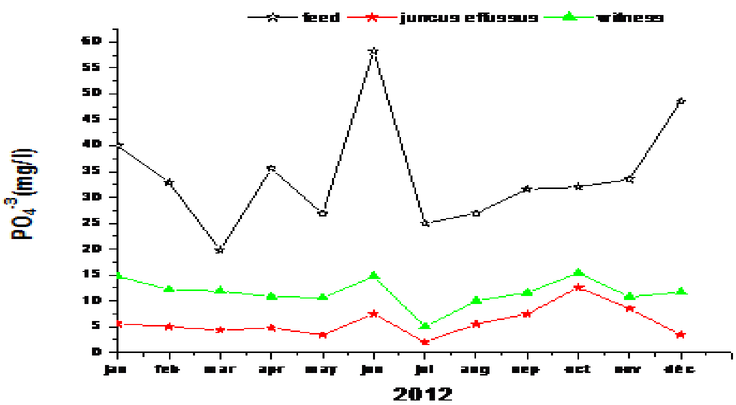

Figure 9: Temporal evolution of PO_4^{3-} at the input and the output of both planted and unplanted systems

Bacteria removal

Total *Coliforms*

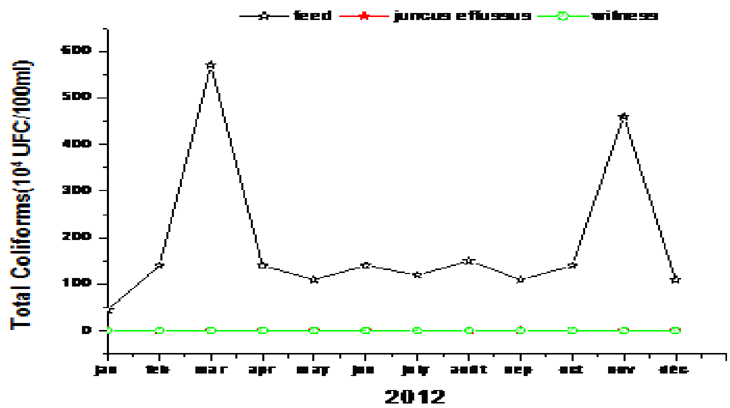

Figure 10: Temporal evolution of total coliforms at the input and the output of both planted and unplanted systems

Figure 10 shows the number of colonies in the wastewater and the treated waters. In general the number of colonies of total Coliforms in wastewater is greater than that in the treated water in both planted and unplanted basins at a rate of 1862500.00 ± 1577847.35 UFC/100mL in wastewater and a rate of 3816,67 ± 2162,42) UFC / 100ml and 35500,00 ± 27972,39 in treated water in planted and unplanted basins respectively. The purification yield in both basins is 99.97% and 90.09% respectively.

Total *Streptococcus*

Figure 11 shows the number of colonies of total *streptococcus* in the wastewater and the treated waters. The number of colonies is about 1116666.67±1312487.8 UFC/100mL in wastewater and 1358.33±932.70 UFC / 100mL and 40916.67±29181.12 UFC / 100mL in treated water in planted and unplanted basins respectively. The purification yield in both basins is 99.90% and 96% respectively.

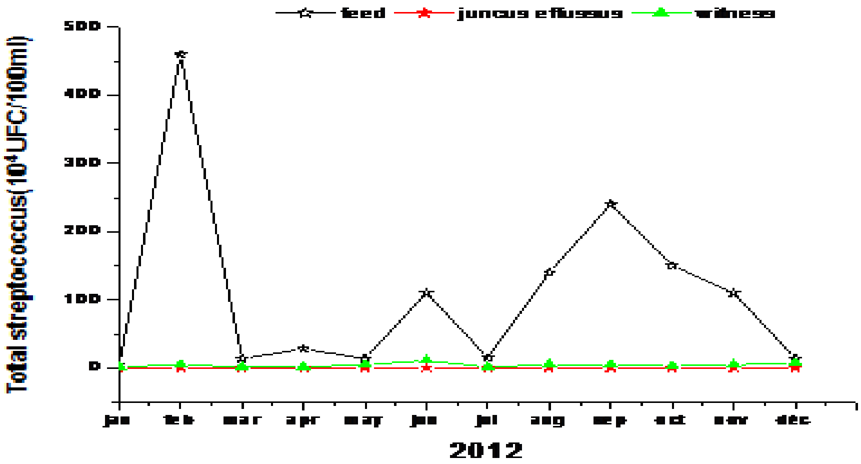

Figure 11: Temporal evolution of total *streptococcus* at the input and the output of both planted and unplanted. systems

E coli

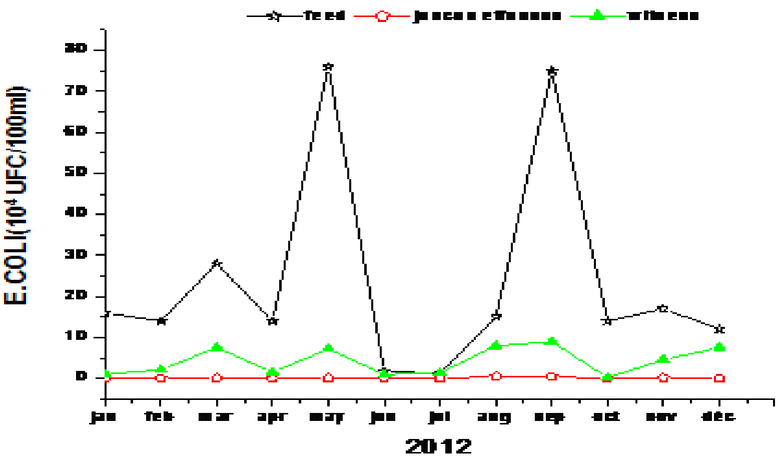

Figure 12: Temporal evolution of total en E. coli at the input and the output of both planted and unplanted systems

Figure 12 shows the number of E. coli colonies in the wastewater and the treated water. In general the number of E. coli colonies in the wastewater is greater than the number of colonies in the treated water in both planted and unplanted basins. The number of colonies is 236666.67 ± 251727.61 UFC/100 mL in wastewater and 1395.83 ± 1721.98UEC/100ml and 42583.33 ± 33543.61 UFC/100 mL in planted and unplanted basins respectively. Removal yield of E. coli in treated water in the planted and unplanted basins is 99.41 % and 82 %, respectively. There is a considerable decrease in bacteria in the treated water reaching up to 99% and this can be explained by the natural death of the bacteria as a result of change in the living medium or smash of organic materials. Moreover the difference in the removal rate of bacteria between the planted and unplanted basins is due to the fact that plant roots secrete acids (toxic biologically) which contribute to the killing of bacteria as was interpreted by VINCENT et al [13].

CONCLUSION

Today phyto-purification 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* Bathroom of subsurface horizontal flow to cleanse wastewater (sewage) using a widespread plant. 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. Moreover 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.

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