CONSTRUCTED WETLANDS, AN ALTERNATIVE WAY OF WASTEWATER TREATMENT

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ABSTRACT

Wetlands hold properties that make them unique among major ecosystems on the earth. Wetlands are an edge habitat located in areas between terrestrial and aquatic ecosystems. The idea that natural wetlands posses the ability to treat various wastewater discharges owing to their high rate of biological activities has been known for a long time. Constructed wetlands mimic natural wetlands and are designed to treat municipal, agricultural and industrial wastewater from point and nonpoint sources. As wastewater flow through the system, suspended solids, nutrients, and organic materials are filtered, absorbed, or degraded by plants and microorganisms living in wetland. In many areas, septic tank systems with field lines are commonly utilized to treat wastewater discharges from households or other sources. These septic systems usually fail when soil percolation rates are inadequate for field lines to work properly. A subsurface or surface flow constructed wetland can provide further treatment of the effluent in these situations with minimal cost and maintenance. The objective of this study was to investigate the wastewater treatment efficacy and water quality improvement by six residential constructed wetland systems. The constructed wetlands are located in four Counties in north Alabama. Water samples were collected monthly for one year from inlet and outlet points of each cell within each system and analyzed for the following water quality parameters: biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), phosphorus (P), ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), total Kjeldahl nitrogen (TKN), and fecal coliform bacteria (FC). All the parameters analyzed were greatly reduced from influent to effluent points. The BOD_5 was reduced up to 85%, while FC bacteria reduction was as high as 99% at most of the sites. There was significant reduction in TSS (88%), TKN (74%), P (80%), and NH_4-N (56%) in most of the constructed wetlands. Data also showed that treatment of septic tank effluent continued.

INTRODUCTION

Wetlands serve as important links between aquatic and terrestrial systems and impact down-stream ecosystem productivity by serving as sinks, sources, and transformers of chemical contaminants and nutrients (Reddy 1993). Natural and constructed wetlands receive, hold, and recycle nutrients which are continually washed from upland regions or other sources. These nutrients support a wide variety of vegetation and microorganisms (Hammer and Bastian 1989). The ability of natural wetlands to treat and purify various wastewater has been known for a long time and has led to increased research in developing constructed wetlands specifically for this task (Bastian, Shanaghan, and Thompson 1989). A constructed wetland can be a surface or sub-surface flow system which closely resemble natural wetlands. Since discharges of wastewater to a natural wetland is an illegal action, constructed wetland have been designed to be legal receptors of polluted water. Constructed wetlands act as biofilters which possess the ability to remove chemical pollutants, viral and bacterial pathogens, and particulate matter through a variety of biological, chemical, and physical processes in the plant rizosphere (Gersberg et al, 1989; Burgoon, Reddy, and DeBusk 1989).

In rural areas, septic tank systems with field lines are commonly utilized to handle waste water discharged from households. These systems usually fail when the soils percolation rates are inadequate for the field lines to work properly. Small subsurface flow constructed wetlands can provide further treatment of septic tank effluent in these situations (Kadlec and Watson 1993).

The objectives of this study were: 1) To quantify the ability of selected constructed wetlands to improve water quality of septic tank effluent. 2) To evaluate the seasonal efficiency of these system with regard to wastewater treatment.

MATERIALS AND METHODS

A sub-surface flow constructed wetland for the treatment of wastewater has three components: A substrate (generally gravel or sand), emergent plants, and microorganisms to treat the wastewater passing through the cells. Six, one or two cell residential constructed wetlands located in four counties in North Alabama were selected for this study. Water samples were collected on a monthly basis for one year to cover all seasons with regard to temperature and other climatic factors. These systems were designed and installed by Tennessee Valley Authority (TVA) and Alabama Department of Public Health (ADPH). The residence names were: Terrell, Thompson, Mizell, Johnson, Waver and Venable (Table 1). Figure 1 shows a schematic of a typical constructed wetland. Wastewater samples were collected from effluent, influent and intermediate points for water quality analysis, and the following water quality parameters were determined: Biochemical oxygen demand (BOD), chemical oxygen demand (COD), Fecal coliform bacteria (FC), total suspended solids (TSS), Total Kjeldahl nitrogen (TKN), NH4-N, NO3-N, total phosphorus (TP), alkalinity (ALK), electrical conductivity (EC), and PH.

The wetland cells are from 30 to 50 cm deep, and usually have a 20 mm polyethylene liner, and are filled with 1.25 to 2.5 cm pea gravel. Each cell contains a perforated inlet header located 5 to 7.5 cm below the gravel surface and a perforated outlet header located at the bottom of the cell. The water level of these sub-surface flow systems was maintained approximately 5 cm below the surface of the substrate in order to prevent problems with odors, mosquitoes, and other insect victors. The gravel substrate in this type of system provide support for the vegetation, surface area for microorganisms to attach and colonize. The wastewater flows horizontally through the rhizosphere of the wetland plants, and this is where the treatment occurs through the processes of nutrient uptake, sorption, filtration, precipitation, oxygenation, and most importantly degradation. The effluent which exits, the wetland cells is collected in the outlet channel for discharge to a sand filter, field lines, or is recycled for further treatment.

Plants selected for these systems included variety of wetland and terrestrial species that have the following characteristics, roots with a high surface area, active colonizers possessing spreading rhizome systems, efficient in translocating oxygen to the rhizosphere to support the aerobic microorganisms, and produce large vegetative biomass for maximal water transpiration, and nutrient assimilation. These plant species included: Cattail (*Typha latipolia*), bulrush (*scirpus validus*), Canna lily (*canna flaccida*), day lily (*Hemerocullis sp*), Iris (*iris pseudacorus*), arrowhead (*SagiHaria latifolia*), pickerelweed (*Ponitederva lanceolota*), and maidencane (*Panicum hemitomon*).

RESULTS AND DISCUSSIONS

To simplify the results and avoid the repetition, only the data from one site will be presented and discussed here for all the parameters.

Terrell Residence

There was a significant decrease in BOD from influent to intermediate and from intermediate to effluent points (Table 1a). Over the 13 months sampling period, influent BOD ranged from 60 to 196.3 mg/L, while the effluent BOD ranged from 12.1 to 40 mg/L. The overall efficiency of constructed wetland to remove BOD from influent to effluent averaged 81.9% for the entire sampling period. This results is in agreement with the results from Gray and Biddlestone, 1995. The BOD is a measure of the amount of dissolved oxygen consumed by microorganisms while assimilating the organic waste present in the wastewater as the source of energy. The reduction in BOD of wastewater as it passes through the constructed wetland is of a major importance in determining the ability of these systems for treating wastewater discharge and improving the water quality. There was a significant decrease in BOD from influent to effluent points for all the seasons, however, the greatest reduction (86%) from influent to effluent points occurred during the spring season (Table 1a). The COD decreased significantly from influent to effluent points. The COD removal was significant for all the seasons (Table 1a). Inorganic nitrogen (NO_3-N and NH_4-N) were reduced significantly from influent to effluent points. The reduction was greater for NO_3-N than NH_4-N. This is due to the lack of oxygen in deeper part of the wetland which reduces nitrification of NH_4 to NO_3. The greatest reduction of NH_4-N occurred in winter followed by fall seasons (Tables 1a and 1b). The reduction of TSS generally is due to the processes such as filtration, sedimentation, and adsorption by plant roots and gravel surface as the waste water passes through these systems. The TSS reduction ranged from 10 to 85 percent from influent to effluent points (Tables 1a and 1b) Constructed wetlands are very efficient in removing FC bacteria. The removal processes are combination of filtration, adsorption, exposure to ultraviolet rays in sunlight, and natural die off. The efficiency of FC bacteria removal in most of the constructed wetlands studied was as high as 99 percent from influent to effluent points. Total Kjeldahl nitrogen (TKN) is a measure of NH_4-N plus organic-N is an important water quality parameter. The processes of nitrification followed by denitrification are the primary means of N removal in a constructed wetland. Table 2 show the average yearly and seasonal variation of TKN removal. Other parameters such as alkalinity (ALK), DO, EC, and TP were also reduced from influent to effluent points. However, the removal efficiency was different and insignificant from season to season (Tables 2 and 3).

Despite the few problems encountered, because, initially these systems were not designed and installed for research purposes, the overall efficiency of the constructed wetlands studied in treating the septic tank discharges on a year round basis proved to be very good to excellent. The data obtained from this study provided an indication of the potential wastewater treatment capabilities of small subsurface flow constructed wetlands for use at the residential and other suitable sites.

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Table 1a. Yearly and seasonal averages of the water quality parameters at Terrell residence.

POINT	BOD	COD	NO_3-N	NH_4-N	TSS	FC
	---mg/L---					Col/100 ml
Influent	125.47 a	247.33 a	1.83 a	30.47 a	208.58 a	595,250 a
Intermediate	60.99 b	161.45 b	0.56 b	24.18 b	124.75 b	64,617 b
Effluent	22.76 c	67.40 c	0.31 c	19.93 c	114.75 b	23,330 b

SEASON	BOD		COD		NO_3-N	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
	---mg/L---					
Summer	123.93 a	27.97 b	299.00 a	88.00 b	0.66 a	6.27 b
Fall	86.00 a	23.37 b	176.13 a	68.90 b	0.55 a	0.11 b
Winter	132.60 a	19.10 b	281.40 a	70.40 b	0.45 a	0.06 b
Spring	159.33 a	20.60 b	236.63 a	42.33 b	0.87a	0.18 b

Means followed by the same letter within each column for points, and within each row for seasons, within each parameter, respectively, are not significantly different at 5% level (DMRT).

Table 1b. Seasonal variation of NH_4-N, TSS, and FC for influent and effluent points at Terrell residence.

SEASON	NH_4-N		TSS		FC	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
	---mg/L---				col/100 ml	
Summer	21.67 a	14.63 b	317.70 a	214.30 b	1,016,667 a	1,987 b
Fall	31.60 a	20.40 b	211.00 a	116.67 b	393,333 a	57,600 b
Winter	28.00 a	12.20 b	155.67 a	60.00 b	267,667 a	5,167 b
Spring	40.60 a	32.50 b	150.00 a	68.00 b	703,333 a	28,567 b

Means followed by the same letter within each row for each parameter, respectively are not significantly different at 5% level (DMRT)

Table 2. Yearly and seasonal averages of the water quality parameters at Terrell residence.

POINT	ALK	TKN	TP
Influent	381.0 a	74.9 a	3.66 a
Intermediate	334.5 b	58.1 b	1.92 b
Effluent	315.3 b	51.3 b	1.29 b

SEASON	ALK		TKN		TP	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
	mg/L					
Summer	260.00 a	240.00 a	58.33 a	52.50 a	3.93 a	1.33 b
Fall	353.33 a	260.00 a	83.73 a	49.63 b	4.07 a	1.07 b
Winter	400.00 a	313.30 a	77.00 a	47.40 b	9.30a	1.27 a
Spring	530.67 a	428.00 b	80.83 b	56.00 b	4.33 a	1.50 b

Means followed by the same letter within each column for points, and within each row for seasons, within each parameter, respectively, are not significantly different at 5% level (DMRT).

Table 3. Seasonal variation of EC and DO for influent and effluent points at Terrell residence.

SEASON	EC		DO	
	Influent	Effluent	Influent	Effluent
	µs/cm		mg/L	
Summer	1.1 a	1.0 a	1.1 a	1.0 a
Fall	0.8 a	0.6 b	0.8 a	0.6 b
Winter	0.8 a	0.7 a	6.2 a	2.9 b
Spring	1.0 a	1.2 a	1.1 a	1.2 a

Means followed by the same letter within each row for each parameters, respectively are not significantly different at 5% level (DMRT).