American-Eurasian J. Agric. & Environ. Sci., 12 (4): 423-428, 2012
ISSN 1818-6769

The Efficiency of Constructed Wetland to Treat Primary Sewage Effluent Under Different Operational Conditions

S.A. Aboulroos, M.M. Kamel and S.G. Abdel Hakim

Department of Soil Science, Faculty of Agriculture, Cairo University, Giza, Egypt

Abstract: The efficiency of constructed wetland to treat weak and medium primary sewage effluent was tested under three rates of sewage inflow and two types of growing plants (*i.e.*, leaf cattail and common reed). The capability of the wetland to remove COD, BOD, TSS, TDS and *F. coliform* from the primary weak sewage increased with decreasing the rate of the sewage inflow from 12 L/hr. to 6L/hr., with little or no further changes at a rate of 3 L/hr. The two plants (Leaf cattail and common reed) were equally effective in sewage purification. Levels of either COD, BOD or TSS in the treated primary weak sewage at all rates of sewage inflow and numbers of *F. coliform* in the sewage treated only at the 6 and 3 l/hr rates of inflow fulfill the requirements of the guidelines for the use of wastewater in agriculture. The capability of the wetland to remove BOD and COD decreased with increasing the strength of the primary sewage. At any given rate of inflow, the percent removal of BOD and COD from the medium sewage was less than that from the weak one. This decrease in the capability was much more observed for BOD removal than COD removal. The reduced ability of the wetlands to control high BOD/COD levels in the medium sewage system is thought to be that there is not enough oxygen in the system to do its job.

Key words: BOD · COD · Wetland · Sewage effluent · *Fecal colifom* · Sewage strength

INTRODUCTION

Domestic wastewater is one of the current environmental issues all over the world. Sewage effluent is laden with different kinds of organic and inorganic pollutants and pathogens. Safe use of sewage effluent in agriculture necessitates treatment of the effluent to remove pollutants and pathogens. Egypt produces an estimated volume of 2.4 billion cubic meters (BCM) of municipal wastewater every year and only 1.0 BCM of this wastewater is treated and reused in irrigation [1, 2]. The volume of wastewater produced by small settlements is in many cases not enough for the cost effective operation of conventional treatment plant.

Wetlands have been used for many years as small scale treatment of wastewater from factories or small community having no access to public sewage system [3-6]. The ability of constructed wetland to treat wastewater from pollutants such as, COD, BOD, TSS, N, P, heavy metals and pathogenic microorganisms have been reported by different authors but with varying degrees of success. The efficiency of the constructed wetlands in wastewater purification was found to be affected by the strength of the sewage [7-9], the design of the wetland cells [10, 11], the operational conditions [12], the type of plants [13] and the type of substrate [12].

The objectives of this study is to test the capability of small- scale constructed wetland to treat weak and strong sewage effluent under different rates of sewage inflow and different types of plants. The quality of the treated sewage with respect to its suitability for irrigation and safety to the environment will be evaluated according to the guidelines for the safe use of wastewater in agriculture.

MATERIALS AND METHODS

Four units of gravel bed hydroponics system (GBH) were designed and located in Zienin sewage treatment plant, Giza, Egypt. The units were made of galvanized steel with dimensions of (2 x0.5 x 0.5 m) for length, width and depth, respectively. All units were filled with different gravel diameter (1-7 mm) as growth media.

The wetlands were planted with either leaf cattail or common reed. Primary sewage effluent was applied to the wetland under different rates of inflow including 12 l/hr.,

Correspoding Auhtor: S.A. Aboulroos, Department of Soil Science, Faculty of Agriculture, Cairo University, Giza, Egypt.

6 l/hr. and 3 l/hr. Two experiment were carried out to study the ability of the wetlands to treat primary sewage effluent that have different strength, i.e., weak and medium sewage The strength of the sewage was defined according to the level of the various components. Values of 100 mg/l BOD, 250 mg/l COD and 350 mg/l TSS denote weak sewage; 200 mg/l BOD, 500 mg/l COD and 700 mg/l TSS denote medium sewage [14]. The experiments were carried out during spring and summer (April to August) with temperature range of 35-38°C. Each experiment lasted for a period of one month for each rate of inflow. Samples of the inflow and outflow effluents were collected every 12 hr. intervals for analyses. The system performance efficiencies were monitored through the determination of total suspended solids (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD), total dissolved solids (TDS), pH and pathogenic microorganisms (*F. coliform*).

Methods of Analyses: BOD was determined following the method described in the ISO [15] and COD was determined using the reactor digestion method as described by Jirka and Carter [16]. Measurement of TSS was done by using a paper filtration method [17]; TDS by using EC meter; pH by using glass electrode. *Fecal coliforms* bacteria (FC) were counted using Endo agar media [18]. Statistical analysis of the data was carried out using MSTAT program.

RESULTS AND DISCUSSION

Treatment of Weak Sewage Effluent: Analyses of the sewage effluent (Table 1) indicate that the primary sewage used in the experiment is typically a weak sewage. The level of the various components of the sewage changed slightly from time to time throughout the course of the experiment. However these variations are statistically insignificant. The table also shows that the level of BOD is less than that of COD; the ratio of BOD/COD is about 0.55.

Table 1: Properties of the primary weak sewage effluent used in the experiment

Parameter	Concentration		
	Min.		Min.
COD mg/l	140	COD mg/l	140
BOD mg/l	80	BOD mg/l	80
TSS mg/l	82	TSS mg/l	82
TDS mg/l	1250	TDS mg/l	1250
pH	6.3	pH	6.3

The Constructed wetlands were able to substantially decrease the level of the various components of the sewage (Table 2). The data obtained from the common reed wetland cells were almost identical to those obtained from the leaf cattail cells. The two plants were equally effective in sewage purification. Generally the efficiency of the wetlands to purify the primary sewage increased with decreasing the rate of sewage inflow. At the rate of sewage inflow of 12 l/hr., the leaf cattail and common reed wetland cells decreased, on average, the values of COD, BOD, TSS and TDS of the primary sewage by 63, 59, 59 and 10 %, respectively. Decreasing the rate of sewage inflow to 6 l/hr. increased the magnitude of the reduction of all components significantly. Further reduction in the rate of sewage inflow to 3 l/hr. produced only slight insignificant decrease. Among all the parameters studied, the TDS shows the least change upon treatment in the wetlands. The pH values of the treated effluent are in the range of 7.2 and 7.3 irrespective of the rate of sewage inflow or type of plants. These values are about 0.2 units higher than those of the untreated effluent. It seems that this increase in pH is due to the removal of organic load from the sewage effluent upon treatment.

The removal percentage of *F. coliform* varied between 96 and 99 %, irrespective of the rate of sewage inflow or the type of plants grown. However, the number of *F. coliform* in the effluent treated at a rate of sewage inflow of 12 L/hr. is significantly higher than those treated at the inflow rate of 6 or 3 L/hr.

Table 3 shows the range of the values of the various components in the sewage treated by the wetland cells compared with the corresponding values in secondary sewage produced in different sewage plants in Egypt. The upper limit of the range is that of the sewage treated at the high rate of sewage inflow (12 l/hr.), whereas the lower limit is that for the slow rate of inflow (3 l/hr). Also the guidelines for the use of treated sewage in irrigation in Egypt were shown in the table.

The Table shows that the levels of either COD, BOD or TSS in the treated wastewater at all rates of inflow are within the range recorded for the secondary sewage produced by sewage treatment plants in Egypt. According to the Egyptian guidelines, the effluent treated by the wetlands under any of the tested rate of sewage inflow can be used safely for irrigation of cereal crops, industrial crops, fodder crops, pasture and trees (category B wastewater). However, the numbers of *F. coliform* in the wastewater treated by the wetlands only at the rates of sewage inflow of 6 and 3 l/hr. were less than the standard recommended by the Egyptian guidelines for the use of

Table 2: Efficiency of constructed wetland planted with leaf cattail and common reeds to treat weak sewage under different rates of sewage inflow

		Out flow effluent concentration			
	In flow effluent concentration	Leaf cattail cells		Common reeds cells	
Rate of sewage inflow (l/hr.)	Avg.	Avg.	Removal (%)	Avg.	Removal (%)
COD (mg/l.)					
12	176^{a}	66^{b}	62	63^{b}	64.0
6	171^{a}	45^{c}	74	42^{c}	75.0
3	168^{a}	39^{c}	77	37^{c}	78.0
BOD (mg/l.)					
12	94^{a}	41^{b}	56	36^{bc}	62.0
6	92^{a}	30^{cd}	67	27^{d}	71.0
3	94^{a}	30^{cd}	68	27^{d}	71.0
TSS (mg/l.)					
12	114^{a}	48^{b}	58	46^{bc}	60.0
6	111^{a}	41^{bcd}	63	38^{cde}	66.0
3	107^{a}	33^{de}	69	32^{e}	70.0
TDS (mg/l.)					
12	1261^{d}	1120^{h}	11	1152^{g}	9.5
6	1267^{d}	1178^{e}	7	1165^{f}	8.0
3	1504^{b}	1542^{a}	-	1408^{c}	6.0
F. coliform (cfu/100ml)					
12	34×10^{4a}	13×10^{3b}	96	11×10^{3b}	96.0
6	28×10^{4a}	13×10^{2c}	99	12×10^{2c}	99.0
3	34×10^{4a}	14×10^{2c}	99	12×10^{2c}	99.0

Table 3: Estimates of the properties of secondary sewage effluents and the guidelines for wastewater use in irrigation in Egypt

		Secondary sewage		Guidelines
Parameter	Treated weak sewage	Range	Average	80
COD (mg/l.)	37-56	41-129	68	60
BOD (mg/l.)	27-41	18-78	34	50
TSS (mg/l.)	32-48	21-169	43	2000
TDS (mg/l.)	1120-1542	450-890	647	5000
F. coliform (cfu/ 100ml)	1200-13000	2000-10000	6600	80

wastewater in irrigation and fulfill the requirements of the WHO guidelines for the use of category (B) wastewater in agriculture.

These results raise the question about the best rate of sewage inflow to be used during treatment of weak sewage in wetlands. As far as the quality of the resultant effluent was always within the permissible limits for use in irrigation, thus the final decision on the selection will be based on the volume of wastewater treaded every day by the wetland cell. Thus, from the economical point of view, the faster rate of sewage inflow is suitable for the treatment of weak sewage by the wetland cells. This conclusion may not be valid if strict guideline for *F. coliforom* in the wastewater (category B) is adapted.

Treatment of Medium Effluent: Data in Table 4 show that the initial level of COD and BOD in the medium sewage are, on the average, 404 and 265 mg/l., respectively. These values are about 2.4 and 2.8 times, respectively higher than the corresponding values of the weak sewage used in the first experiment. The table also shows that the level of BOD is less than that of COD and the ratio of BOD/COD is about 0.66.

Table 4 shows that the percent removal of COD by either plant was always low at the highest rate of sewage inflow and increased with decreasing the inflow rate, being in accordance with the pattern of COD removal found in the weak sewage experiment. However and at any given rate of inflow, COD removal from the medium sewage was slightly less than that from the weak one, *i.e.*, the capability of the wetland to remove the COD decreased with increasing the strength of the primary sewage. This decrease in the capability of the wetlands is not affected by the rate of sewage inflow. The two plants of the wetland produced the same results.

Table 4: Efficiency of constructed wetland planted with leaf cattail and common reeds to treat medium sewage under different rates of sewage inflow

	In flow effluent concentration	Out flow effluent concentration			
		Leaf cattail cells		Common reeds cells	
Rate of sewage inflow (l/hr.)	Avg. (mg/l.)	Ag. (mg/l.)	Rmoval (%)	Ag. (mg/l.)	Rmoval (%)
COD					
12	445^{b}	185^{e}	58	185^{ef}	58
6	410^{c}	132^{h}	68	127^{h}	69
3	357^{d}	100^{i}	72	90^{j}	74
BOD					
12	277^{b}	153^{f}	45	169^{e}	39
6	268^{c}	120^{h}	55	136^{g}	49
3	250^{d}	110^{i}	56	118^{h}	53

The effect of the rate of sewage inflow on BOD removal is similar in trend to that reported for COD but with different magnitude. The high organic load of the medium sewage has more adverse effect on the ability of the wetland to reduce the BOD level than it has on COD.

When compared with the weak sewage experiment, data of Table 4 show that the ability of the cattail wetland to remove BOD of the medium sewage was less by about 11, 12 and 12 %, than the corresponding values reported for the weak sewage treated at sewage inflow rates of 12, 6 and 3 l/hr., respectively. As for the common reed cells, the abilities to remove BOD were even more adversely affected; they were less by 23, 22 and 18 %, respectively, than those reported for the weak sewage.

The reduced abilities of the wetland to remove BOD and to a lesser extent COD as moving from weak to medium sewage, were much reflected on the quality of the effluent produced. The concentration of COD in the treated wastewater of both cattail and common reed cells were, on average, 185, 130 and 95 mg/l. for the rates of sewage inflow of 12, 6 and 3 l/hr., respectively. The values for the sewage inflow rates of 12 and 6 l/hr. were higher than those found in secondary sewage produced from sewage treatment plants (Table 3). Although, the values of COD in the wastewater obtained at a rate of sewage inflow of 3 l/hr. were within the range reported for secondary treated wastewater, yet it was about 1.5 times higher than the reported average value. Also this concentration was higher than the recommended level reported in the guideline for the use in irrigation.

Similarly, the concentrations of BOD in the treated wastewater in both wetland cells were, on the average, 161, 128 and 114 mg/l. for the sewage inflow rates of 12, 6 and 3 l/hr., respectively. Compared with the data in Table 3, none of these values was within the range of BOD level reported for the secondary sewage. Also, the concentration of BOD shown by the slowest rate of sewage inflow was 2.5 time higher than the value recommended by the guidelines for the use of this water in irrigation.

The reduced ability of the wetlands to control high BOD/COD levels in the medium sewage system is thought to be that there is not enough oxygen in the system to do its job. This is usually based on suspicions that the mechanical processes that generate air and oxygen, in relation to the volume capacity of the system, are not functioning well enough or are inadequate.

A first conclusion from these results could be that the small scale constructed wetland used herein is suitable for treating weak sewage rather than treating medium sewage. However, although the percent removal of COD and BOD from medium sewage is lower than that from weak sewage, yet the magnitude of reduction in the level of these components are much greater in case of medium sewage than in weak sewage. Fig. 1 Shows that the cattail and common reed cells are able to reduce the initial COD level of the medium sewage by values that ranges from 260 to 280 mg/l. as compared with only 110 to 130 mg/l. in case of weak sewage. Similarly, the two wetland cells were able to decrease the initial concentration of BOD in the medium sewage by 108 and 148 mg/l. as compared with 58 and 67 mg/l. for the weak sewage.

This means that, in spite of the poor quality of the effluent from medium sewage, yet the constructed wetland still offer a good tool for treating this effluent if some modifications are made to increase the level of oxygen in the media. This is typically an engineering solution. Traditional methods tend to either increase the oxygen levels (dissolved oxygen) and or increase the retention time. This has to be studied in future research work.

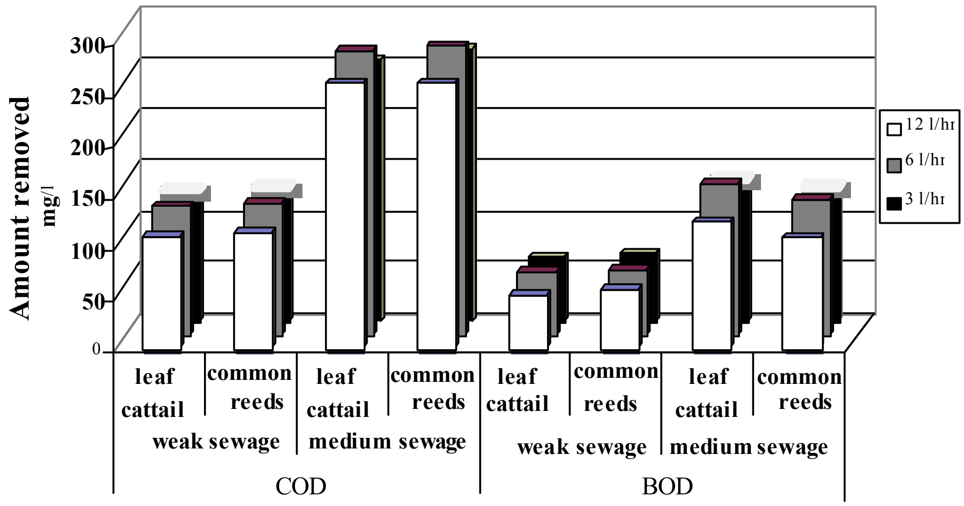

Fig. 1: Reduction in the initial levels of COD and BOD from weak sewage and medium sewage after treatment by constructed wetlands planted with leaf cattail and common reeds under different rates of sewage inflow

REFERENCES

1. EEAA, Egyptian Environmental Affairs Agency, 2004. The annual report of water quality of the River Nile and its branches. Ministry of State for Environmental Affairs, pp: 246.
2. MWRI, Ministry of Water Resources and Irrigation, 2002. Survey of Nile System Pollution Sources. Agricultural Policy Reform Program Report, 64: E-1.
3. Vymazal, J. and L. Kröpfelová, 2009. Removal of organics in constructed wetlands with horizontal sub-surface flow. Sci. Total Environ., 407: 3911-3922.
4. Vymazal, J., 2007. Removal of nutrients in various types of constructed wetlands. Sci. Total Environ., 380: 48-65.
5. Kuschk, P., A. Wießner, R. Müller and M. Kästner, 2005. Constructed wetlands: treating wastewater with cenoses of plants and microorganisms. A Research Association at UFZ Centre for Environmental Research Leipzig-Halle, Helmholtz Association, pp: 32.
6. Lorion, R., 2001. Constructed Wetlands: Passive Systems for Wastewater Treatment. Technology Status Report prepared for the U.S. EPA, pp: 29.
7. Ayaz, S. and L. Akca, 2001. Treatment of wastewater by natural systems. Environ. Inter., 26: 189-195.
8. Shrestha, R., R. Haberl, J. Laber, R. Manandahr and J. Mader, 2001. Application of constructed wetlands for wastewater treatment in Nepal. Water Sci. Technol., 44: 381-386.
9. Rousseau, D., P. Vanrolleghem and N. Pauwa, 2004. Constructed wetlands in Flanders: a performance analysis. Ecol. Eng., 23: 151-163.
10. Akratos, C. and V. Tsihrintzis, 2007. Effect of temperature, HRT, vegetation and porousmedia on removal efficiency of pilot-scale horizontal subsurface flow constructed wetlands. Ecol. Eng., 29: 173-191.
11. Avsar, Y., H. Tarabeah, S. Kimchie and I. Ozturk, 2007. Rehabilitation by constructed wetlands of available wastewater treatment plant in Sakhnin. Eco. Eng., 2(9): 27-32.
12. Vymazal, J., 1998. Removal of BOD_5 in constructed wetlands with horizontal sub-surface flow: Czech experience. In: Proceedings of the 6th International Conference on Constructed Wetlands for Wastewater Treatment, Aguas de Sao Pedro, Brazil, pp: 167-175.
13. Johnson, K. and P. Younger, 2006. The co-treatment of sewage and mine waters in aerobic wetlands. Eng. Geo., 85: 53-61.
14. Thomas, R. and J. Law, 1977. Properties of waste waters. In: Soils for Management of Organic Wastes and Waste Waters (Eds. R.C. Dinauer, *et al.*). Soil Science Society of America, American Society of Agronomy and Crop Science Society of America (publishers), Madison, Wisconsin USA, pp: 47-72.
15. ISO, International Standard Organization, 1990. Water Quality - Determination of Biochemical Oxygen Demand after 5 Days (BOD5), Dilution and Seeding Method. ISO 5815, Geneva, pp: 15.

16. Jirka, A. and M. Carter, 1975. Micro semi automated analysis of surface and wastewaters for chemical oxygen demand. Analytical Chem., 47: 1397-1402.
17. HMSO, Her Majesty's Stationery Office, 1980. Suspended, settle able and total dissolved solids in water and effluents. HMSO Publication, pp: 6-13.
18. APHA, American Public Health Association, 1989. Standard Methods for the Examination of Water and Wastewater (17th Ed.). Washington D.C., USA, pp: 116.