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PERFORMANCE OF A SUBSURFACE CONSTRUCTED WETLAND IN IRAN

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ABSTRACT

The high capital, operational and maintenance costs of municipal wastewater treatment plants in Iran are a concern for the government. Wastewater treatments in natural systems have shown suitable methods for their low cost. The performance of a pilot-scale subsurface constructed wetland with *Phragmites australis* to treat municipal wastewater has been investigated.The purpose of this study was to determine the surface area requirement per person in an arid region to achieve an acceptable quality in terms of discharge standards.

Experiments were carried out in two cells (15 x 10 mxm) with media size ranging from 4-8 mm. One cell was used as blank (unplanted) and the other one was planted. Different hydraulic loading rates ranging from 5 to 20 L/min were used. Minimum land requirement was determined to be 1-2 m^2/P.E. to reduce COD (86±4%), BOD_5 (90±3%), TSS (89±4%), TN (34±6%), TP (56±5%) and fecal coliform (>99%). © 1998 Published by Elsevier Science Ltd. All rights reserved

KEYWORDS

Constructed wetland; municipal wastewater; subsurface; Iran.

INTRODUCTION

Wastewater is purified during contact with media and the roots of reeds in constructed wetland. Physical, chemical and biological processes are involved in wastewater treatment. Aerobic and anaerobic bacteria growing on media and rhizomes are responsible for removal of organic carbon and nitrogen in wastewater (Reed *et al.*, 1988; Conly *et al.*, 1991).

There have been a lot of studies to treat municipal wastewater by constructed wetland in developed and developing countries (Reed *et al.*, 1988). The high capital and operational cost of activated sludge in Iran have attracted the attention of munincipality staff in charge of wastewater toward a low cost and appropriate method to treat wastewater. The appropriate methods have been determined to be facultative ponds and constructed subsurface wetlands (CSW) to achieve discharge standards (BOD_5, 30; TSS, 40 mg/L and total coliform 1000/100 ml for irrigation). There have not been enough data available for the performance of CSW in Iran.

The purpose of this study was to determine the land requirement per person in Tehran to treat municipal wastewater.

MATERIALS AND METHODS

Two identical cells were used. Each cell dimension was 10 m wide and 15 m long. The first 1.6 m of each cell designated as sedimentation basin. The rest of cell legth was filled with 4-8 mm gravel (media) up to 0.6 m from bottom of cell. The hydraulic conductivity of the media was measured (500 m/d). The media were covered with 15 cm of soil. One cell (wetland) was planted with *Phragmites australis* every 0.5 m.

Wastewater was pumped to each cell from a municipal wastewater treatment influent line. The influent was supplied from one point to each cell while the effluent was discharged from three points along the width of each cell. Three sampling wells were installed along the length of each cell.

Weekly measurements were made of COD, BOD_5, TSS of influent and effluent. Sampling was carried out by collecting samples from influent to sedimentation basin, wetland, blank (unplanted) and effluent from both cells. Analysis of TN, NH_4, NO_3, NO_2, organic nitrogen, total phosphorus and total coliforms were performed at the end of the experiment. All analytical measurement were done in accordance with the 19th edition of Standard Methods (APHA, 1992).

The experiment was run for nine months in four phases. In phase number 1, 2, 3 and 4 the flow rates were 5, 10, 20 and 20 L/min respectively. In phase number 4, the effect of wetland length and temperature were evaluated.

RESULTS

The results from the first phase of experiment with 5 L/min are shown in Table 1. Phase one was the start up of the experiment after planting reeds in wetland. It took 30 days for this phase to reach steady state conditions. The influent concentration to the sedimatation basin has been averaged from the beginning to the end of this phase. The change of BOD_5 during this phase is shown in Figure 1.

Table 1. Performance of the phase one at steady state

		Sed.	Wetland	Blank
BOD_5	IN(mg/L)	210±95	160±40	160±40
	OUT(mg/L)	160±40	28	10
	REM.%	20±15	82.5	94
COD	IN(mg/L)	284±97	226±20	226±20
	OUT(mg/L)	226±20	67	32
	REM%	15±23	70	85
TSS	IN(mg/L)	350±277	182±75	182±75
	OUT(mg/L)	182±75	90	48
	REM%	31	50	70
pH	OUT	7.45±0.13	7.68±0.29	7.68±0.3

In Figure 1 the first point is the influent concentration of BOD_5 to sedimentation basin and and the second point is the BOD_5 concentration into media for wetland and blank cell. The first effluent sampling has been carried out after one HRT in both cells. The BOD_5, COD and TSS removal efficiency in this phase was determined to be more in blank than in wetland.

The organic load as BOD_5 was determined to be 8.6 g/m^2 in wetland. The land requirement with 5 L/min for each person was determined to be 3.72 m^2.

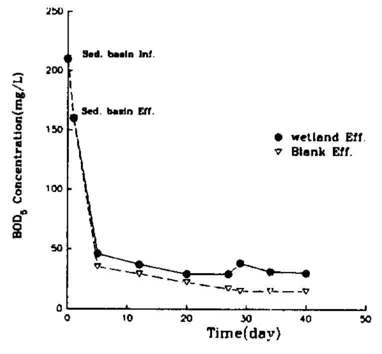

Figure 1. BOD_5 reduction in wetland and unplanted beds in phase one.

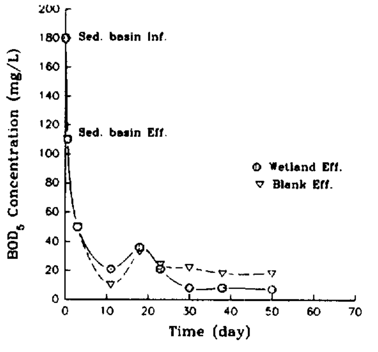

Figure 2. BOD_5 reduction in wetland and unplanted bed in phase two.

Table 2. Performance of the phase two at steady state

		Sed.	Wetland	Blank
BOD_5	IN(mg/L)	180±44	110±36	110±36
	OUT(mg/L)	110±36	7.3	18
	REM.%	38.6±4	93±2.5	82±6
COD	IN(mg/L)	317±120	150±46	150±46
	OUT(mg/L)	150±46	13	29
	REM%	51±4	91±2	79±6
TSS	IN(mg/L)	264±84	148±44	148±44
	OUT(mg/L)	148±44	32±16	28±23
	REM%	44±1	79±5	83±11
pH		7.47±0.25	7.47±0.2	7.33±0.2

Once the effluent quality had stabilized in phase one the flow rate was increased to 10 L/min. Results from phase number two are provided in Table 2. After one HRT, the effluent BOD_5 concentration was increased to 50 mg/L in wetland and blank cells. After one week the BOD_5 in effluent decreased to less than 25 mg/L in wetland and 10 mg/L in blank. Again the effluent quality started to increase until day 17. This could be from a shock load in influent. In this phase removal efficiency of wetland got better than blank from day seventeen. It took about forty days for the system to reach steady state conditions (Figure 2). This phase was run for 60 days. Land requirement for each person was determined to be 1.86 m^2.

The organic load as BOD_5 was 12±3.8 g/m^2.In phase three the flow rate was increased to 20 L/min in wetland and 15 L/min in blank. The reason for difference in the flowrate was the lack of pump capacity to discharge enough wastewater. Therefore there is no reason to compare wetland and blank in this phase. Results from this phase are shown in Table 3. Influent concentration to wetland was higher than influent concentration to sedimentation basin. The reason was that high flow rate resuspended the contents of the sedimentation basin which were settled from phase one and phase two. The change of BOD_5 in wetland and blank are shown in Figure 3. Doubling flow rate in wetland has increased effluent BOD_5 concentration to 40 mg/L and stabilized after fifty days to 19 mg/L.

The organic load as BOD_5 on wetland and land requirement in phase three was determined to be 45±21 g/m^2 and 1 m^2/PE. Twenty litres per minute was the maximum allowable flow rate to achieve Iranian Environmental Agency standards.

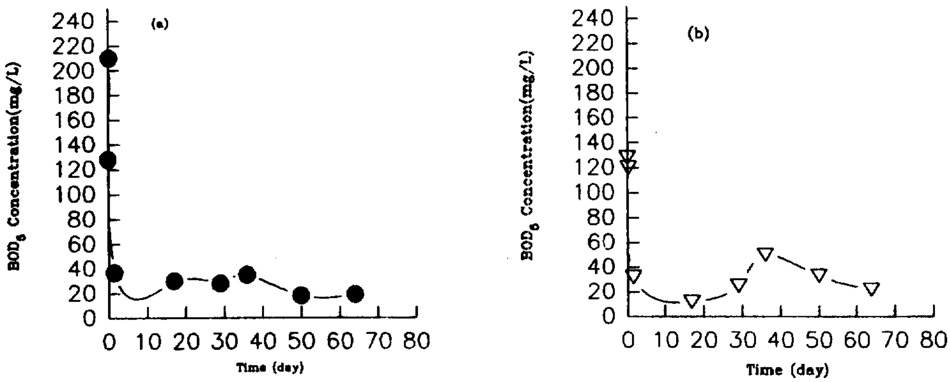

Figure 3.BOD_5 reduction in (a) wetland and (b) unplanted beds in phase three.

Table 3. Performance of the phase three at steady state

		Sed.	Wetland
BOD_5	IN(mg/L)	128±100	210±100
	OUT(mg/L)	210±100	19±4
	REM.%	-	90±3
COD	IN(mg/L)	307±88	300±100
	OUT(mg/L)	300±100	40±3
	REM%	3±4.5	86±4
TSS	IN(mg/L)	257±140	300±76
	OUT(mg/L)	300±76	36±20
	REM%	-	89±4
pH		7.29±0.12	7.23±0.1

Nutrient removal

Nutrients removal was evaluated when minimum land requirement was obtained. Thirty four percent nitrogen removal was achieved when flow rate was 20 L/min. Concentration of nitrate was increased from 0.96 mg/L as N to 20.47 mg/L as N. Ammonium and organic nitrogen removal were determined to be 70% and 98% respectively. Phosphorus reduction was determined to be 56%.

Pathgen removal

Total coliforms and fecal coliforms removal were measured in wetland and blank. Both cells have shown more than 99% removal. The number of coliforms and fecal coliforms were higher than discharge standards.

Temperature effect

Temperature effect on BOD_5, COD and TSS was evaluated for two months. The air temperature was dropped from 20°C to 8°C while wastewater temperature was dropped from 23°C to 13°C. Effluent BOD_5 concentration increased from 16 to 32 mg/L.

Effect of distance on removal efficiency

Figure 4 shows the BOD_5 at different points along the cell length parallel to the flow path. The first point (1.6 m) is the influent to the wetland after sedimentation basin. The most BOD_5 removal is observed in the first three metre of cell.

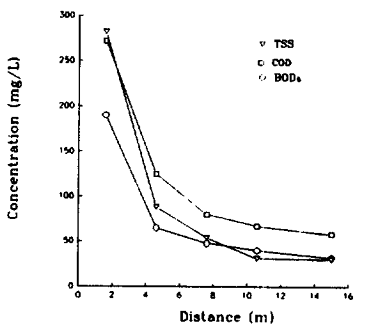

Figure 4. Effluent concentration of BOD_5, COD and TSS at different points in wetland.

DISCUSSION

The municipal wastewater was treated in constructed subsurface wetland. The system demonstrated the potential to reduce BOD_5, COD and TSS to standard levels. Removal efficiencies of BOD_5, COD and TSS were positively correlated with retention time. However, mass removal of BOD_5, COD and TSS increased with increasing organic load. This experiment has shown that it is possible to apply more organic load (200 kg/ha.d) on constructed subsurface wetland than has been reported by others (<133 kg/ha.d) (Metcalf and Eddy, 1991). These authors found that the most important design parameters in constructed subsurface wetland are HRT and organic load on cross section area of bed. In this experiment, the maximum allowable organic load was determined to be one kg/m^2 without clogging problems.

Nitrogen and phosphorus removal were poor in this study. In arid regions, effluent from wastewater treatment is being used for irrigation. Therefore nitrate and phosphorus can be used as fertilizer.

CONCLUSION

This experiment suggests that constructed subsurface wetland is an appropriate method to treat municipal wastewater in Iran. The high organic load in this method is applicable with 1-2 m^2/P.E. The important design parameter is determined to be the length of flow distribution and HRT to achieve good removal efficiecy.

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