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Full Length Research Paper

Investigation of decontamination effect of *Phragmites australis* for Konya domestic wastewater treatment

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In this study, decontamination effect of *Phragmites australis* for Konya domestic wastewater treatment was searched. For this reason, pilot subsurface horizontal flow constructed wetland including 3 pools was formed by using reed (*Phragmites australis)*. The mean decontamination rate of domestic wastewater, retention time for 3.96 days in the pool, was 64.5% for biological oxygen demand (BOD), 68% for chemical oxygen demand (COD), 79.7% for suspended solids (SS), 21.0% for Total Phosphorus (TP) and 20.7% for total nitrogen (TN), and increased with other tested retention times (4.56 and 5.4 days). These types of systems are generally more economical in terms equipment and maintenance costs, when compared with other treatment systems. Treatment of domestic wastewater in rural areas (for maximum ten thousand population) with this natural system will extremely provide benefits in prevention of environmental pollution.

Key words: Domestic wastewater, wastewater decontamination, *Phragmites australis*, reed, natural treatment.

INTRODUCTION

Domestic wastewater collection and treatment are an important environmental problem in our country as this is the case in all over the world. Turkey has limited sources in terms of drinking water and potable water. For this reason, it's necessary to treat domestic wastewater in a planned way and use it for irrigation water. Nowadays, the wastewater discharged to environment without any treatment has started to pollute underground water by streams, rivers, lakes and seas, even by leakage and has become a threat to the environment and human health (Anonymous, 2004a). Therefore, researches related with determination of water quality, treatment of wastewater and ecotoxic effects of wastewater has recently increased in our country (Akkoz et al., 2009; Ozdemir et al., 2010a, b; Karadavut et al., 2010, 2011; Ozdemir et al., 2011; Kalipci and Ozdemir, 2011).

The negative effects of domestic and industrial wastewaters discharged to our water sources without any treatment on our water sources matter to environment and public health as well as economy. It's necessary to treat contaminant loads of wastewater in order to do no harm to environment or to be used again. Different contaminant properties of this water bring about the necessity of different physical, chemical and biological treatment processes. These mentioned processes require expensive technological equipments, consumables as well as high operational cost and information. The usage constrictions of stated systems increase one's charm for "Natural Treatment" methods based on using just natural materials and methods (Anonymous, 2004b). In recent years, the use of constructed wetland has increased all around the world for the treatment of wastewater. It was informed that the approximate number of constructed wetland is 50.000 in Germany, 1000 in Austria, 800 in England, 300 in Italy, 200 in Denmark, 160 in Czech Republic, 120 in Portugal and 8000 in North America (Vymazal, 2005).

In this study, it was aimed to treat Konya domestic wastewater by using *Phragmites australis* plant in subsurface horizontal flow constructed wetland. In constructed wetlands, the main disadvantage of surface flow systems is smell problem and increase of

Abbreviations: HRT, Hydraulic retention time; **SS,** suspended solids; **COD,** chemical oxygen demand; **BOD_5,** biological oxygen demand; **TP,** total phosphorus; **TN,** total nitrogen.

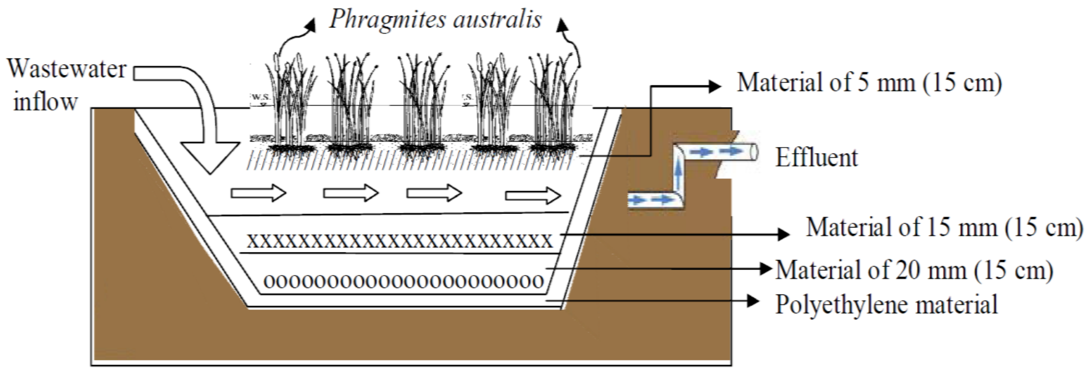


Figure 1. Schematic appearance of pilot scale subsurface horizontal flow constructed wetland system (The schematic appearance of only one pool is shown in Figure 1).

Figure 2. *Phragmites australis* planted in pilot scale subsurface horizontal flow constructed wetland system.

mosquitoes and others in number. Since the plants are quite dense, an accurate success is not gained in mosquito control (OEMC, 2001). The most important advantages of subsurface flow wetlands are giving off less smell, not permitting the reproduction of mosquitos and others which pose problems in surface flow systems, its efficiency in decreasing the amount of algae in the effluent of rock or gravel bed (EPA, 1999). In this study performed for this reason, decontamination of Konya domestic wastewater was searched by using subsurface horizontal flow system.

MATERIALS AND METHODS

Study field

The study field constituted of three pools which was constructed on 50 m^2 area having 5 m × 10 m × 0.60 m (width × length × depth) dimension in the city center as a pilot scale horizontal flow wetland system. The clearing pool was compressed in order to provide impermeability by digging 90 cm and was covered with polyethylene material. The bed depth was 60 cm and bottom slope was 0.05%. Along the bed depth, 20 mm-material each of them having 20 cm thickness, then 15 mm-size material and 5 mm-coarse sand material, where *P. australis* was planted on top, were spread from bottom to the surface. The density of plant was 4 plant/m² and the level of water was 5 cm lower than the surface. The schematic appearance of the experimental study system (for only one pool) is shown in Figure 1.

The Properties of the Plant used in the Study Field

In pilot scale subsurface horizontal flow constructed wetland system, *P. australis* plant (Figure 2) which is easily found in the region was used. *P. australis* belongs to Poaceae (Gramineae) family and is quite common in stream and lake sides and in water in our country. It's a European-Siberian element having wide distribution. *P. australis* is a genotype having economical importance. It is considered as invasive species which can spread at 4.5 m having 5-15 mm stock thickness. It's grown in places that are well-watered and the ground water level is high. The pH of the

Table 1. Amount of pollution for wastewater before treatment (mg/l).

Parameter	Value	The results of analysis
BOD	Maximum	356.0
	Minimum	184.0
	Medium	268.5
COD	Maximum	528.4
	Minimum	268.4
	Medium	318.4
SS	Maximum	184.0
	Minimum	106.0
	Medium	141.3
TP	Maximum	16.4
	Minimum	9.2
	Medium	12.6
TN	Maximum	68.1
	Minimum	41.5
	Medium	58.7

habitat should be within the limits of 4.8 and 8.2. It is a durable, creeping, with rootstock and stolon perennial plant. Its rootstocks have the property of growing horizontally and its roots penetrate into the deep. Its roots divaricate strongly. They can reach 1 to 2 m length. Its rootstocks may trail from 2 m to 20 m in a year. In these plants, approximately 80% of the biomass is in the roots and 20% of it is in the upper green part. The leaf blades become scanty in bottom parts and may grow up to 60 × 3 cm. The plant constitutes of cellulose in the rate of 50% and has fibrils having 0.8-3.0 mm length and 5.0-30.5 cm thickness. This mentioned plant may be cultivated by seeds and rootstocks, but its common cultivating method is by rootstocks (Batterson and Hall, 1984; Davis, 1985; Secmen et al., 1995; Baytop, 1997; Ozer et al., 1999).

METHODS

In this study, *P. australis* plant was planted to 3 constructed wetlands and water samples were taken from influent and effluent of the treatment system. Hydraulic retention time (HRT) was determined according to the following equation from Metcalf and Eddy (1991). According to this, the hydraulic retention time for 2.75, 3.25 and 3.75 m^3/day flow rate in the constructed wetlands was determined as HRT = 5.4 day, HRT = 4.56 day and HRT = 3.96 day, respectively.

$$t = \frac{nLWd}{Q}$$

Where t = retention time (day), n = effective porosity of the medium (%), L = bed length (m), W = bed width (m), d = bed depth (m), Q= average flow in the bed (m^3/day/ m^2).

Based on the results of analysis applied to the samples, the removal rates of main pollutant factors such as suspended solids (SS), chemical oxygen demand (COD), biological oxygen demand (BOD_5), total phosphorus (TP), and total nitrogen (TN) were determined.

Analysis of data

The analysis was carried out both in the field and in the laboratory. Temperature and pH values were measured with WTW pH 330i / SET equipment, dissolved oxygen with WTW OXİ 340i / SET equipment, total solid matter and salinity with WTW LF 330i / SET equipment, turbidity with WTW TURB 355 IR (Portable Turbidimeter / 0 -1100 NTU) equipment in the field and the following analysis were carried out in the laboratory.

BOD_5 analysis was performed with WTW Oxi Top IS 12 system, COD measurements were taken by using COD (5220)/ Closed Reflux, colorimetric method and standard methods method. SS analysis was determined gravimetrically by TSS 2540 D standard methods. TP analysis was determined colorimetric by standard methods 4500 PC. In the analysis of TN measurements, Apollo 9000 TOC – TN Analyzer was used.

RESULTS AND DISCUSSION

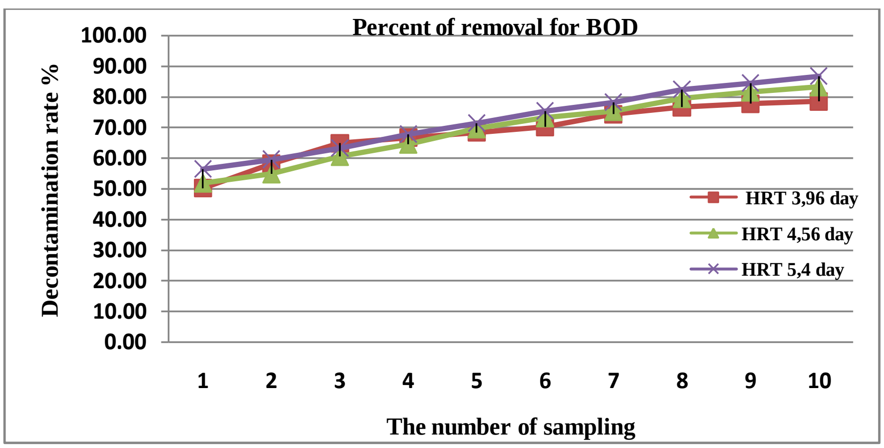
Within the scope of this research, the results of pollution analysis for the samples taken before treatment of domestic wastewater given to the system are given in Table 1. When the results of pollution analysis for the samples taken before treatment of domestic wastewater given to pilot scale subsurface horizontal flow constructed wetland system are considered, the average values were determined as BOD 268.5 mg/l, COD 318.4 mg/L, SS 141.3 mg/L, TP 12.6 mg/L and TN 58.7 mg/L.

The analysis results of effluent samples belonging to constructed wetlands rested for 5.4, 4.56 and 3.96 day with 2.75, 3.25 and 3.75 m^3/day flow rates taken from constructed wetlands where *P. australis* plant was present were evaluated and their treatment efficiencies (%) are given in Table 2.

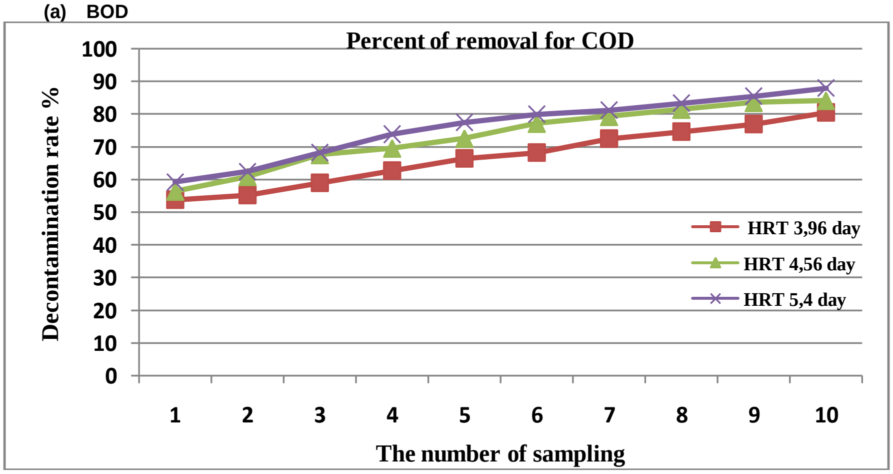
Average removal rates in the pool which is rested for 3.96 days in constructed wetland system were determined as 64.5% for BOD, 68.0% for COD, 79.7% for SS, 21.0% for TP and 20.7% for TN (Figures 3 to 5). Average removal rates of the domestic wastewater which is rested for 4.56 days in the pool were determined as 65.1% for BOD, 70.8% for COD, 81.8% for SS, 22.7% for TP and 21.9% for TN. Average removal rates of the domestic wastewater which is rested for 5.4 days in the pool were determined as 71.2% for BOD, 75.1% for COD, 87.3% for SS, 24.5% for TP and 23.5% for TN (Figures 3 to 5). In the study of Dunne et al. (2004), it was determined that wetlands might be suitable for treatment when BOD, SS, NH_4 and soluble reactive phosphorus were considered. Al-Omari and Fayyad (2003) performed a study related with the performance of subsurface flow constructed wetlands for the treatment of domestic wastewater in Jordan. The results showed that subsurface flow systems had the capacity for the removal of BOD, various forms of nitrogen, SS and fecal coliforms. Batty and Younger (2004) determined that

Table 2. Treatment efficiencies (%) for different HRTs in constructed wetlands where *Phragmites australis* plant was present.

Parameter	Value	HRT = 3.96 day	HRT = 4.56 day	HRT = 5.4 day
BOD	Maximum	78.5	83.2	86.7
	Minimum	50.2	51.8	56.4
	Medium	64.5	65.1	71.2
COD	Maximum	80.4	84.1	87.9
	Minimum	53.8	56.3	59.2
	Medium	68.0	70.8	75.1
SS	Maximum	88.2	90.5	96.8
	Minimum	71.2	73.5	78.4
	Medium	79.7	81.8	87.3
TP	Maximum	36.9	38.4	41.2
	Minimum	6.2	6.4	6.9
	Medium	21.0	22.7	24.5
TN	Maximum	28.7	30.1	32.4
	Minimum	13.1	14.1	16.8
	Medium	20.7	21.9	23.5



(a) BOD



(b) COD

Figure 3. Removal rates in constructed wetlands for 2.75, 3.25 and 3.75 m^3/ day flow rates (a) BOD and (b) COD.

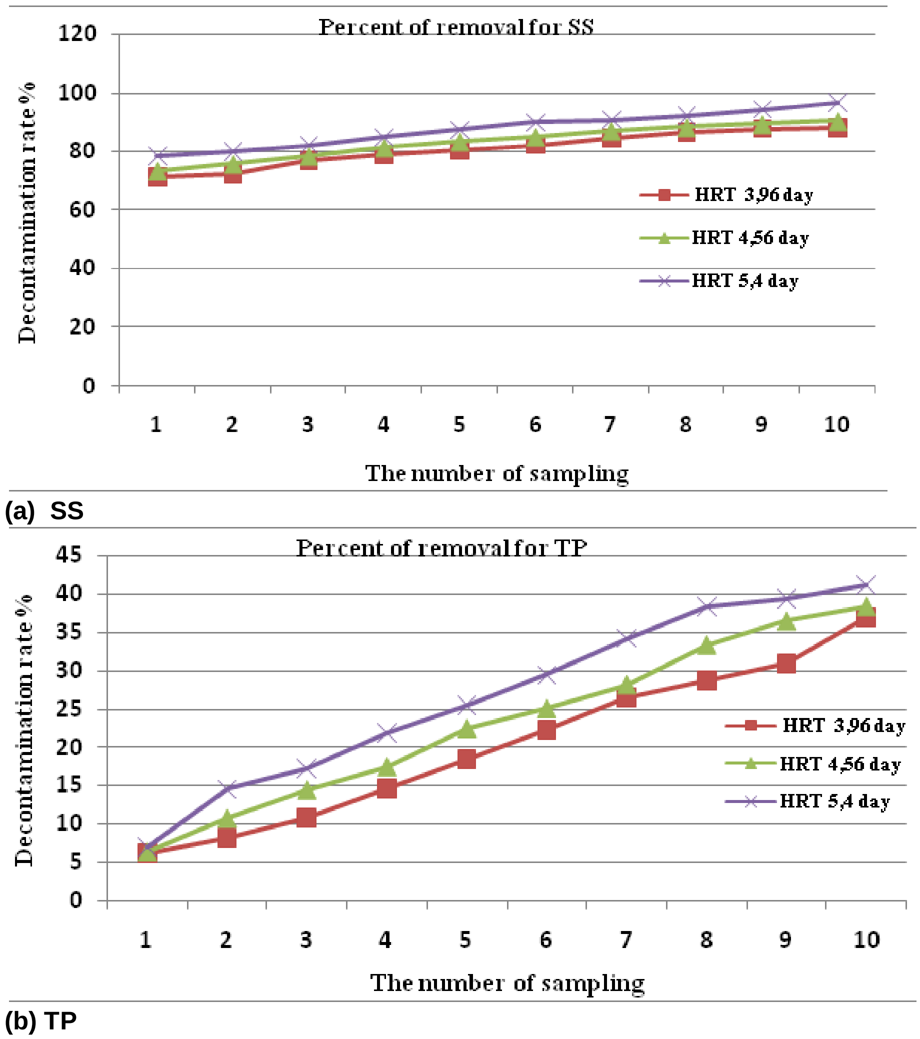


Figure 4. Removal rates in constructed wetlands for 2.75, 3.25 and 3.75 m^3/ day flow rates (a) SS and (b) TP.

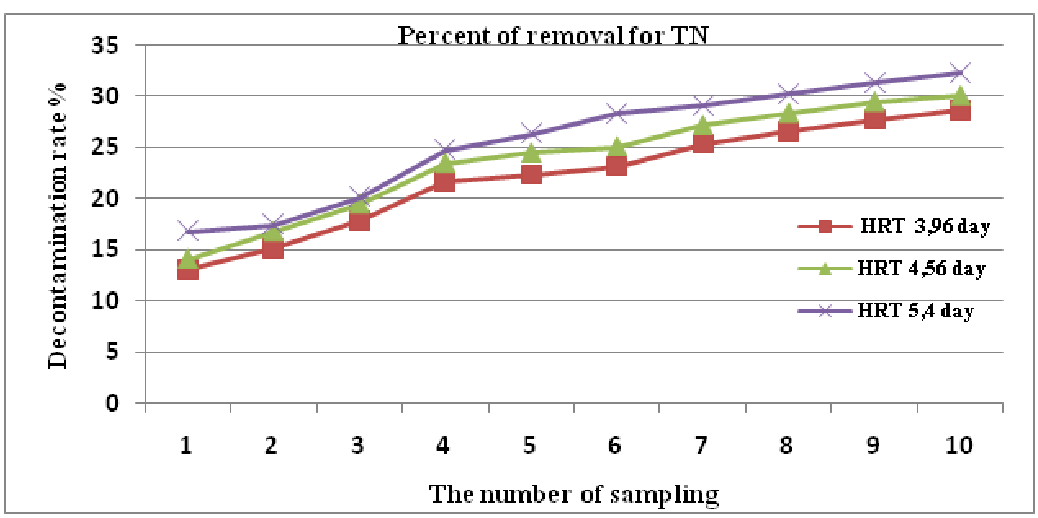


Figure 5. TN removal rates in constructed wetlands for 2.75, 3.25 and 3.75 m^3/ day flow rates.

down wetlands took the water polluted with acidic metals due to the water kept in acidic excavated soil including metal in aerobic wetland which was planted with *P. australis* in UK. It was also indicated that *P. australis* stored heavy metals in its roots and rootstocks (Kraus, 1987; Peverly et al., 1995; Ye et al., 1997). As a result of Bozbek (2006)'s study, it was concluded that heavy metals were stored in *P. australis* and *Typha angustifolia* plants and both plants could be used as a bioindicator in the determination of environmental changes. Oron et al. (2004) formed a wetland system by using *Lemna gibba* for the treatment of domestic wastewater. As a result of their study, it was determined that the system was suitable for sediment since its hydraulic efficiency was very high. It was found that TSS and organic material were removed more by the system. Peterson et al. (2003) investigated sediment removal capacity of a constructed wetland which was planted with *Rhizophora spp.* Sediment efficiency was obtained as 40 and 70% for wetland and sediment pool, respectively. Kao et al. (2006) studied on the disposal of an industrial wastewater in a pilot-scale constructed wetland. *Phragmites communis* and *T. orientalis* plants were used to cover 40% of wetlands and *Pistia stratiotes* (water salad) and *Ipomoea aquatica* (water spinach) were used as floating plants. It was determined that just *P. communis* plant can bear the wastewater and provides discharge standards of present industrial wastewater in Taiwan.

In our system, the best removal rate was obtained in the pool where it was rested the most (5.4 day). In the study of Koskiaho et al. (2003) which was performed in order to remove agricultural nutrients by constructed wetlands, it was determined that the best performance was indicated by constructed wetland having the longest resting period. In the research of Tawfic (2003) with pilot treatment system, the treatment efficiencies of *P. australis, Cyperus rotundus,* and *Eichhornia crassipes* plants which will be used in natural treatment were investigated under less than one day retention time conditions and it was determined that the treatment rate provided by plants varied in very narrow boundaries.

Conclusion

In the study of Song et al. (2006), it was indicated that constructed wetland system had a quite good efficiency for SS, COD, BOD, total coliform and fecal coliform. Arceivala (2002), on the other hand, reported that usage of constructed wetlands was suitable for places where population density is low and it's necessary to treat low flow rates with high standards. Vymazal (2000) indicated that wetlands can be used for the removal of organic material and suspended solids supposing that they are constructed target driven.

As a result of our pilot-scale study, it was determined that *P. australis* plant can be easily found and used in the vicinity and it can be conveniently used for the decontamination of domestic wastewater in constructed wetlands formed with 5.4 day and 4.56 day hydraulic retention time. Most of the municipals in our country do not have a wastewater treatment facility due to its high construction cost and operational expenses. Some municipals which have wastewater treatment facility have difficulty in operating it since it has high operational expenses. In this study, these types of systems are more economical than other treatment systems in terms of cost, operation and maintenance fees. In rural area (for maximum ten thousand population), treatment of domestic wastewater with this natural system will extremely provide benefits in the prevention of environmental pollution.

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