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The use of Horizontal Flow Constructed Wetland for Treatment of Sanitary Wastewater in Iraq

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Abstract

Constructed wetland is engineering systems used for wastewater treatment, whose objective is to reuse water, under the controlled condition, the mechanisms of treatment that occur in natural environments, through the development and get better the process that includes the porous media, plants, and gathering microbial. This paper explains horizontal flow in constructed wetland treatment, the horizontal flow is moving through the gravel media bed and vegetation which permits the wastewater flow through roots and has contact with the biofilm created in the subsurface wetland.

To estimate the quality of treated water, some physical, chemical and biological parameters were measured.

Treated wastewater from fieldwork showed removal efficiency was increased with time and showed the average removal after detention time of 3, 4, and 6 days, respectively, (47.7 %, 53.2 %, 77.5%) removal of COD, (45.1%, 52.8%, 64.4%) removal of TN, (55.4%, 58.8%, 72.2%) removal of NH4, also average removal of Nitrate was (19.41%) after 3 days. The results showed that the system was effective in removing target pollutants.

Keywords: Wetland treatment, Experimental work, horizontal subsurface flow.

1. Introduction

Lack of water is a challenge worldwide because of growing population and industrialization. The problem is exacerbated by the increasing use of water due to rising civilization standards. It has grown to a scale that no doubt must be solved in the near future [1].

Many issues resulting in water lack could be avoided with better water management. Wastewater treatment and recycling methods can be an alternative source to provide fresh water in the coming decades. That is because freshwater resources are limited and more than 70% of water are consumed for irrigation purposes [1]. Conventional wastewater treatment goes through primary, secondary and tertiary treatment which is expensive to build, operate and maintain. Among the current treatment technologies applied in urban wastewater reuses, constructed wetlands were complemented to be the most suitable ones in terms of pollutant removal.

Constructed wetlands (CWs) are wastewater treatment technique that takes advantage of the physical, chemical, and biological operations occurring in soils to get better water quality. Treated wetlands are engineering facilities that resort to following these normal conditions however in a more controlled way [2]. CWs are very active in the removal of organics and suspended solids. While the nitrogen removal is low relatively but could be amended by using a mixture of various types of constructed wetlands meeting the irrigation reuse criterion. The phosphorus removal is usually low except private media with high absorption ability is used [2]. Choosing the right technology is essential to achieve sustainability of water and sanitation services. CWs are very active in pollutants removal, low energy requirements, ease of maintenance and relatively have low construction and operating costs. Thus, CWs can be considered as a sustainable treatment technology [3].

2. Constructed Wetland Components

A wetland is a black box includes complex components of water, substrate (media), plants, litter, worms, and insect larvae, and sets of microorganisms [4]. Generally, the three main components of CWs are plants, microorganisms, and media [5]. These components interact with each other and this interaction results in treatment and degradation of pollutants.

3. Mechanisms of Pollutants Removal by CWs

The mechanisms of pollutants removal in CWs are plenty and often interrelated. These mechanisms include [5]:

1. Settling of suspended particulate.
2. Filtration and chemical sedimentation through touching of the water with the substrate and litter.
3. Transformation of chemical.
4. Adsorption on the surfaces of plants, substrate, sediment, and litter.
5. Lysis and uptake of pollutants and nutrients by microorganisms and plants.
6. Natural death of organics (plants and microorganisms).

4. Types of Constructed Wetland Systems

According to the way of water flow through the wetland basins, CWs can be classified into; (1) subsurface flow wetlands and (2) surface flow wetlands. In the first type, the water flows underground through the porosity of the granular medium, whereas; in the second type, the water flows over the granular medium under atmosphere pressure condition (free surface flow) [6].

Subsurface flow CWs can also be subdivided into horizontal flow or vertical flow systems. In the horizontal subsurface flow system (HSFS), the wastewater is maintained at a constant depth and flows horizontally below the surface of the granular medium. In vertical subsurface flow system (VSFS), the wastewater is distributed over the surface of the wetland and trickles down through the granular medium [7]. CWs can also be a combination of (VSFS) and (HSFS) in order to fulfill higher treatment efficiency by using the advantages of individual systems [8]. The present study is concerning

HSFS, thus, more attention shall be given to this type. CWs are rare in Iraq. The recorded performance for pollution removal is relatively poor. Therefore, wetland treatment is considered as the aim of this study. Hence performance data that will guide the design and operation of wetland systems in an invitation to efficiencies for irrigation and diverse applications is desirable.

5. Materials and Methods

This trial was carried out at the location of sewage treatment plant in Basrah University - Garmmat Ali campus; it is located at Longitude: (47°44'54.283"E) and Latitude: (30°33′20.531"N). A schematic diagram and photo of this trail are presented in Figs. 1 and 2, respectively. Thus, there was a provenance of primary treatment of wastewater, which could be moved from the septic tank to the constructed wetland station [9].

Fig. 1 Photo of the wetland treatment system [9].

A laboratory-scale horizontal-flow CW was constructed of fiberglass basin (3 m length, 1.20 m width, and 1 m high) placed at a concrete base. The basin is fed by gravity as it is located under the storage tank, Fig. 3. Local gravel is placed in the basin to depth 0.6 m as a substrate, where the depth of the media in subsurface flow wetlands has ranged from 0.3 to 0.9 m with 0.6 m being most common [8]. This gravel was placed from coarse to fine in a way that water does not take adhesive and prevents oxygen to enter through the substrate as shown in Fig. 4. The inlet is located at the tank head and the outlet is located at the tank end. The aquatic plants were planted to be part of this system.

Typha Domingo’s (Cattail), is the preferred plant which has been planted as part of HSFS CW, since it is a fast growing plant and is not a source of food for animals [10].

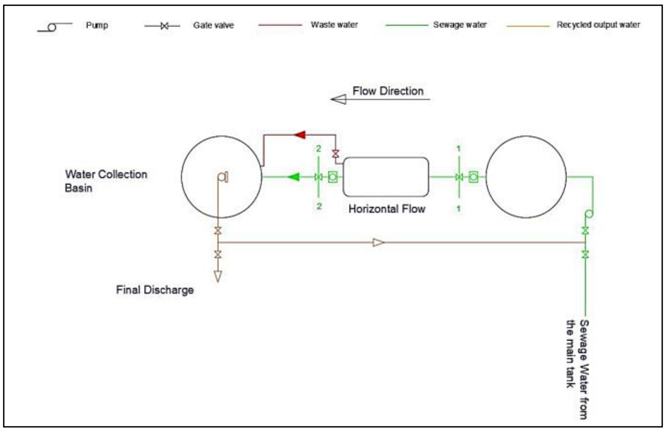

Fig. 2 Schematic diagram of horizontal wetland treatment Typha Domingo’s.

Fig. 3 Storage tanks.

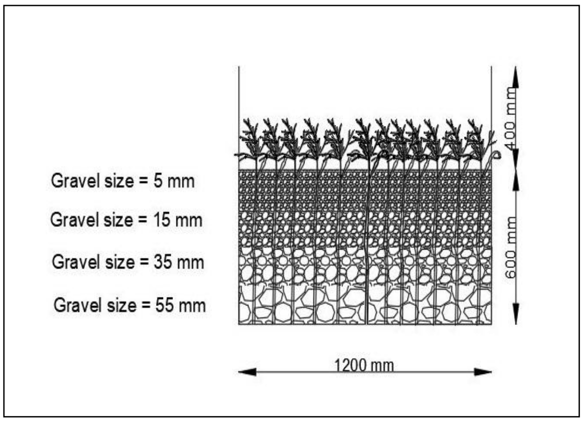

Fig. 4 Cross-section of (HSSF CWs) media.

6. Results and Discussion

1. To get a reliable treatment system for horizontal flow wetland, the system has been operated for hot and cold conditions. The field work started from March, 2018 and ended on February, 2019. However, the work was stopped for a period of six months (from June, 2018 to December, 2018) due to plants death as a result of water salinity increase.

Primary wastewater treatment and treated water by horizontal flow wetland samples after a retention time of three days were collected. They were collected using polyethylene bottles, then directly carried to the lab for analysis of selected water quality parameters.

These parameters include Chemical Oxygen Demand (COD), Ammonium (NH4), Nitrate (NO3), and Total Nitrogen (TN). Tables 1, 2, and 3 show samples of the measured parameters in the experimental work after retention time of 3, 4, and 6 days respectively.

2. The efficiency of wetland system has been evaluated using the percentage of pollutions (COD, NH4, NO3, and TN) concentrations removal at different of detention time. The percentage of removal is defined using Eq. (1). It was calculated for each considered parameter using the measured values of initial and final (after end of detention time) concentrations. The obtained removal percentage for the considered parameters during the wetland system operation for three samples at summer, spring, and winter after detention time of 3, 4, and 6 days are shown in Figs. 5, 6, and 7 respectively.

$$CWE = \frac{IP_i - FP_i}{IP_i} \times 100 \qquad (1)$$

Where;
CWE : is wetland efficiency.
IP_i : initial concentration of parameter No i.
FP_i : final concentration of parameter No i.

Table 1 An overview of the experimental results after retention time 3 days.

	Date	COD (mg/l)	NH4 (mg/l)	NO3 (mg/l)	TN (mg/l)	Temp.
Inlet	15/3/18	528	11.9	3.32		25.4
Outlet		145	7	2.81		
Inlet	19/3/2018	350	36.4	9.98		26
Outlet		100	10.5	3.81		
Inlet	8/4/2018	240	11.2	5.81		26.7
Outlet		75	5.6	6.04		
Inlet	22/4/2018	510	13.2	5.97		27.9
Outlet		113	2.8	5.55		
Inlet	20/5/2018	176	20.16	4.72	22	33
outlet		28.6	13.96	3.1	9.5	
Inlet	17/12/2018	200	42	3.03	68.4	18
Outlet		180	14	1,8	24.5	
Inlet	23/12/2018	600	23	4.75	36	17.7
Outlet		400	5.76	3.8	21	
Inlet	30/12/2018	400	3.6	6.0	35	19.5
Outlet		334	1.4	1.4	21	
Inlet	7/1/2019	400	3.3	5.96	14	19
Outlet		160	2.9	4.5	9.8	
Inlet	13/1/2019	220	14.4	8.5	35	19.3
Outlet		200	4.3	6.2	14	
Inlet	20/1/2019	320	14.4	3.31	35	18.5
Outlet		264	12.9	2.81	32.2	
Inlet	27/1/2019	240	21.6	9.9	49	18
Outlet		200	11.5	7.8	28	
Inlet	4/2/2019	360	17.3	6.04	40.6	17.8
Outlet		60	7.2	5.8	21	
Inlet	17/2/2019	340	18	5.96	35	19
Outlet		200	10.8	5.3	21	
Inlet	24/2/2019	380	16.6	9.94	32	18.5
Outlet		260	5.8	8.4	11	

Table 2 An overview of the experimental results after retention time 4 days.

	Date	COD (mg/l)	NH4 (mg/l)	TN (mg/l)	Temp.
Inlet	20/5/2018	176	20.16	22.4	32.7
Outlet		17.1	2.8	8.4	
Inlet	30/12/2018	400	3.6	35	19
Outlet		180	1.4	14	
Inlet	7/1/2019	400	3.3	14	18.2
Outlet		100	1.44	7	
Inlet	13/1/2019	220	14.4	35	18
Outlet		180	3.6	11.2	
Inlet	20/1/2019	320	14.4	35	18
Outlet		220	10.8	25.2	
Inlet	27/1/2019	240	21.6	49	9.6
Outlet		120	10.8	25.2	

Table 3 An overview of the experimental results after retention time 6 days.

	Date	COD (mg/l)	NH4 (mg/l)	TN (mg/l)	Temp.
Inlet	20/5/2018	176	20.16	22.4	34
Outlet		10	2.8	8.4	
Inlet	17/12/2018	200	42	68.4	17.5
Outlet		40	11.5	14	
Inlet	23/12/2018	600	23	36	18
Outlet		61	1.4	11	
Inlet	30/12/2018	400	3.6	35	19
Outlet		160	0.72	11	
Inlet	7/1/2019	400	3.3	14	18.2
outlet		40	0.72	7	
Inlet	13/1/2019	220	14.4	35	17.5
Outlet		60	2.8	9.8	
Inlet	20/1/2019	320	14.4	35	18
Outlet		180	9.4	19.6	
Inlet	27/1/2019	240	21.6	49	18.5
Outlet		40	9.36	21	
Inlet	4/2/2019	360	17.28	40.6	17.8
Outlet		20	3.6	11.2	
Inlet	17/2/2019	340	18	35	18
Outlet		100	7.2	14	
Inlet	24/2/2019	380	16.5	32	19.5
Outlet		100	4.3	8.4	

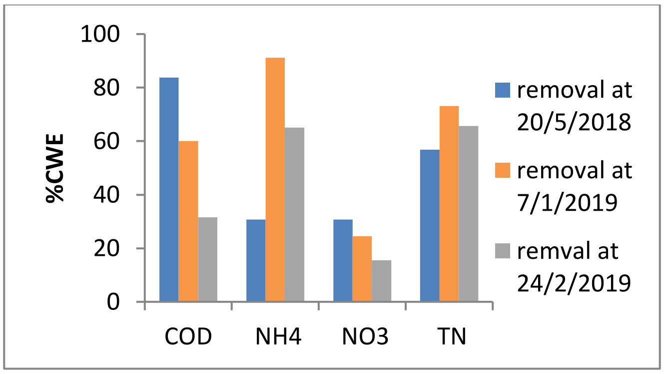

Fig. 5 The efficient removal of parameters after 3 days.

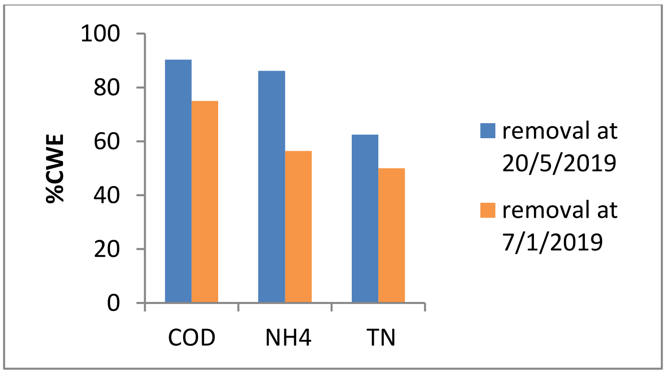

Fig. 6 The efficient removal of parameters after 4 days.

From these figures it can be shown that the removal increased with increasing detention time.

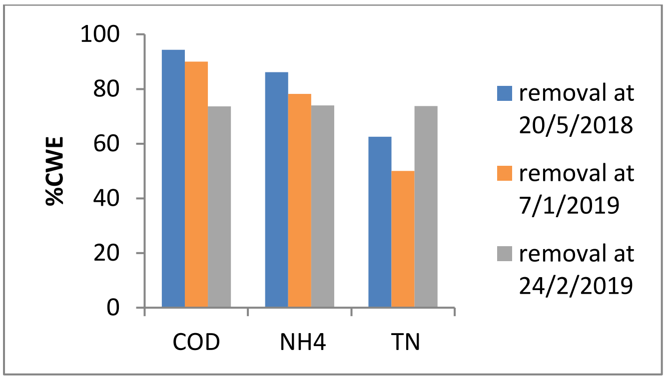

Fig. 7 The efficient removal of parameters after 6 days.

7. Conclusions

1. The laboratory-scale HSFS WCs systems demonstrated to be efficient in the treatment of sanitary wastewater, and the special ability of HSFS for nutrients and pollutants removal for the case of the parameters of this study has been fully assured.
2. The HSFS was leading acclimatize with the variation of seasons its showing well when the temperature increases.
3. Considerable removal of organics was obtained from HSFS CWs, maximum efficiency 94.4%, 93.9%, 61.8%, and 79.5% was obtained for COD, NH4, NO3, and TN, respectively.
4. The average removal of COD up to (46.2%, 53.2%, 77.5%), TN (45.1%, 52.8%, 64.4%), NH4-N (55.4%, 58.8%, 72.2%) after 3, 4, 6 days, respectively, also average removal of Nitrate was (19.41%) after 3 days.
5. The rated pollutant removal could be amended by increasing retention time and thus, the longer retention time would promote enough time for the bacteria to degrade the pollutants.

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