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PERFORMANCE OF VERTICAL FLOW CONSTRUCTED WETLAND FOR SEWAGE TREATMENT USING DIFFERENT AQUATIC PLANTS IN THE SOUTH OF IRAQ

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Abstract

The use of natural wetlands for wastewater treatment not only decreases economic costs and energy usage but also decreases pollution. The vertical flow of constructed wetlands offers a more oxygenated ecosystem and greatly decreases both microbial wastewater types and organic matter. In this research, vertical flow constructed wetlands were constructed and separated into twin adjacent beds (I & II), each planting with aquatic plants as *Aquatic Canna* was planted (Cell I) while (Cell II) was planted with *Cyperus Alternifolius* to improve the water quality of pre-treated by sedimentation tank installed before wetland. In the current study, the removal pattern is examined and is correlated to plant sorts. The purpose of this study is to compare the efficiency of *Aquatic Canna* and *Cyperus Alternifolius* in the treatment of domestic wastewater by vertical flow constructed wetland. *Aquatic Canna*'s fibrous rooting system created high aerobic conditions in the treatment bed, which in turn encouraged greater removal compared to wetland cell planting by *Cyperus Alternifolius*. According to the monitoring study about four months, pollutants concentration based on average efficiencies of removal for the *Canna* cell and *Cyperus* cell were as follows: COD (72.41% and 67.24%), NH_4 -N (48.14% and 40.74%), TN (50.90% and 41.81%), TP (44.87% and 39.74%) and TSS (72.73% and 81.82%). In general, the treatment performance of the cell planted with *Canna* was better than that planted with *Cyperus*.

Keywords: Domestic wastewater, Vertical Flow Constructed Wetland (VFCW), *Aquatic Canna*, *Cyperus Alternifolius* .

1. Introduction

Constructed wetlands have proved to be high-efficiency wastewater treatment systems. It is a cheap cost technology capable of effectively treating domestic and industrial wastewater. Although the treatment of animal waste is fairly modern technology and properly managed and controlled, it can prove useful in removing nutrient concentration [1]. The efficiency of wetland systems is very well to efficiently minimize TSS, BOD, and fecal coliform. Most wetland systems treat nitrogen ammonia and Total Nitrogen and Phosphorus with less removal efficiency [2].

Vertical Flow Constructed Wetlands (VFCWs) are much uniformly in the distribution of root and water-root connected and have limited strong odor and insect-proliferation issues because they have no free water surface [3]. While VFCWs have been utilised to decrease the total suspended solids, chemical oxygen demand, and coliform bacteria, there is increasing interesting in their utilise to remove nitrogen and phosphorus. The degradation of microbial is an important factor for the nitrification and denitrification process in constructed wetlands, where aerobic and anaerobic conditions are generated, while phosphorus adsorption to the substrate is a significant Phosphorous degradation process [4].

At a conventional municipal wastewater treatment plant, the wetland system of an experimental vertical flow has been developed to manipulate the loading rate as desired and several tests were conducted to evaluate vertical flow beds treatment efficiency [5]. The research indicates that the ability of VFCWs to decrease BOD_5 and nitrification is so substantial and that the system's demand for the area was measured. VFCWs have been reported to be highly efficient in reducing TSS and BOD_5, and they already nitrify even during cold winters at high loading rates [6]. Phosphorus removal is very limited in VFCWs and a media of sand bed that has a highly effective capacity for link phosphorus to an extended amount of time cannot be obtained [7].

The existence and function of plants in the treatment of various types of wastewater are clearly until now [8]. This increases the microbe growth region, which creates up to 90% biofilm and transports oxygen inside the system [9]. There is a shortage of comparative comprehensive evaluation of the effectiveness of wetlands, planted with different sorts of the plant while utilising for advanced treatment. Numerous studies have revealed that differences in the efficiency of nutrient removal are due to various wetland plants. The concept that appropriates plant species are selected to utilise in constructed wetlands systems relies on the sort of nature of the wetland. Generally, plant selection is an important factor for the wastewater treatment system in a constructed wetland. In the small wetlands, ornamental plants for instance *Canna* and *Heliconia* are used to enhance their aesthetic in the tropical regions. In the wetland system, both species have well grown, and Canna is growing at a higher rate than *Heliconia* [10]. *Canna* is a wetland plant widely used in P. R. China and other nations as it has a very fast rate of growth, big biomass, and nice growth with a large ability to remove nutrients [11]. *Canna*, defined as a plant for phytoremediationv [12], had a growing root system with better root growth, the maximum number of the root, higher root biomass, and much further larger area of root than other types of plants.

To our information, a few studies are essential for the use of VFCWs for post-treatment technologies. The palm umbrella or *Cyperus Alternifolius* is another aquatic fenny used in wetlands. This plant has big, thin, and green leaves, growing in good condition for up to one meter. It is well-known and is increasing rapidly. This type of plant can be utilised for wastewater treatment in the system of wetland [13].

The purpose of the current research objective to investigate the capability of two types of local plants in a small constructed wetland in Basra city for domestic wastewater treatment and specified the impact on water quality from these treatments by different aquatic plants.

2. Materials and Methodologies

2.1. Experimental setup

Our constructed wetland is a VFCW was 2m wide, 4m in length, and 0.5m depth is lined with a 30 mm PVC liner to eliminate seepage into the soil. This constructed wetland was prepared at Basra city in Iraq. Based on Fig. 1, it consists of two lateral wetland bed cells (4 m long and 1 m width). Each wetland cell area is divided into S-shaped gallery; the slope of the gallery (corridor) bottom is 1% along the flow direction. The depth of this constructed wetland is 0.5m as mentioned before is the same for two cells was consists of three layers of different size gravel filled (from bottom to top) the first layer is 0.15m consisted of coarse gravel size (15-20) mm, the second layer of 0.15m consists of median gravel size (8-15) mm, and third layer 0.15m also consists of fine gravel size (5-8) mm and the remain 0.05m is freeboard. Where the two cells in the constructed wetland are planted with the species of locally available plants, the first cell bed (I) was planted with the *Aquatic Canna* plant while the second cell bed (II) was planted with *Cyperus Alternifolius.*

The raw domestic wastewater was pumped once a day from the nearby manhole to the primary tank of sediment (2 m³) using a pump that is submersible. The wastewater collected for primary treatment in this tank was diverted via perforated PVC pipes to the wetland cells. Sampling was done after one month of beginning wetland operation with a hydraulic retention time was 24 hours on average.

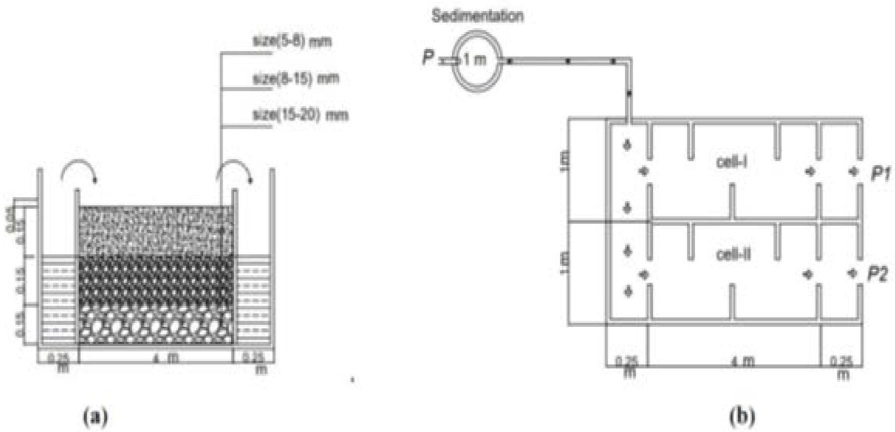

Fig. 1. (a) CW Cross-section and (b) Experimental layout.

2.2. Plantation of the constructed wetland cells

In this study, were chosen two experimental local plant growths in Basrah city, its *Cyperus Alternifolius* (Fig. 2) and *Aquatic Canna* (Fig. 3) as wetland plants used in this experiment. As shown below brief details explain several features of these plants.

Fig. 2. ***Cyperus Alternifolius*****.**

Fig. 3. ***Aquatic Canna*****.**

2.3. Water quality monitoring studies and analytical methods

Samples were collected (3 times per week) from the influent point (*P*) and another two samples of effluent at (P_1) and (P_2) from constructed wetland as shown in Fig. 1 and transported in polyethylene bottles to the laboratory and analysed within 24 hours of collection. The following water quality parameters were measured: biochemical oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN), total phosphorus (TP), ammonia-nitrogen (NH_4-N), and total suspended solid (TSS) according to the standard methods for the examination of water and wastewater [14].

2.3.1. Physical test method

The study period was about four months; from February to June the ambient temperature during this period is between 25 to 40 C° and pH is about (5.5-7). The analytical physical techniques determination methods used in this combined experiment and the frequency tests for the first test are Temperature which tests by mercury thermometer two times per day and flow rate which tests irregularly by stopwatch and volumetric cylinder.

2.3.2. Chemical test method

In this research, the analytical techniques used were implemented following to the methods mentioned in standard methods for the examination of water and wastewater [14], the book provides a standard method, analysis of the specific items.

3. Properties of the Domestic Wastewater usage in this Research

The properties of the raw domestic wastewater treated in the constructed wetland were illustrated in Table 1.

Table 1. Properties of the normal domestic wastewater.

Sewage	Coefficients (mg/l)					
	BOD_5	COD	TSS	TP	NH_4-N	TN
Average Domestic Sewage Values	200	410	272	7	25.0	60
Raw Sewage (This Study)	220	290	110	7.8	27	55

Since the raw domestic sewage was retained for (two to three) hours in the tank of sediment, without any anaerobic circumstances being created, sewage is added to the wetland cells. Theoretically, as predicted concentration levels of TSS have decreased almost by 50% after primary treatment, and BOD5 and COD concentration levels were reduced by about 10% and 25%, respectively. The little amounts raised the TP concentration values of the primary treated wastewater. The transition from long-chained polyphosphates to short-chained phosphates through the sedimentation process can explain this rise. The ammonium-nitrogen and total nitrogen concentration levels were not substantially increase in aerobic conditions in the sedimentation tank.

4. Discussion of the results

The quality of sewage from the different daily uses of people who live in a cluster of homes fluctuates in the town of Abu Al-Khasib in Basra, southern Iraq, and is greatly affected by climate change by seasons of the year, for instance, varies with the utilities of water for different life activities in summer and winter, and for cleaning purposes, detergents have been utilize in large quantities and created more sewage wastewater compared to the summer period. In turn, this resulted in high increases especially in the concentration values of NH_4-N, TN, and TP. Also, the rise in the number of organic contaminants and detergent carbons has affected COD influent concentrations. Values of COD influent then showed parallel variations in suspended solids and phosphorus concentrations. Table 2 shows the average concentration of parameters of influent and effluent, such as COD, TSS, TP, NH_4-N, and TN in the constructed wetland.

Table 2. Average influent and effluent concentration coefficients from wetland cells planted with *Aquatic Canna* and *Cyperus Alternifolius*.

Coefficients (mg/l)	Average Influent	Average effluent in *Aquatic Canna*	Average effluent in *Cyperus Alternifolius*
COD	290	80	95
TSS	110	30	20
NH_4-N	27	14	16
TN	55	27	32
TP	7.8	4.3	4.7

4.1. TSS removal

The concentrations effluent for Total Suspended Solids (TSS) of the *Aquatic Canna* and *Cyperus Alternifolius* of cells constructed wetland Table 2 varied between 30 mg/l and 20 mg/l respectively. Through constructed wetland cells start-up phase, although effluent of (TSS) concentrations were very little (<12 mg/l); TSS effluent values increased as time passed. The clogged up of the voids in the cells of the wetland, weather changes, and intensive rains could explain by IWA report [4]. As explained by Börner et al. [15], the solids in the effluent of the wetland are components of the non-trapped influential solids in the mineralization process, the excess sludge, and plant matter solids. A one-year-old constructed wetland planting by emerging plants and having a dense root system will improve the efficiency of the TSS decrease via giving a bigger area on the surface, decreasing velocity of water, and improving root network sedimentation and filtration [8].

Since the constructed wetlands have been operated for about four months, the observed average TSS removal efficiencies were 72.73% and 81.82% for *Aquatic Canna and Cyperus Alternifolius* respectively (Fig. 4) the sedimentation, filtration, bacterial decomposition, and wetland media adsorption processes can mostly be related [16] and the density of plant roots in the second cell is greater than the plant in the first cell, which has a major role in depositing suspended materials in a greater amount. The deposition of tied up suspended solids will block the wetland refine over time and decrease the hydraulic conductivity of the substratum media, resulting in a surface overflow [17]. The treatment performances of both aquatic plants in constructed wetlands demonstrated like to the TSS concentrations with differently constructed wetlands [18].

4.2. COD removal

The average influential concentration of COD in all treatment cells bed (one and two) was 290 mg/l and the effluent concentration in the WHO standard was 120-150 mg/l: ranges from 80-95 mg/l, based on the presence of different components in the various cells of constructed wetland. The concentration of COD of effluents was also affected by influent concentrations, precipitation, and seasonal variations relative to TSS concentrations of effluents. The average COD removal efficiency was 72.41% and 67.24 % respectively for cell (I) *Aquatic Canna* and cell (II) *Cyperus Alternifolius*, Fig 4. COD that is removed in wetland environments was assisted by aerobic and anaerobic microorganisms that are heterotrophic [3]. Oxygen diffusion and convection are influenced by the COD load of the wastewater added to the cells of wetland, design of wetland cells, operating cases, and type of food [18]. Oxygen released from the plant roots to the rhizosphere is another significant parameter that affects the removal of COD. Compared to biological degradation, the absorption of organic matter by plants is insignificant [19]. Besides, Zhang et al. [20] indicate a significant reason for COD removal as a result of the combined aerobic and anaerobic organic carbon degradation effect.

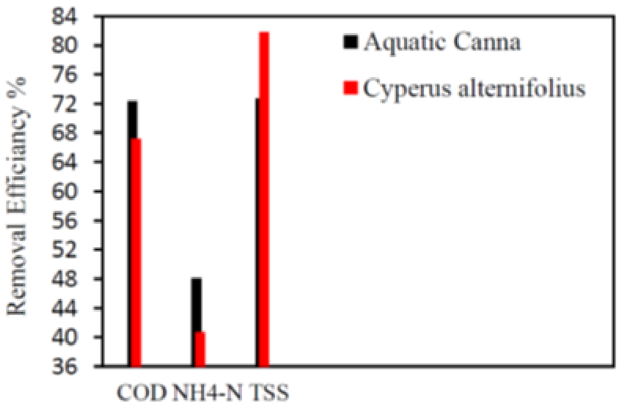

Fig. 4. Removal efficiency for COD,NH_4-N, and TSS.

The decrease of COD was thought to be mainly due to biological conversion during the monitoring time as the root region of the plant had not been well-formed during this period. Although different performances of COD removal were predicted for each of the cells because of their various plants. This can be described by the low organic wastewater content supplied to the wetlands, which is unlikely to have closed the pores of substrates with settled organic substances in six months. Also, a similar pattern in the treatment of COD in both wetlands could be attributed to an adequate diffusion of oxygen into both cells of wetland that was essential for aerobic conversion. Vymazal et al. [18] have mentioned that it is so hard to have effluent COD values less than 50 mg/l if the COD: BOD ratio of the sewage is so high.

4.3. NH_4-N removal

In constructed wetlands, nitrification/denitrification, ammonification, plant uptake, and matrix adsorbent are the removal mechanisms for nitrogen. Various studies have shown that microbial nitrification/denitrification is the main removal system in most of the constructed wetlands [18]. By biological nitrification, untreated ammonia can produce an extensive oxygen demand and it can cause eutrophication in the receiving waters and could be harmful to water-based microorganisms. There is a need to manage nitrogen in wastewater effluents has therefore been generally recognized and several treatment processes have been advanced to eliminate nitrogen from the wastewater stream [21].

In vertical flow wetland systems, enhanced oxygenation in the matrices of wetlands by loaded intermittently, kind of particle, and filtrate volume, which may lead to increased nitrification efficiency. Also, most biodegradable carbon has to be removed from wastewater to ensure effective nitrogen removal, so that the nitrifying bacteria can quickly turn ammonium into nitrate [22]. By biological denitrification, the nitrate generated can then be decreased to a gas of nitrogen. Just carbon removal and suspended solid can be accomplished at higher organic loads in the wetlands, while nitrification and denitrification can occur at lower loads [18]. The ammonium (NH_4-N) effluent values were influenced by the influent of ammonium concentrations in our research. However, the impact on nitrogen removal of different operational factors can vary from that of COD removal. As shown in Fig. 4 removal of ammonium-nitrogen in the cell (I) planted with *Aquatic Canna* and cell (II) planted with *Cyperus Alternifolius* was 48.14% and 40.74% respectively which supports the importance of macrophyte presence.

The percentage of ammonia-nitrogen removal efficiency was observed higher in a cell (I) compared to a cell (II). In comparison with another system of vertical flow wetland in other countries, both systems showed better nitrification [18]. The existence of *Aquatic Canna* could be said to significantly affect nutrients removal. The rooting mechanism of the fiber helps ensure that aerobic conditions exist in the treatment bed. The existence of *Aquatic Canna* could be of major importance particularly in the case of compact wetlands. The higher leaf area (amount not computed) could help to improve the process of assimilation and lead to greater nutrient removal.

4.4. TN and TP removal

As shown in Fig. 5, the efficiency of Total Nitrogen (TN) and Total Phosphorus (TP) removal among both species did not differ significantly. While many studies indicate that *Aquatic Canna* is highly efficient because *Aquatic Canna*, its growth rate was very high [10], however, variations between plant types in the removal of nitrate and COD were attributable to variances in chlorophyll fluorescence, a photosynthetic feature that leads to various root lengths and total root biomass.

The oxygen that releasing to the rhizosphere by the wetland plant was immediately controlled by the entire root biomass and had a major effect on the removal of ammonia and total dissolved phosphorus and COD resulting from root system filtration. The capacity of nutrient uptake was usually associated with environment preference and affected by the construction of the root and rhizome.

Although a strong positive association between the release of root oxygen, the porosity of root, and the loss rate of radial oxygen was also found to be positively associated with the response of plants to domestic wastewater and the removal of TN and TP, so that the removal of nutrients among species may not be significantly different [23]. Also, the species of aquatic plants selected have been more successful in removal efficiency over the long term. The different efficiency of removing contaminants among aquatic plant kinds was not more than extremely high, particularly in a short time. The effect of aging in small size constructed wetlands on essential removal parameters, including temperature, PH, conductivity, the dissolved oxygen concentration, and oxidizing possibility [24].

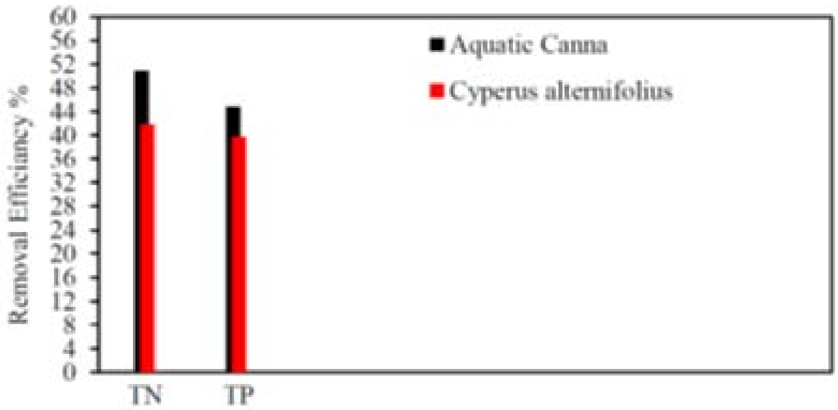

Fig. 5. Removal efficiency for TN and TP.

5. Conclusions

The significant purpose of the study was to evaluate the impact of two various aquatic plants on the efficiency of the nutrient removal of the constructed wetlands performed similarly in the weather of Basra city. In one of the wetland cells (*Aquatic Canna*), the media of filtration chose were gravel with different sizes in three layers, whereas in the other cell (*Cyperus Alternifolius*) also the media was gravel with different sizes in three layers. Total removal from both treatment cells could be concluded: plant life influences interaction among plant wastewater microorganisms, microbial attachment sites supply sufficient resident wastewater period, wastewater part trapping and settlement, pollutant adsorbent surface region, plant oxygen storage consumption from the rhizosphere.

According to the analysis of results, *Aquatic Canna* can be concluded to be more efficient than *Cyperus Alternifolius* in terms of COD, and NH_4-N removal. Both aquatic plants had nearly similar removal efficiency for total phosphorous and total nitrogen removal performances. Compared with other wetland applications in other countries, increased wetland ammonification and nitrification abilities have been recorded. The efficiency of two different plants and the variations among the aerobic and anaerobic ecosystems in the constructed wetland cells may have resulted in differences in removal performances.

The results showed that the priority of the selection of plants depended on the high organic removal quality, biomass, rate of growth, and the value of rhizobacteria that do a significant function in removing pollutants from wastewater. Due to a higher rate of growth, biomass, and COD removal efficiency than other plants, *Canna* was the preferred selection for small wetlands for sewage wastewater treatment systems.

Cyperus was well grown, widely occurring everywhere, and it was possible to cut leaves for handicraft. *Canna* can also be considered for a small constructed wetland for sewage wastewater treatment systems as its flowers are aesthetically preferable. To achieve optimal efficiency for wastewater treatment from aquatic plants, a species' ability to adapt to climate circumstances should also be considered.

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