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Full Length Research Paper

Phragmites Australis (Marsh Plant) as Wastewater Treatment Material

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In India, the most common method of disposal of waste water is by land spreading. This treatment method has numerous problems, namely high labour requirements and the potential for eutrophication of surface and ground waters. In this regard's some other alternative have to be introduced like sand filters and wetland, which are economical as well as less process charges. Constructed wetlands for wastewater treatment have substantially developed in the last decades. As an eco-friendly treatment process, constructed wetlands may enable the effective, economical, and ecological treatment of agricultural, industrial, and municipal wastewater. The present study reviews the recent developments in wetland technology for wastewater treatment as well as focus on affect and application.

Keywords*:* Contaminates; dissolved; drinking water; pollutants; plant cells

INTRODUCTION

Waste water treatment is big issue now days due to high cost of equipment and chemical. As well as some time it cannot be reduced the pollutant like heavy metal or contain nitrogen up to the required limit. Due untreated water affect the social (health) and nature (soil, flora and fauna) life. Especially when soil is polluted it affects all the system. It is due to spreading of untreated runaway and leachates. In land spreading on free-draining soils, the main nutrient removal processes are filtration, soil adsorption, microbial decomposition, and plant uptake. The latter two processes are active in reducing nitrate-nitrogen (NO_3-N) concentrations; however, if NO_3-N passes beyond the root zone it can be leached to the groundwater. Analyses of five Irish borehole (well) waters underlying light textured soils receiving high nitrogen (N) applications have yielded NO_3-N concentrations greater than the EU maximum allowable concentration (MAC) of 11.3 mg L^{-1} for drinking water (Richards et al., 1998). In that study, Richards et al. (1998) found, that in a plot comprising a sand loam overlying a sandy silt loam to 106 cm deep receiving a mean wastewater application rate of 677 kg N ha^{-1} yr^{-1}, mainly as organic N, soil water NO_3-N concentration was 23 mg NO_3-N L^{-1}. The Nitrate Directive, (EEC, 1991) has focused considerable attention on the disposal of agricultural wastewaters in India, where about 25% of the land area is devoted to dairy farming (Carton, 2001). A survey of 1132 rivers and streams from 2001 to 2003 (Toner et al., 2005) estimated that the percentage of pollution attributed to agriculture was approximately 32%, 32% and 15% in rivers and streams which were slightly, moderately, and seriously polluted, respectively.

In recent years, the use of constructed wetlands (CWs) for the waste water treatment has been gaining popularity, due to their relatively low capital costs and maintenance requirements. However, intermittent sand filtration (ISF) may have the potential to treat waste water effectively and, where denitrification is incorporated, to reduce NO_3-N to low levels. To date, the use of ISF for the treatment of agricultural wastewater has been limited. They have been used in the dewatering of swine wastewater following addition of organic polymers to increase settlement of suspended solids (SS) and organic compounds (Vanotti et al., 2005; Szogi et al., 2006) and in the treatment of detergent and milk fat wastewaters (Liu et al., 1998; Liu et al, 2000; Liu et al., 2003).

Phragmites Australis is a tall, aquatic perennial in the family of Gramineae. It is commonly known as Common Reed Grass. It is a gregarious plant, and can grow erect

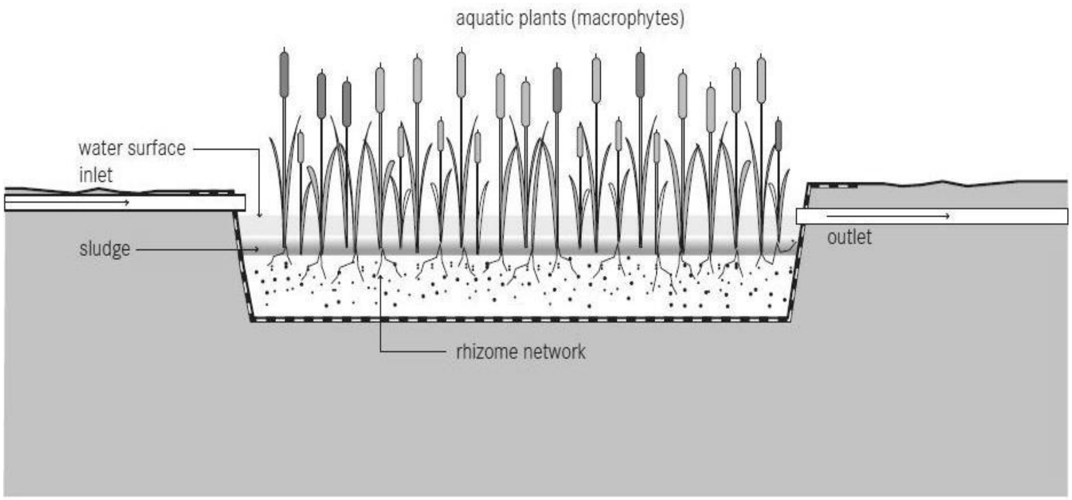

Figure.1: Systematic flow diagram of wetland

up to 4 m tall, with creeping stolons up to 20 m long. The stems grow up to 1.5 cm wide, are hollow and many noded. The leaves are 20-60 cm long by 8-30 mm wide and alternate. The inflorescence is 20-70 cm long on drooping panicles, dense with many fine branches, brownish when young but turn silver upon maturity.

Phragmites is a highly invasive plant. Phragmites can spread laterally throughout the year by producing new shoots from spreading rhizomes. Phragmites Australis also propagates through seeds and stem cuttings. However the seed germination rate is low. The plant grows abundantly in moist and water-logged areas, both freshwater and brackish, along rivers, ditches, lake shores and ponds. It is also common in abandoned mining areas. It is widespread throughout India. In this regard's an effort has been made to discuss the importance of wetland to treat the waste water with marsh plant.

Constructed wetland

The scientific studies on the use of CWs for wastewater treatment began in the middle of the last century. The first experiments were undertaken by Käthe Seidel in Germany in the early 1950s at the Max Planck Institute in Plön (Seidel, 1955). In her report, she discussed the possibility "of lessening the over fertilization, pollution and silting up of inland waters through appropriate plants, thereby allowing the contaminated waters to support life once more" (Seidel, Happel, & Graue, 1978). Author opines that macrophytes (e.g., Schoenoplectus lacustris) are capable of removing large quantities of organic and inorganic substances from polluted water. Moreover, Schoenoplectus spp. (bulrush) not only enriches the soil on which it grows in bacteria and humus but apparently exudes antibiotics. Bacteria and heavy metals in the polluted water are eliminated and removed by passing through the macrophytes. Constructed wetlands are wastewater treatment systems composed of one or more treatment cells in a built and partially controlled environment designed and constructed to provide wastewater treatment. While constructed wetlands have been used to treat many types of wastewater at various levels of treatment, the constructed wetlands described in this manual provide secondary treatment to municipal wastewater. These are treatment systems that receive primary effluent and treat it to secondary effluent standards and better, in contrast to enhancement systems or polishing wetlands, which receive secondary effluent and treat it further prior to discharge to the environment. This distinction emphasizes the degree of treatment more than the means of treatment, because the constructed wetlands described in this manual receive higher-strength wastewater than the polishing wetlands that have been widely used as wastewater treatment systems for the last 20 years. The basic flow diagram of CW is shown Figure 1.

Constructed wetlands (CWs) have been proved to be "cost-effective" methods for wastewater treatment. They also provide other landscape and social benefits such as wildlife habitat, research laboratories, and recreational uses (U.S. EPA, 1999). CWs are artificial wetland systems that are designed to exploit the physical, chemical, and biological treatment processes that occur in wetlands and provide for the reduction in organic material, total suspended solids, nutrients, and pathogenic organisms. CWs emulate the natural treatment processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality (Arroyo, Ansola, & Luis, 2010). The

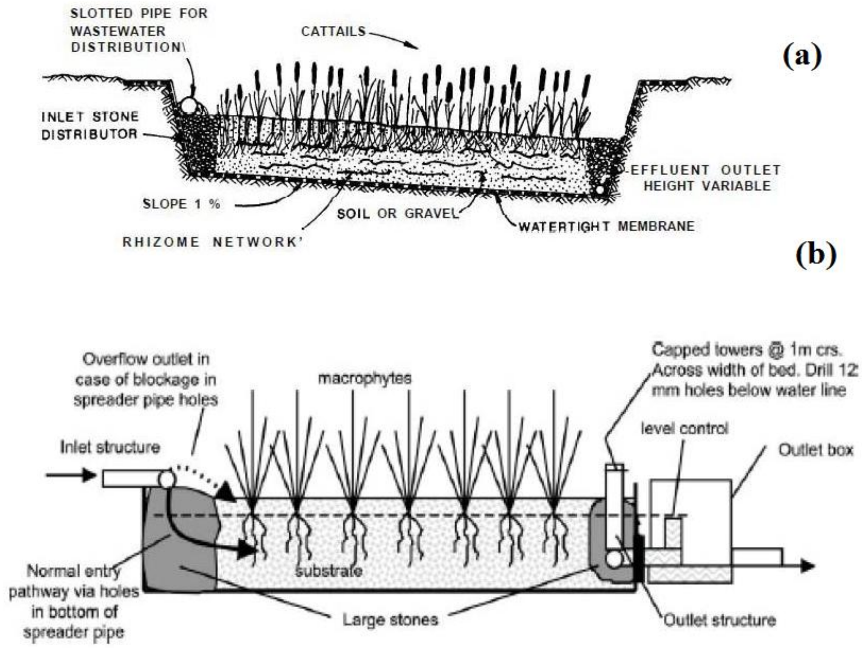

Figure 2. Types of constructed Wetland (a) Free water surface (b) Subsurface

vegetation and microbial communities in the wetlands can adapt to the wastewater inflow and utilize the various organic and inorganic pollutants during their metabolic and other life processes (Brix, 1994). Compared with the conventional treatment process, CWs provide advanced wastewater treatment that is highly valued but of low cost in terms of investment, operation, and maintenance. How to integrate wastewater treatment processes with the landscape-featured CW poses a challenge to landscape architects. And how to wisely use and manage the irrigation water is another important consideration.

Types of Constructed wetland

There are two types of CW: free water surface constructed wetlands (FWS CWs) and subsurface CWs. In FWS CWs, wastewater flows in a shallow water layer over a soil substrate which is shown in Figure 2.

Subsurface CWs may be either subsurface horizontal flow CWs (SSHF CWs) or subsurface vertical flow CWs. In SSHF CWs, wastewater flows horizontally through the substrate. In SSVF CWs, wastewater is dosed intermittently onto the surface of sand and gravel filters and gradually drains through the filter media before collecting in a drain at the base. CWs may be planted with a mixture of submerged, emergent and, in the case of FWS CWs, floating vegetation. The large surface area of CWs provides an environment for the physical/physico-chemical retention and biological reduction of organic matter and nutrients (Geary and Moore, 1999; Knight et al., 2000). Depending on the type of CW used, its design, organic loading rate and hydraulic retention time (HRT) (Karpiscak et al., 1999), a CW can have a significant nutrient removal capability. However, due to the effect of changing temperatures, the treatment efficiency of these systems tends to change throughout the year (Bachand and Horne, 2000; Healy and Cawley, 2002).

Factor affects the wetland

Media selection

For FWS CWs, a substrate rich in iron, calcium and aluminium is recommended. For SSHF CWs, a soil or gravel is recommended (Cooper et al., 1996). In SSVF CWs, an active sand layer with a depth of 1.0 m (effective grain size, d_{10}=0.25 – 1.2 mm, coefficient of uniformity, Cu<3.5) is recommended (Brix and Arias, 2005).

Loading control

FWS CWs and SSHF CWs are normally sized in accordance with (Kadlec and Knight, 1996):

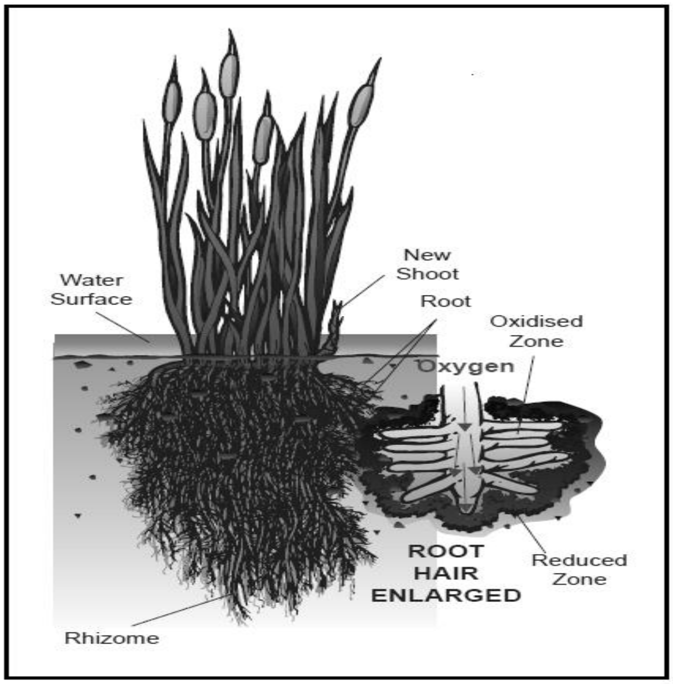

Figure 3 . The extensive root system of marsh plants (modified from Cooper *et al.*, 1996)

$$A = \left(\frac{0.0365Q}{k}\right)\ln\left(\frac{C_i - C^*}{C_e - C^*}\right) \quad (1)$$

Where A = required wetland area (ha)
C_e = the outlet concentration (mg L^{-1})
C_i = inlet concentration (mg L^{-1})
C* = background concentration (mg L^{-1})
k = first-order areal rate constant (m yr^{-1})
Q = hydraulic loading rate (m d^{-1})

Depending on the water quality parameter used to size the CW, the constants in the model (C* and k) may be different for FWS CWs and SSHF CWs (Kadlec and Knight, 1996). For example, if using BOD_5 to size a CW, $C^* = 3.5 + 0.053C_i$ for a FWS CW or a SSHF CW and k would be 34 and 180 m yr^{-1} for a FWS CW and a SSHF CW, respectively (Kadlec and Knight, 1996). In CW design, it is difficult to account for variables such as climate variation, pre-treatment control, and time to maturation. Therefore, design guidelines tend to be conservative. Organic and SS loading rates not exceeding 6 g BOD_5 m^{-2} d^{-1} and 5 g SS m^{-2} d^{-1}, respectively, are recommended for FWS CWs (US EPA, 1992). SSVF CWs may be operated in single-pass mode, intermittently loaded 8-12 times d^{-1}, or in recirculation mode, intermittently loaded 16 – 24 times d^{-1} (Brix and Arias, 2005). Winter and Goetz (2003) recommend a maximum organic loading rate of 20 g COD m^{-2} d^{-1} and a maximum SS influent concentration of 100 mg L^{-1} for SSVF CWs. Even when these loading conditions are satisfied, the performance of CWs may be variable.

Selection of plant

India has a cool temperate west maritime climate. In these climatic conditions, common reed (*Phragmites australis* (Cav.) Trin. ex Steud.) and common cattail (*Typha latifolia* L.) are mainly planted in CWs. As the amount of oxygen released by the emergent vegetation into the surrounding soil is small (Armstrong et al., 1990), anaerobic conditions predominate. Harvesting of the emergent macrophytes has a pronounced effect on the growth and nutrient uptake rates. Although nutrient uptake and growth rates are higher in young vegetation stands (Greenway and Whoolley, 2001), other factors such as nutrient loading and hydraulic retention time (HRT) may significantly affect the uptake rates (Reddy et al., 2001; Hardej and Ozimek, 2002). In cool temperate west maritime climates, shoot re-growth depends on the time of year at which harvesting takes place. Harvesting during June/July produces good shoot re-growth, whereas August/September harvesting tends not to produce significant re-growth (figure 3).

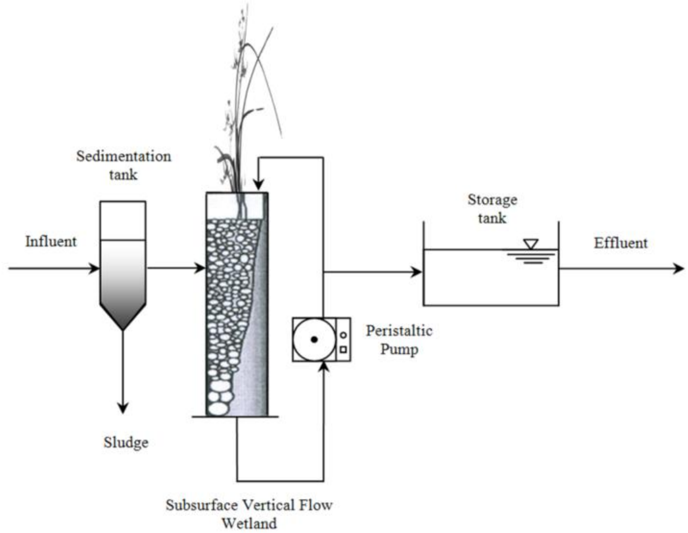

Figure 4. Combined model of sand filter and wetland

Temperature:

Although temperature affects the performance of FWS CWs, SSHF CWs and SSVF CWs, they generally meet relevant effluent discharge criteria in colder climates (Maehlum et al., 1995; Vymazal, 2002; Rousseau et al., 2004). In Europe, effluent BOD_5 and SS standards for discharge into surface waters range from 250 mg BOD_5 L^{-1} in the India to 25 mg BOD_5 L^{-1} in Austria and 70 mg SS L^{-1} in the India to 35 mg SS L^{-1} in the Czech Republic, respectively (Rousseau et al., 2004). In Norway, where mean winter temperatures can drop below -10^{o}C, Maehlum et al. (1995) used an CW to treat septic tank wastewater. Under an organic loading rate of approximately 4 g BOD_5 m^{-2} d^{-1}, BOD_5 and Tot-N was removed by 93% and 48%, respectively.

Comparatively study between sand filters and constructed wetland

Sand filters have been used for the treatment of domestic wastewater for over a hundred years. Sand filters may be operated either in single-pass or recirculation mode. In single-pass mode, following primary sedimentation, the wastewater is intermittently dosed onto a stratified sand filter (Gross and Mitchell, 1985). On a single pass through the system, organic carbon removal, ammonification and nitrification occur. Factors affecting the retention of bacteria in porous media include straining, the grain size of the filter media, and the hydraulic loading rate (Stevik et al., 2004). Removals of greater than 99.9% have been recorded for faecal coliforms (Vanlandingham and Gross, 1998). A study comparing single-pass sand filters (33.5 m^2), FWS CWs (53 m^2), and peat biofiltration systems (28 m^2) for the treatment of septic tank effluent (Puraflo^{TM}, Bord na Mona, India) has shown that single-pass sand filters have the greatest organic and nutrient removal efficiency, although the difference in performance between the sand filtration and peat biofiltration systems is small (White, 1995). White (1995) measured organic carbon removals of 92% and nitrification of 91% for sand filters. Organic carbon removals of 87 and 82% were measured for the peat biofiltration and constructed wetland systems, respectively. No nitrification occurred in the constructed wetlands, and the percentage nitrification in the peat biofiltration systems was 90%.

Virus removal has also been estimated to occur in the first 30 cm of stratified sand filter sand (Gross and Mitchell, 1985; Gross, 1990), although removal is dependent on the hydraulic loading rate and degree of saturation of the filter (Reneau et al., 1989). In a series of columns containing medium concrete sand (d_{10} = 0.32 mm) and loaded with dechlorinated tap water containing MS2 bacteriophage at hydraulic loading rates of 51, 81, 12.2, and 16.3 L m^{-2} d^{-1}, Vanlandingham and Gross (1998) found average MS2 phage removal efficiencies of 99.6%, 98.6%, 99.9%, and 97.2%, respectively

Constructed wetland remove organic matter, SS and nitrify N (Brix et al., 2002; Weedon, 2003) but, similar to sand filter, have poor long-term P removal rates (Brix and Arias, 2005). Both systems are limited by the maximum organic loading rate that may be applied to their surfaces. Depending on the strength of the influent wastewater, a maximum organic loading rate of approximately 24 g COD m^{-2} d^{-1} may be applied in ISF (Rodgers et al., 2005), whereas a maximum organic loading rate of 20 g COD m^{-2} d^{-1} is recommended for SSVF CWs (Winter and Goetz, 2003). SSVF CWs are differentiated from SF by their surface covering of emergent vegetation which affects the infiltration of wastewater into the filter media (Molle et al., 2006). The combined constructed with wetland and sand filter was shown in Figure 4.

Application

Wastewater must undergo septic tank pre-treatment prior to entering a CW (EPA, 2000). In municipal wastewater treatment, an activated sludge plant provides initial settlement, organic carbon removal and partial nitrification (Healy and Cawley, 2002). To protect against groundwater contamination, all FWS CWs, SSHF and SSVF CWs should be lined with an impervious layer e.g., a high density polyethylene liner (HDPL).

SSHF CWs are ideal for cold climates because wastewater treatment occurs below the surface (Werker et al., 2002). They are the most common CW system used in Europe (Vymazal, 2005). SSHF CWs have good organic, SS and faecal coliform removal rates but have poor NH_4-N removal rates (Neralla et al., 2000; Weaver et al., 2001; Steer et al., 2005, Vymazal, 2005). In Texas, USA, Neralla et al. (2000) monitored 8 SSHF CWs comprising gravel media ranging in size from 0.95 to 1.6 cm and receiving domestic effluent from a septic tank. Under organic loading rates ranging from 2 to 5 g BOD_5 m^{-2} d^{-1}, average effluent BOD_5 and SS removals of 80% and 88%, respectively, were measured. An average NH_4-N removal of 39% was also measured and nitrification did not occur. These results were similar to Steer et al. (2005) who studied the performance of 8 SSHF CWs treating domestic effluent, comprising two 25m^2 SSHF CWs connected in series and preceded by a septic tank. Over a 5 yr. duration, average BOD_5 and SS removals of 69-98% and 77-83%, respectively, were measured and NH_4-N was reduced by approximately 70% .

SSVF CWs are commonly used for domestic wastewater treatment. When the organic loading rate does not exceed a maximum allowable organic loading rate of 20 g COD m^{-2} d^{-1} (Winter and Goetz, 2003), they effectively remove organic matter, SS and nutrients (von Felde and Kunst, 1997). Luederitz et al. (2001) intermittently loaded a SSVF CW, comprising a 0.6 m active sand layer (sand/gravel, 0 – 4 mm) 800 m^2 in area and preceded by an anaerobic digester, at an organic loading rate of 35 g COD m^{-2} d^{-1} (21 g BOD_5 m^{-2} d^{-1}) and measured a COD removal of 94% and Tot-N removal of 61%. With a SSVF CW having the same active sand layer but preceded by two unaerated ponds and receiving an organic loading rate of 20 g COD m^{-2} d^{-1} (10 g BOD_5 m^{-2} d^{-1}), COD and Tot-N removals were 99.5% and 93.8%, respectively.

Recently, a modified version of the SSVF CW, the two-stage vertical flow constructed wetland (VFCW), has been gaining popularity in France, where there are currently around 400 VFCWs in operation (Molle et al., 2006). The first stage of this system comprises 3 parallel vertical flow sand filters which are alternately intermittently dosed with raw wastewater at an organic loading rate of 300 g COD m^{-2} d^{-1}. In this first stage, COD and SS removal takes place. They contain a 30 cm-deep fine gravel layer (2-8 mm in size) which overlies a 10-20 cm-deep transition layer (5 mm in size) and a 10-20 cm-deep drainage layer (20-40 mm in size) (Molle et al., 2005). The second stage comprises two identical vertical flow sand filters which contain a 30 cm-deep fine gravel layer (effective grain size, d_{10} < 0.40 mm) which overlies a 10-20 cm-deep transition layer (3-10 mm in size) and a 10-20 cm-deep drainage layer (20-40 mm in size) (Molle et al., 2005). Nitrification mainly occurs in the second stage. Results from these systems have been good with COD and SS removals of 90% and 95%, respectively, being measured and nitrification at 85% (Molle et al., 2005).

FWS CWs are also effective in organic matter, SS, and faecal coliform removal (Ran et al., 2004) but, similar to SSHF CWs, have low N removals (Healy et al., 2004; Ran et al., 2004). Studies have reported settlement as the main N removal pathway (Toet et al., 2005). In a 2-cell FWS CW, planted with duckweed and preceded by a preliminary storage tank and a primary sedimentation tank, Ran et al. (2004) measured average BOD_5 and SS removals of 71% and 80%, respectively, when the system was loaded at an organic loading rate of 16 g BOD_5 m^{-2} d^{-1}. Removal of N within the system seemed to be due mainly to sedimentation and plant uptake, as NH_4-N removals of 14% were measured.

When FWS CWs are in a marsh - retention pond - marsh formation, low flushing rates and little surface cover means that eutrophication may occur in the retention pond during warmer periods of the year (Healy and Cawley, 2002). In a 2-year study of a 3-cell FWS CW for tertiary treatment of municipal wastewaters in Williamstown, India, Healy and Cawley (2002) measured average BOD_5 and SS removals of 49% and 90%, respectively but noted the occurrence of algal blooms in the retention pond during the summer months.

N removal in CWs is accomplished primarily by physical settlement, denitrification and plant/microbial uptake. Plant uptake does not represent permanent removal unless plants are routinely harvested. Phosphorus (P) is removed through short-term or long-term storage. Uptake by bacteria, algae and duckweed (Lemma *spp.*), and macrophytes provides an initial removal mechanism (Kadlec, 1997). However, this is only a short-term P storage as 35%-75 % of P stored is eventually released back into the water upon dieback of algae and microbes (Richardson and Craft, 1993; White et al., 2000). Anaerobic conditions which exist at the soil/water interface may also cause the release of P back into the water column (Patrick and Khald, 1974). The only long-term P storage in the wetland is via peat accumulation and substrate fixation. The efficiency of long-term peat storage is a function of the loading rate and also depends on the amount of native iron, calcium, aluminium, and organic matter in the substrate (Shatwell and Cordery, 1999). Lake and reservoir sediments have been shown to act as P sinks (Richardson and Craft, 1993; White et al., 2000). At P loading rates of less than

5g P m^{-2} yr^{-1}, wetland sediment can absorb greater than 90% of the total incoming P (Faulkner and Richardson, 1989).

CONCLUSIONS

The wetland technology for wastewater treatment is continuously improving. Numerous papers and investigations about wetland technology have been published in the past year. Although all the studies reviewed in this paper focused on the enhancement of wetland treatment, a variety of methods were involved. Some studies were based on engineering technology and some were applications of chemical analysis methodology. The review is helpful in keeping updated with the current trends in the development of wastewater treatment wetlands. Vegetation increases the removal rates of all wetland types for all types of pollutants. However, the species of the vegetation does not significantly influence the removal rates. Further research is needed to explore the capacity of other porous substrates and the feasibility of combined substrates. Similarly, investigations on wet-drying hydraulic loading are needed to test other types of wetlands. Additionally, the effect of the environment should be tested in further assessments of wetland treatment.

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