Wastewater Treatment by Using *Schoenoplectuslitoralis*
معالجة مياه الصرف الصحي باستخدام نبات الجولان *Schoenoplectuslitoralis*

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Abstract

The present study examined the use of phytoremediation on initially treated wastewater,which was collected from the primary sedimentation of Hammdan wastewater treatment plant (WWTP) in Basrah – Iraq. The application of free water surface system (FWS) using *Schoenoplectuslitoralis* for six weeks.As demonstrated results of the experiment the efficiency of *S. litoralis* in this system and its effective role through the reduction of the main pollution indicators (salinity, TDS, TSS, BOD_5, COD, total alkalinity, chlorides, sulfates, reactive nitrates and reactive phosphate) at the percentages of (54.26%), (51.85%), (97.51%), (95.2%), (88.96%), (73.87%), (60.45%), (39.56%), (85.28%), (87.5%), respectively. The efficiency of this plant to remove the actual concentrations of trace elements (copper, iron, lead and zinc) were at (2.66, 2.91, 1.11, 7.16) µg / l, respectively. The plant also possessed at capability in reducing the rate of the total number of bacteria, from 682.33 bacteria/ml before the treatment to 56.33 bacteria / ml after treatment.

Keywords: Phytoremediation, free water surface system (FWS), Wastewater, *Schoenoplectuslitoralis*.

Introduction

Pollution in general leads to a change in many of the physical, chemical and biological characteristics of rivers and streams due to the continuous discharge of wastewater in large quantities and inefficient processing units (Rashid *et al*., 2004). Wastewater resulting from household waste, hospital wastewater and waste of commercial facilities is one the most important sources of the most common water pollution (Al-Enazi, 2016).

Therefore, the use of biological treatment has become very important, because it aims to use a vital system to remove pollutants (organic, inorganic substances and heavy metals) from wastewater, and this system is low cost and works to reduce the nutrients and pathogens significantly like the best modern methods (Priya*et al*., 2012 ; Manal*et al*., 2014). A phytoremediation is a form of bioremediation that means the use of certain plants that have the ability to reduce pollution levels through plant metabolic mechanisms leading to the removal, or analysis of various pollutants (AL- Sanjari, 2011; Ojuederie, 2017). These plants play the role of biofilters, which drag and absorb the mineral, toxic and suspended organic matter, absorb it, precipitate it to the bottom, and allow the bacteria to turn them into products of inorganic represent the role of nutrients to plants (Zerov, 1979). The use of aquatic plants for the purification and improvement of water quality is one of the best methods to enrich mechanical or chemical plants for their high efficiency in removing or reducing most types of pollutants (Vymazal, 2005). Hammer (1989) emphasized that aquatic plants treat wastewater efficiently, and relatively cheap when compared to conventional treatment systems approved.One of the most important applications of phytoremediation, is the use of the free water surface (FWS), this one of the systems of constructed wetlands (CW). This system is ergonomically designed for the passage of initially treated wastewater in the treatment plants.While the growth medium consists of gravel, sand and soil to help plants grow. The medium of sand and gravel was used for the first time at the end of the year 1980,and a size of 10 - 20 mm, which works to reduce the concentration of pollutants in wastewater significantly (Vymazal and Kröpfelová, 2008).

The *S. litoralis*is considered one of the most important aquatic plants in preserving the biological balance in its environment and contributing to the regulation of nutrients in the environment. The *S. litoralis*is spread widely in rivers and marshes, which includes 77 species that spread in different parts of the world and has enormous productivity (Smith, 2002).It is located at the edges of the temporary marshes and is the dominant plant when the water is shallow depth of no more than 1.5 - 2 meters (Shu, 2010). The *S. litoralis* has been widely used in the constructed wetlands (CW) for the treatment of wastewater all over the world(Tanner, 2001).also explained Vohla *et al*. (2005) The *S. litoralis*has a significant role to absorb and remove more than 90% of the nutrients and organic matter from wastewater.

Materials and methods

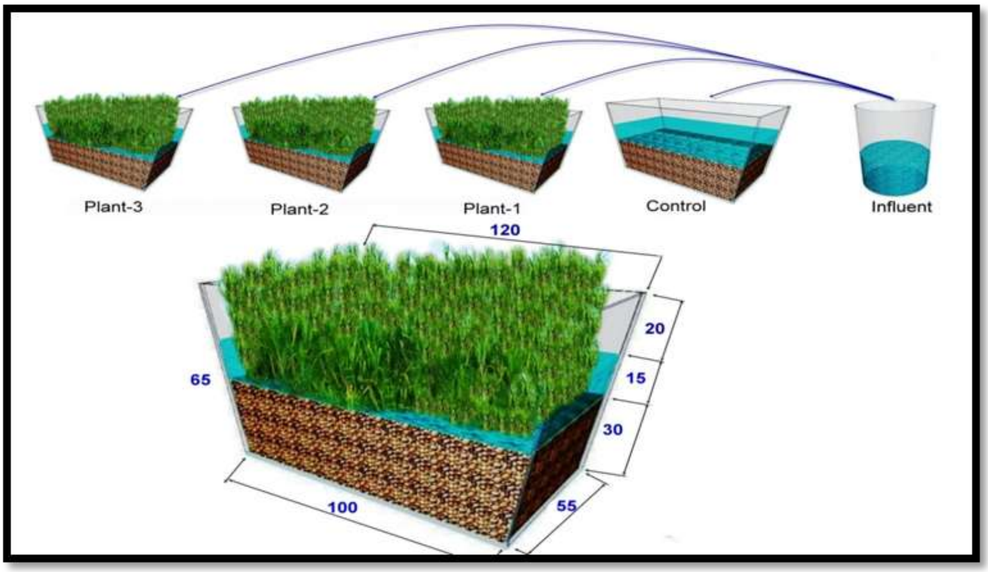
Samples Collection

Schoenoplectuslitoralis (Schrader) Palla, Bot. Jahrb. Syst. was collected from the south of Sindbad Island on the banks of the Shatt al-Arab (image 1).Samples were kept in plastic bags after cleaning with river water.

Image (1) *Schenoplectuslitoralis* collection site in south of Sindbad Island

Description system free water surface (FWS):

Schenoplectuslitoralis was cultured, The plant numbers were 20 plants per basin and their lengths were between 0.5 - 1.5 m. Figure (1) shows a diagram of the treatment basins made of fiberglass,rectangular 120 cm from the top, length 100 cm at the base, width 55 cm and height 65 cm, the difference between the base and the top basin 20 cm (Vymazal**,** 2001).A layer of gravel and sand was placed at the bottom of the basins at a height of 30 cm, At the bottom were large stones 10 cm deep and 1 - 2 cm in size, the second layer with a depth of 10 cm consisting of stones of size between (1 - 0.5) cm and the third layer was 10 cm deep with the same characteristics as the second layer but mixed with agricultural sand (1: 3) gravel: sand.The different gravel sizes are very important in the treatment because the gravel and sand layers are very hard, the pollutants in the water will leak out very quickly to be treated by aquatic plants(Manal*et al*., 2014). Added a volume of 120 liters of wastewater from the primary sedimentation of Hammdan wastewater treatment plant (WWTP) in Basrahto the three plant basins after the adaptation of these plants for 15 days, the environmental characteristics of the basins were measured every seven days.



Figure(1): scheme for the system phytoremediation

(the drawing program 3Dmax)

Physical, chemical and biological tests of water samples were conducted using traditional methods as established by the American public health association (APHA, 2005). Measurement of BOD_5 using TS 606 (WTW) It consists of (Incubator with OxiTop®). Measurement of chemical oxygen demand using photometer COD Vario type PCH 53529

(Aqualytic) Using the Kits. This study was used to analyze of variance (ANOVA), least significancedifference (LSD), standard deviation and correlation coefficient to find the significant among the parameters by statistical package for social science (SPSS-17) (Al-Rawi and Khalaf Allah, 2000).

Results and Discussion

Constructed Wetland System (CWS) is used for initial treatment (in removing suspended materials), Secondary (removal of organic and nutritious materials) and tertiary (rehabilitation of the region and give it aesthetic), for the purpose of disposal of various waste products for domestic, agricultural and industrial which they are considered physical, chemical and biological treatments (Mthembu*et al*., 2013). Table (1) shows percentage rates of reduction in the studied factors by *S. litoralis*in phytoremediation within six weeks.

Table (1):percentage rates of reduction in the studied factors by *S. litoralis*

Date	Salinity %	TDS %	TSS %	BOD %	COD %	Alkaloids %	Cl %	SO_4 %	No_3 %	Po_4 %
First week	0	0	0	0	0	0	0	0	0	0
second week	1.03	1.68-	59.68	35.80	30.34	9.19	7.59-	3.37	24.19	17.5
Third week	13.95	9.22	79.93	57.60	50.61	27.26	8.59	15.20	40.30	41.75
fourth week	25.84	21.26	88.28	80.80	67.84	41.45	32.42	22.90	55.89	55.75
Fifth week	40.57	33.28	94.14	89.00	86.05	58.23	46.49	29.74	70.51	70.75
Sixth week	54.26	51.85	97.51	95.20	88.96	73.87	60.45	39.56	85.28	87.5

The results of the present study, as shown in Fig.(2), showed that the plant selected for phytoremediation using application of free water surface system (FWS) reduced the salinity of initially treated wastewater in basins during the study period, this is due to the fact that this plant is able to drag many positive and negative ions, including sodium and chloride from water as important elements in metabolic processes (Liphschitz and Waisel, 1982).The results of the study show that the *S. litoralis*did not reduce the salinity rates during the first week of treatment, this indicates that the *S. litoralis* has the ability to adapt to different concentrations of salinity, this is consistent with Rout and Shaw (2001), about the high ability of this plant to tolerate high concentrations of salinity.

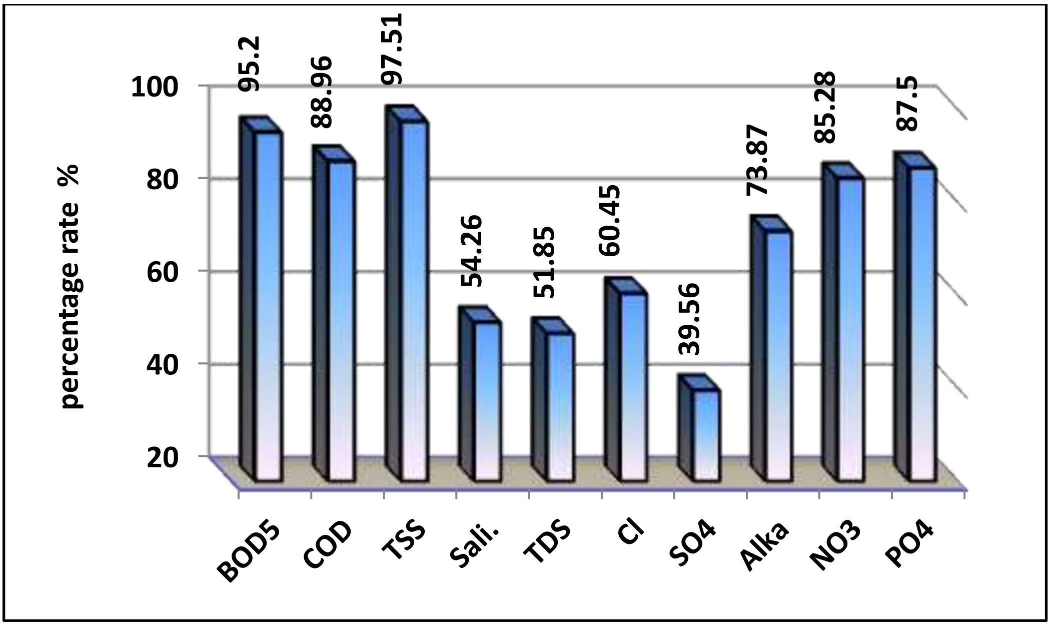


Figure (2): Percentage of the efficiency of the *S. litoralis* in the reductionpollutant rates during six weeks

The present study shows that the *S. litoralis*has reduced concentrations of total dissolved solids (TDS)to (51.85 %), because this plant needs some elements of dissolved salts as essential elements of its growth and reproduction such as calcium, magnesium, sodium, potassium, carbonates, bicarbonates, sulphates and chlorides (Abawi, 2009). During the first week of treatment it was found that total dissolved solids were not removed but the removal process became more successful as time progressed, because the *S. litoralis* needed a period of adaptation before the process of treatment and removal of dissolved solids.

The plant used in the present study using free water surface (FWS)has been very successful in removing the total suspended solids (TSS) of wastewater and with high efficiency by removing the total suspended solids during the first week, because the *S. litoralis* plant works as biofiltersby attracting the suspended material and dissolved in water and absorb it, and push it to the bottom of precipitation, then the water becomes clear and transparent. The aquatic plants are characterized by their ability to filter particles through adhesion at the upper surface of the plant (IWA, 2000), and deposition of suspended solids and making them stagnant in the lower layer (Kadlec and Knight, 1996). In addition, filtration and precipitation processes play a significant role in the removal of organic matter, nutrients and pathogens (Kadlec, 1999).

The process of reducing biological oxygen demand (BOD_5)was very highthrough what is shown by the results of the efficiency *S. litoralis* the process has been very high since the first week of treatment,because the biological oxygen demand (BOD_5) is one of the most important signs to determine the degree of water pollution in organic matter, this significant decrease indicates the aerobic decomposition of the organic matter, this confirms theself-purification process in the plant treatment basins. The rhizoremediation process of aquatic plants plays an important role by providing oxygen around the root region and provide aerobic conditions in the rhizosphere, and then to encourage the existing bacteria to remove organic pollutants in wastewater by physical and biological processes, including sedimentation and microbial decomposition (Rajkumar*et al*., 2009).*S. litoralis* has been a major role in removing or stabilizing organic pollutants by phytostabilization (Hardej and Ozimek, 2002). This corresponds with the high efficiency of the plant *S. litoralis* used in this system during the present study of the removal of organic matter as a result of a decrease biological oxygen demand (BOD_5) of wastewater values, It recorded the highest rate of decline in the treatment basins 95.2%, the high efficiency of the decline in organic matter is due to the fact that organic matter in this system is more susceptible to biodegradation when aquatic plants provide conditions for oxidation (Molle*et al*., 2005).

The results of the present study indicate that the highest rate of decrease in the chemical oxygen demand (COD) was 88.96%.Vohla *et al*. (2005) found *Schenoplectus sp*. plant it has a significant role in absorbing and removing more than 90% of the nutrients and organic matter from wastewater using phytoremediation systems as these systems provide a good environment for the growth of bacteria, which in turn destroy these pollutants.The low chemical oxygen demand has been shown to be effective since the first week of treatment,this large removal indicates the high capacity of the *S. litoralis* plant in terms of its ability to oxidize the amount of organic matter present.

Results in the present study showed a decrease of the alkaloid, reaching the highest rate of decline (73.87%), the removal efficiency of the alkaloid has begun in the second week, there is a strong relationship between the concentration of bicarbonate and the growth of aquatic plants, because bicarbonates directly affect photosynthesis, growth and long-term survival of aquatic plants (Vestergaard and Sand-Jensen, 2000). Explained Vadstrup and Madsen (1995)Carbon monoxide, such as bicarbonate and carbon dioxide, are one of the most important factors in the productivity and distribution of aquatic plants on the water surface, and the reduction of the values of bicarbonates by aquatic plants as well as through their orderly work in the environment (Marschner, 1995).

The present study recorded success in the low chlorides values during six weeks of treatment time, the values in the basins decreased by 60.45%. The highest efficiency of the reduction of chlorides begun in the third week because the need for plants to chloride is low concentration, and its fundamental importance as a key factor for an oxidation process during the process of photosynthesis and the release of oxygen, and it is one of the elements that plants need to grow and to maintain the ionic balance within the cell (Harrington *et al.*, 2001).

The results of the present study confirmed that *S. litoralis* has the ability to reduce the sulfate in the water was achieved by removing 39.56% in the treated water within six weeks.The efficiency of the plant to remove sulfates began in the middle of processing time because sulfur is different from other toxic pollutants, It is one of the necessary elements of the plant in natural concentrations, but its increase causes burns in plant leaves (Al-Tamimi, 1994). The removal of sulfates from wastewater by the study plant as an essential nutrient that plants need for growth and the formation of a part of the amino acids and protein,because sulfates play an important role in controlling cellular processes and in the production of chlorophyll (Dravidian and Kopriva, 2010).

Nitrates are pollutants to the environment, although they are essential nutrients for the plant, it absorbed by the plant and involved in the construction of protoplasm of plant cells because it is the most oxidizing state of nitrogen which is the most stable (Moustafa, 2002). The *S. litoralis* plant has high efficiency of reduced nitrates, due to the fact that these plants provide high conditions for reduced nitrates and intensive growth of important microorganisms in the conversion of nitrogen to nitrate or by a direct introduction by the plant (Senzia*et al*., 2003). The efficiency of nitrate removal has been very clear since the first week, confirming that the free water surface system (FWS) is highly efficient in treating contaminated water, because aquatic plants are one of the important ways to treat high concentrations of nutrients and reduce the high proportion of nitrates and this gives the characteristics of plants ideal for use of nutrients in wetland systems, which produces rapid growth rates, thus giving high purity of treated water (Mthembu*et al*., 2013).

The water treatment system used in the present study showed the highest percentage of phosphate decrease, which the highest removal rate of 87.5%. This is due to the fact that this system provides good conditions for the processes of absorption, adsorption and precipitation, or by taking the plant directly to phosphates or storing it in plant tissues (Xu*et al*., 2006). The present study confirmed that *S. litoralis* had the ability to remove phosphate and the removal efficiency was at the second week, this is due to the fact that these plants, although they have high productivity and large mass but take certain percentages of phosphate, This is consistent with Greenway (2003), we observed a decrease in the values of phosphate concentrations of plants using in the constructed wetland as having large biomass and the ability to store abundant amounts of nutrients inside their bodies.

The results in Table (2) show the effect of plant treatment using *S. litoralis* on the concentrations of trace elements in water, concentrations of copper, iron, lead and phosphorus elements in the initially treated wastewater in the basins were 5.73, 7.18, 4.31, 13.76 mg / L respectively, after processing 0.72, 1.09, 1.87, 2.79 mg / L, respectively.

Table (2) Concentrations of dissolved trace elements in wastewater

(mg / L) before and after byusing *S. litoralis*

Elements	Pre-treatment	Control	After treatment	Control	The actual efficiency of the plant
Cu	0.06 ± 5.73	5.51	0.05 ± 0.72	3.16	**2.66**
Fe	0.07 ± 7.18	7.48	0.1 ± 1.09	4.30	**2.91**
Pb	0.07 ± 4.31	4.37	0.09 ± 1.87	3.04	**1.11**
Zn	± 13.76 0.07	14.03	0.03 ± 2.79	10.22	**7.16**

The trace element values (Cu, Fe, Pb, Zn) showed a significant decrease at the end of treatment. This difference is due to the ability of the *S. litoralis* to reduce these elements from the initially treated wastewater.Where there are different mechanisms for withdrawing these elements from contaminated water using aquatic plants (Favas and Pratas, 2007).The most likely mechanism is phytoextraction by roots, through which the elements are absorbed by the enzymatic action and then phytostabilization (Lasat, 2002). The roots and root buds of plants filter and the concentration of compounds in wastewater by a rhizofiltration process, particularly mineral elements, the roots remove these minerals from the water through the secretions of broken enzymes of organic acids and thus decompose organic pollutants as well as toxic pollutants (Chaudhry*et al*., 2005).

Table (3) shows the average total number of bacteria (bacteria / ml) before and after treatment by*S. litoralis*in the initially treated wastewater. The total number of bacteria before treatment was 682.33 b / ml and became 56.33 b / ml when treated.

Table (3) rates of total number of bacteria (bacteria / ml) before and after phytoremediation

Treatment plant	*S. litoralis*
Pre-treatment	27.54 ± 682.33
After treatment	6.51 ± 56.33

The rate of the total number of bacteria at the beginning of treatment of wastewater was significant, the reason for the inefficiency of Hammdanwastewater treatment plant (WWTP) in reducing those numbers, while this number decreased after phytoremediation, this is due to the fact that the existing bacteria decompose the organic matter and at the end of the treatment it was observed that the total number of bacteria decreased due to the low concentration and disappearance of nutrients.These bacteria are able to adaptation with large quantities of organic matter, which at first seems indestructible, but over time the ability of bacteria to break down these organic matters increased as their numbers multiplied (Hayek, 1990).The decrease in the total number of bacteria is associated with a decrease in the biological oxygen demand (BOD_5), which confirms the success of the process of self-purification in phytoremediation. Many recent research has confirmed over the past years the ability and effectiveness of constructed wetland systems to remove or reduce pathogenic from wastewater (Karim*et al*., 2004).

We conclude from the present study that the biological treatment using the *S. litoralis* worked to get rid of the bulk of the organic pollutants in the wastewater and does not require the use of any mechanical equipment and the low cost of implementation, as well as the lowest rates in the use of electric power, it is considered one of the technologies environmentally friendly and less expensive between the known treatment technologies. The study also recommends the application of the free water surface (FWS) in large areas of untapped land, because of the efficiency of the system to remove the high organic content and because it is economical and appropriate to Iraq's climate conditions (hot and dry).

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