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Efficiency of a constructed wetland in controlling organic pollutants, nitrogen, and heavy metals from sewage

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ABSTRACT

Introduction: constructed wetlands are efficient systems in controlling sewage pollutants. These systems have a low cost of maintenance and operation and their discharges can be further re-used for irrigation and agricultural purposes. The present study aimed at evaluating the efficiency of such a system in removing various types of pollutants, including organic and mineral compounds, nitrogen, and heavy metals.

Material and method: the system investigated in the present study was composed of two stabilization units, each of them contained two anaerobic ponds and twelve beds. The performance of the system was evaluated by taking 24-hour samples from the system discharges. Data were analyzed using SPSS software package version 12.

Findings: the efficiency of the ponds of the first unit in removing COD and BOD were 29.49±21.8 and 42.63±15 percent, and for the ponds of the second unit were 29.85±18.44 and 66.42±21.81 percent. Moreover, the beds were capable to separate 51.25 percent of all received cadmium. The nitrogen removal efficiency of the system was not acceptable.

Conclusion: although the wetland investigated in the present did not have the desired efficiency, a desirable level of efficiency would be achievable by optimizing the operational and maintenance condition of the system.

KEY WORDS: sewage treatment, constructed wetland, organic compound, heavy metal.

1. INTRODUCTION

Sewages are regarded as a main cause of environmental pollution which should be treated appropriately so that containing an acceptably low level of pollutant factors when releasing to the environment (Dargahi, 2015). Nowadays, sewage treatment by use of natural systems with a product applicable for irrigation and agriculture is of high interest and attracts many attentions in recent years. Utilizing local resources and providing a more pleasant aesthetic landscape, Wetland systems are an affordable alternative for treating sewages. Moreover, the system is considered to be an eco-friendly one, relies on renewable sources such as sunlight, and employs plants and microorganisms as the active agents in the treatment process. Accordingly, the treatment process is so simple that there is no need of advanced and expensive equipment (Langergraber, 2013; Vymazal, 2014). In this technique, plants act as an absorbent of pollutants from waste water and, moreover, microbial activity stimulators play an important role in the process. Furthermore, oxygen and compound released by plants' roots may facilitate pollutant removal processes (Dickopp, 2011).

Constructed wetlands can be used for removing a wide range of pollutant compounds from waste water and sewages, including suspended solids, organic compounds, nutrients, pathogens, metals (Ballesteros, 2016; Zhang, 2014). Sedimentation, filtration, evaporation, plant uptake, and bacterial activity are some of the major mechanisms using which a constructed wetland treats waste water (Ballesteros, 2016). These systems are able to remove organic pollutants by microbial degradation and sedimentation. Suspended solids are separated through sedimentation and filtration mechanisms. Moreover, oxygen required for continuous microbial activities is provided by aerating the water. Nitrogen is removed through such mechanisms as nitrification, denitrification, and volatilization of ammonia under high pH values by algal photosynthesis. In fact, plants in a constructed wetland can be regarded as a temporary storage of pollutants, which absorb nutrients from wastewater and release them into the water again shortly after the plant corruption (Vymazal, 2014). Consequently, since the pollutants have been removed from the waste water, plant biomasses should be harvested and thrown away (Yang, 2016). Plant harvesting should be implemented in regular time intervals based on such factors as plant growth pattern, nutrient removal rate, and heavy metal refining and is of pivotal importance in managing a constructed wetland (Ranieri and Gikas, 2014). The removal of pollutant compounds by the use of plants has been the subject of many studies so far (Chen, 2012). However, it should be considered that the efficiency of constructed wetlands in treating waste water is a function of other factors, as well. The type of wetland system, weather conditions, plants, and microbial populations and diversity all are factors which can influence the efficiency of such systems (Josimov-Dundjerski, 2015). In spite of all capabilities of a constructed wetland in removing all kinds of mineral and organic pollutants (Saeed and Sun, 2012), there are some concerns about them; Bed fouling and low efficiency of removing nitrogen and heavy metals are some important ones (Liu, 2015). Accordingly, the present study was set to address the efficiency of constructed wetlands in removing organic pollutants, nitrogen, cadmium, and pathogens.

2. MATERIALS AND METHODS

In the present study a real constructed wetland was monitored for a period of one year. The wetland was composed of two stabilization units, containing anaerobic ponds with a total volume of 6250 cubic meters and twelve parallel beds. The sampling process was manually performed for all 24 hours of a day. On a random day of each week a 24-hour sample was collected from the input and output of the anaerobic ponds and from the output of beds in accordance with the standard methods recommended by the related bodies (Awwa, 1998). Next, all samples were safely shipped to a laboratory and stored at a temperature of 2-4^{0}C until the time of analyses. In order for ensuring of correctness of experiments, some samples were randomly selected and reevaluated. In the present study, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), oxidation reduction potential, Total Kjheldal Nitrogen (TKN), and cadmium were the parameters investigated in the present study. It should be noted that all steps of sampling, shipping, storing, as well as laboratory analyses were carried out in accordance with the standard methods (Awwa, 1998).

3. RESULTS

The results obtained by analyzing the samples taken from the anaerobic ponds are summarized in Table.1 and 2 and those of the twelve beds are also presented in Table1, Table 2, and Figure 1.

As evident in Table 1 and 2, the average efficiency of ponds in removing COD and BOD were 29.49±21.8 percent and 42.63±15 percent for the first unit and 29.85±18.44 percent and 66.42±21.81 percent for the second unit. So the efficiency of the second unit was higher than that of the first one. The oxidation reduction potential was lower than 100 mV, confirming the presence of an anaerobic condition in units. The efficiency of the twelve beds based on COD and BOD values was evaluated using the plot depicted in Figure 1. It can be inferred from this figure that the highest efficiency of BOD and COD removal belonged to bed number 3 (67±8 percent) followed by bed number 7 (50±9 percent). Moreover, the experiments revealed that the wetland was able to remove cadmium with an efficiency of 61.5±20.54, from which 51.25±23.21 percent was removed by the beds and the remaining 22.08±8.45 percent was separated by the mechanism of sedimentation. In addition, it was observed that the oxidized forms of nitrogen, such as nitrites and nitrates, were of so negligible a concentration in entries of the beds that we were unable to quantify them and their concentrations in discharges of the beds were as low as 1 mgr/liter as well. However, according to the results presented in Table 4, the efficiency of the system in removing TKN was only 26.76±10.18 percent which is not satisfactory. Furthermore, the maximum removal efficiency of N-Organic and N-NH_3 was 19.65 and 16.16 percent, respectively, which means the capability of the system in removing N-Organic was higher than its capability in removing N-NH_3.

Table.1. The characteristics of the crude sewage entering in and discharging from the first anaerobic pond

Parameters	unit	Minimum	Maximum	Mean	Std. Deviation
COD in	mg/l	256	645	415.97	101.77
COD out	mg/l	144	592	293.3	125.59
BOD in	mg/l	151.04	380.55	245.42	60.04
BOD out	mg/l	69.12	284.16	140.79	60.28
COD rem.	%	43.75	8	29.49	19.24
BOD rem.	%	54.23	25.33	42.63	15
ORP	mv	-198	43.33	-165	-103

Table.2. The characteristics of the crude sewage entering in and discharging from the second anaerobic pond

Parameters	unit	Minimum	Maximum	Mean	Std. Deviation
COD in	mg/l	256	645	415.97	101.77
COD out	mg/l	144	592	291.8	122.85
BOD in	mg/l	151.04	380.55	245.42	60.04
BOD out	mg/l	73.44	301.92	148.82	60.65
COD rem.	%	43.75	8.2	29.85	18.44
BOD rem.	%	51.37	20.66	66.42	21.81
ORP	mv	46.67	220	-165	-112

Table.3.The efficiency of the system in removing cadmium

Parameter	Minimum	Maximum	Mean	Std. Deviation
Removal in settling, %	0	30	22.08	8.45
Removal in Beds, %	8	73	51.25	23.21
Removal in system, %	20	80	61.5	20.54
Cadmium in row wastewater, ppb	0.2	0.94	0.5	0.19
Cadmium in anaerobic pond, ppb	0.15	0.65	0.38	0.13
outlet cadmium in beds, ppb	0.04	0.32	0.18	0.07

Table.4.The efficiency of the system in removing TKN

Parameter	unit	Minimum	Maximum	Mean	Std. Deviation
$NH3_{in}$	mg/l	5.7	28	16.16	6.05
$NH3_{out}$	mg/l	5	22.5	14.09	5.38
Removal	%	12.28	19.64	15.3	9.48
N- Organic $_{in}$	mg/l	3.8	18.67	10.6	4.16
N- $Organic_{out}$	mg/l	3.33	15	9.18	3.67
Removal	%	12.36	19.65	13.39	10.08
TKN_{in}	mg/l	9.5	46.67	26.76	10.18
TKN_{out}	mg/l	8.33	37.5	23.39	8.81
Removal	%	12.31	19.64	12.59	8.89

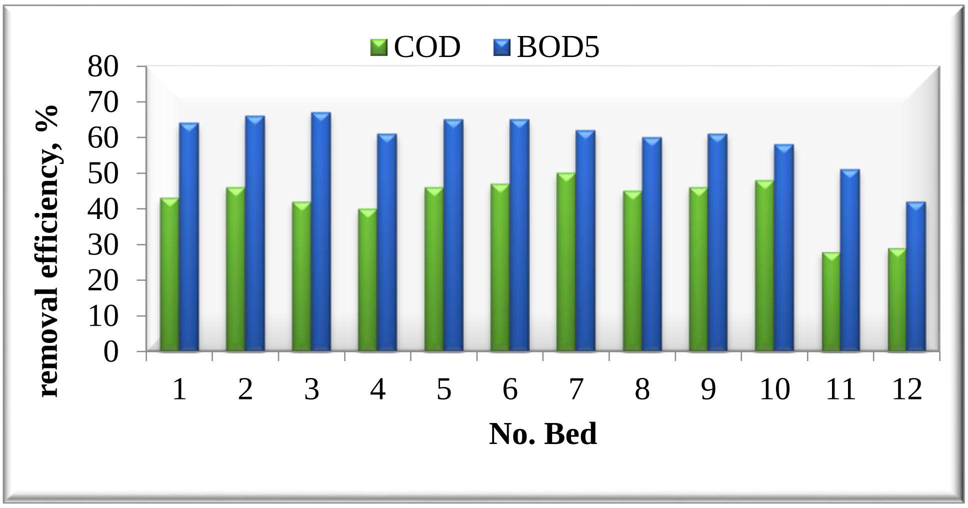

Figure.1. The BOD and COD removal efficiency of the beds

4. DISCUSSION AND CONCLUSION

High efficiency in removing various pollutants, low cost, simple maintenance and operation, and possibility of reusing the treated water for irrigation and agriculture purposes are some of the main advantages of a constructed wetland. Although these advantages make the system an interesting option for treating waste water, there always have been some concerns about inherent problems of such a system. Therefore, in the present study, we aimed at evaluating the efficiency of a real constructed wetland in removing various types of water pollutants. According to the results obtained by the present study, the average COD and BOD of the first and the second anaerobic ponds were 38.75±21.8 and 43.76±15 percent, respectively. By comparing these findings with those reported by other studies, it can be concluded that the performance of the wetland investigated in the present study is not satisfactory. In the study carried out in Abadan, Iran, the efficiency of the same system in removing COD and BOD_5 was reported as 69 and 63 percent respectively (Frankel and Lerman, 1989; Almasi, 2014). Moreover, the oxidation and reduction potential of the system was in the range of anaerobic condition (lower than 100 mV) and although the concentration of suspended solids at the discharge of the system was in line with those mandated by standards, other indices such as COD, BOD, and bacteriologic index were not at a pleasant level. The ability of constructed wetlands in removing microbial pollutants from sewage was investigated by Kipasika (2014). In that study it was also concluded that such a system is not effective in inactivating fecal coliform and pathogens, which is in agreement with the results of the present study. However, there have been studies as well that have reported a removal efficiency of 99 (Kivaisi, 2001) and 91 percent (Mashauri, 2000) for constructed wetlands in removing pathogens and microbial pollutants. As well as microbial pollutants, the system was not effective in controlling cadmium and TKN as well. Arroyo (Arroyo,

2010) reported that the efficiency of a constructed wetland in removing cadmium was about 55 percent, while another study (Jindal and Samorkhom, 2005) outlined that the efficiency of constructed wetlands in removing heavy metals and TKN was 99.9 and 91 percent, respectively. The low efficiency of the constructed wetland investigated in the present study may be due to an improper hydraulic and organic loading rate which led to an inadequate hydraulic retention time.

In overall, the system did not have an acceptable level of stabilized efficiency in removing various types of pollutants. However, it can be postulated that by providing a proper condition in terms of design and operational parameters, it is possible to improve the efficiency of the system. According to this study, it is suggested that, because the system tolerated the present hydraulic load, so bypass canals should not be employed at all in order for avoiding the negative effects of discharging raw sewage into the environment. Moreover, the flow rate of canals carrying sewage from anaerobic ponds to the beds should be regulated so that the minimum required retention time in beds is ensured and the beds be capable of tolerating hydraulic shocks. Modifying the supply canal of each bed in terms of their slope, providing facilities for regulating the sewage rate entering each bed, and regulating the multiple discharge of beds are other suggestions which can be useful in improving the efficiency of the system. Furthermore, economics aspects of constructed wetlands should be taken into account as well. Such systems can be used for production of forage crops and vegetable fibers such as wood which can later be used in paper-making industries. Likewise, these systems create beautiful landscapes that can be considered in terms of tourism.

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