ISSN:
Print - 2277 - 0593
Online - 2315 - 7461

Journal of Natural Science, Engineering and Technology

SUBSURFACE FLOW CONSTRUCTED WETLAND SYSTEM VEGETATED WITH *PHRAGMITES KARKA* IN THE TREATMENT OF DYE-RICH WASTEWATER

A. A BADEJO[1]., A. O COKER[2], V.O OYEDELE[1]

[1]Department of Civil Engineering , Federal University of Agriculture, Abeokuta, Nigeria
[2]Department of Civil Engineering, University of Ibadan, Nigeria
[*]**Corresponding author**: adejo@yahoo.com **Tel: +**2348051161315

ABSTRACT

Some major parts of tropical Africa, especially in West Africa are nowadays grappling with the problem of degradation of the quality of fresh water by the introduction of effluents containing dyes from textile industries. In this study a low cost and economical method of treating dye-rich effluent using locally available macrophyte was investigated. The pilot Constructed Wetland (CW) consists of 1200 × 1000 × 1000 mm plastic tanks, filled with 500 mm deep 10-15 mm size granite overlaid with 150 mm thick sand (C_u = 1.15 and C_c = 6.8) substrate. The substrates had an hydraulic conductivity of 0.002 m/s. The pilot CW was planted with *Phragmites Karka* Retz. at 200 mm c/c to provide a high density bed. Irrigation was done intermittently at 6 days retention period with 0.05 m^3 indigo dye rich wastewater from the local tie and dye textile industries and plant growth monitored. Physico-chemical parameters, Cr, Pb, Cu, Zn and Fe removal were also evaluated. The study revealed a 24 % growth rate reduction in the plants irrigated with indigo dye-rich wastewater. Reduction of TDS (50 %), TSS (66 %), EC (46 %) were also observed and the heavy metals evaluated showed an uptake of 64 %, 68 %, 78 %, 58 %, and 68 % for Cr, Pb, Zn, Cu, and Fe respectively by the CW. *Phragmites karka* as a macrophyte in Constructed Wetland was found to be efficient in dye-rich wastewater treatment.

Keywords: Constructed Wetlands, Dye-rich wastewater, indigo, macrophytes, *Phragmites karka.*

INTRODUCTION

Adire textile is a viable means through which the rich African cultural heritage and ideas could be conveyed to other cultures and outside world. Adire is an integral part of the Egba culture in Abeokuta (Fig. 1), the use of which has crept into offices, campuses and as daily and occasional wears. Dye-rich discharges from the adire manufacture flow into surface and groundwater sources where they cause pollution. The presence of possibly toxic chemicals and heavy metals in adire textile effluent and dye rich wastewater, mostly generated by the local tie and dye operatives, poses high risk to aquatic life and to the health of people making use of these polluted freshwater. It is worth mentioning that apart from adverse chemical, biological and physical effects of the pollutant, dyes in water are an eyesore as they cause aesthetic degradation. This study evaluates the performance of Constructed Wetland (CW) vegetated with locally available macrophytes *Phragmites karka* in treating wastewater rich in local indigo dye.

CW systems are complex matrix of distinct aerobic and anaerobic treatment zones. They are artificial wastewater treatment systems consisting of shallow ponds or channels planted with aquatic plants. CW is a complex integrated system in which water, plants, animals, microorganisms and the environment; sun, soil and air interact to improve water quality (Davies *et al*., 2005). They rely on natural microbial, biological, physical and chemical processes to treat wastewater. CW systems are reportedly employed in treating wastewater for the removal of both biological wastes and non-biological wastes including heavy metals (O'Sullivan *et al*, 2005). During the past few years awareness on the use of CW has increased considerably as a means of treating surface water runoff from farmyards (Poe *et al*., 2003; Carty *et al*., 2008). CW has also been reported to have the potential for the treatment of tannery wastewater as an alternative to conventional biological systems (Calheiros *et al*., 2007). Tremendous successes have been achieved in the use of CW mainly outside Nigeria in treating different types of waste, such as municipal waste, storm water, industrial wastewater, agricultural wastewater and refinery effluents (Frazer-Williams, 2007). CW incorporates a tolerant plant species that is locally available at minimal cost.

The treatment performance in particular, the design transfer characteristics and adsorption properties of CW depend to a great extent on the physical and chemical characteristics of the substrates. Very small particles have very low hydraulic conductivity which encourages surfacing (a situation in which a portion of the wastewater flows on top of the substrate) whereas very large gravels have high conductivity but lack the good wetted surface area per unit volume suitable for microbial habitat and growth. Sand or gravel is favoured as CW substrate because of the greater surface area available to the microorganisms, and the ease and uniformity with which the effluent can flow through sand or gravel (Kadlec and Knight, 1996).

Fig. 1. Local tie and dye industry in Campala Market, Abeokuta. Nigeria

MATERIALS AND METHODS

The CW was irrigated with dye-rich wastewater from the Adire-Kampala market (N 07^0 10' 13.3", E 03^0 22' 41.9) Asero Abeokuta (Fig. 1). The control CW was irrigated with potable water from Umar Kabir Hall of residence, Federal University of Agriculture, Abeokuta, Nigeria.

The pilot CW under study was located at Umar Kabir Hall (N 07^0 14' 01.3", E 003^0 26' 01.4") of the University of Agriculture, Abeokuta, Nigeria. The pilot CW bed consisted of 1000 litres plastic tanks (Fig. 2) with a surface area of 1.2 m^2 each. They consist of 500 mm deep 10-15 mm diameter granite with 150 mm thick overlay of well graded sand (C_u = 1.15, C_c = 6.8 and 0.0025m effective diameter as shown in Fig. 3). The hydraulic conductivity of the substrate was 0.002 m/s. The two beds were planted with transplanted rhizomes of *Phragmites Karka.* Each bed was equipped with drain outlets at the base of the tank for effluent collection. The macrophyte (*P. Karka)* was planted at a distance of 200 mm apart to produce a high density bed. The initial irrigation was with clean water to establish the plants after which the CW bed was irrigated with dye-rich wastewater. The CW bed was irrigated with 0.05 m^3 homogeneous dye-rich wastewater once every six days. Samples were collected at 3 days and 6 days retention periods for analysis.

The macrophyte growth was monitored to determine the effects of the indigo dye-rich wastewater on the plant growth. Macrophytes growth rate was evaluated by measuring its leaves and stem characteristics at five days interval for 2 months after maturation of the CW macrophytes.

Analysis of physico-chemical parameters like pH, electrical conductivity, temperature, total dissolved solids (TDS) and total suspended solids (TSS) were carried out and the presence of five heavy metals: Cr, Pb, Cu, Zn, and Fe was evaluated. Three replica samples were taken for each of the sampling point at every collection period.

Fig. 2: Setup of the pilot scale CW at Umar Kabir Hall, Federal University of Agriculture, Abeokuta. Nigeria

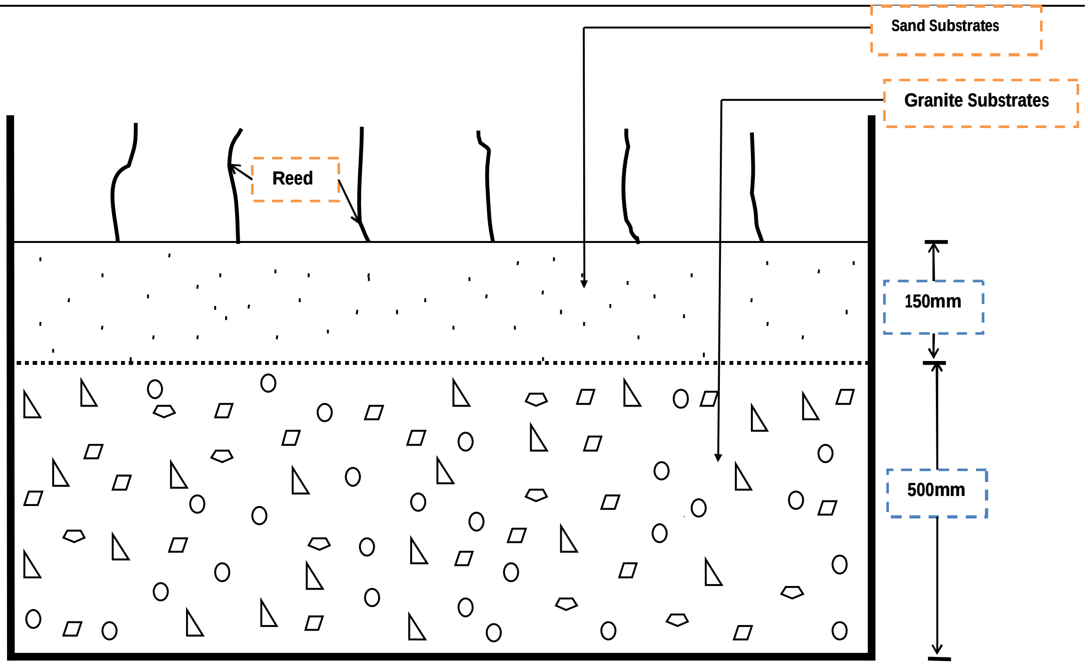

Fig. 3: Section through the CW showing the various components of the CW system

RESULTS AND DISCUSSION

The range of temperature available in the tropics makes treatment faster and more efficient, 7 % reduction in temperature was observed after the six days retention period in the CW. Temperature plays a significant role in wastewater treatment, as it affects microbial activity and vegetation functions. It has been observed that generally for all pollutants, lower removal efficiencies correspond to lower temperatures and higher efficiency corresponds to higher temperature (Akratos and Tsihrintzis, 2007, Ayaz, 2008). The dye rich wastewater investigated was alkaline in nature with pH of 8.97 and the analysis of effluent from the CW showed a decrease in the pH. It was observed that an increase in retention period in the CW results in decrease in pH. The Ministry of Environment (FEPA, 1991) stipulated a pH tolerance limit of between 6.0 - 9.0 for effluent to be discharged through sewers into stream and WHO (2004) recommended a range of 6.5 – 8.5 for water meant for full contact recreation. The EU (Ogunfowokan, *et al*., 2005) also sets protection limits of 6-9 for fisheries and aquatic life. The results obtained after treatment tend more to neutral pH. The total suspended solids (TSS) dropped substantially by an average of 35 % in 3 days, and 66 % in 6 days and the total dissolved solids (TDS) was reduced by an average of 46 % and 50 % at the end of 3 and 6 days retention periods respectively. A reduction in Electrical Conductivity (EC) of 43 % in 3 days, and 46% in 6 days was also observed.

Zn and Cr were the only established heavy metals present in ordinary unprocessed indigo dye, but other metals that were investigated in this research were likely introduced during the processing of the dye by the addition of chemical additives and deep heating of the dye solution in steel and earthenware containers. For the raw influent analysed, Fe has the highest concentration followed by Cr, Cu, Zn, and Pb in descending order

(Table 1). Cr, Pb, Zn, Cu, and Fe had their concentrations reduced by 56%, 53%, 56%, 23%, and 46% respectively in 3 days, and 64%, 68%, 78%, 58%, and 68% respectively in 6 days as shown in Fig. 4. This agrees with the findings that *Phragmites* provide a beneficial ecosystem service by reducing heavy metal contaminants (Windham *et al*, 2001., Windham *et al*., 2003).

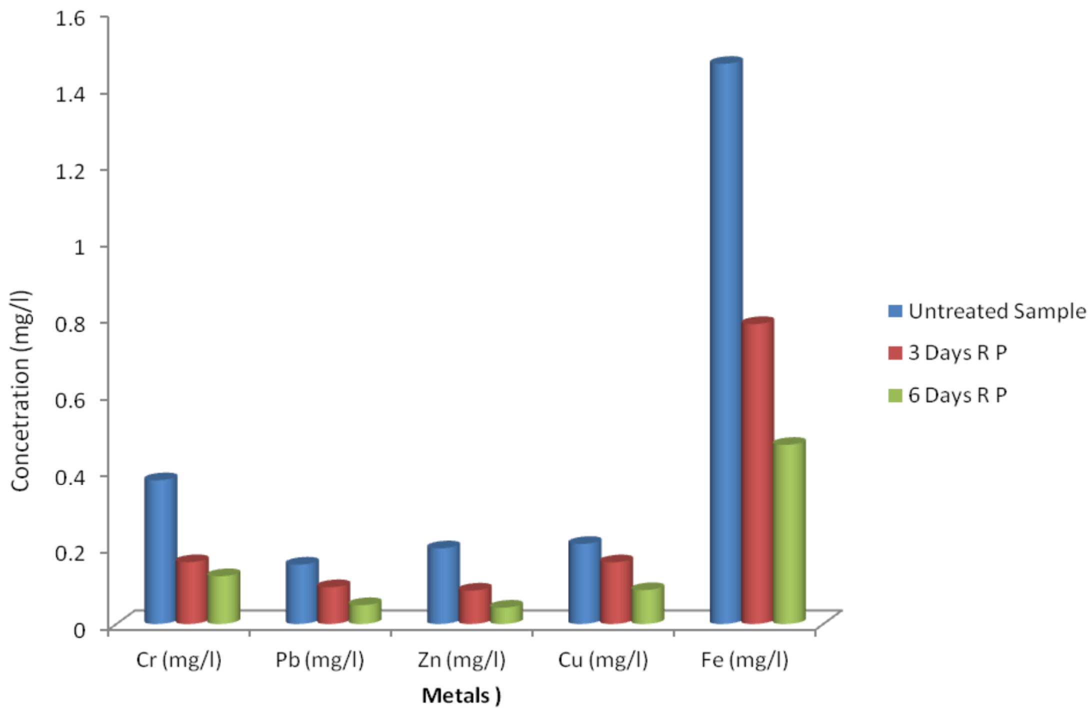

Fig. 4: Reduction in heavy metals with change in retention period in Pilot Scale CW

Table 1. Average composition of influent (dye-rich wastewater) into the CW

Parameters	Results
pH	8.97
EC µS	1414
Temp °C	30.6
TDS (mg/l)	780
TSS (mg/l)	17800
Cr (mg/l)	0.9232
Pb (mg/l)	0.256
Zn (mg/l)	0.434
Cu (mg/l)	0.3012
Fe (mg/l)	2.947

The plants grew at a steady rate. An average of 0.90 % and 0.96 % in 5 days for the experimental and control CW bed respectively before irrigation with dye-rich wastewater. The plant growth rate for the experimental bed dropped to 0.68 % after adding dye-rich wastewater and that of the control was 0.86%. *Phragmites karka* possesses the characteristics of species needed for water quality improvement, it is one of the very few plants that have the potential of the criteria for water quality improvement (Wagner *et al.*, 2004).

CONCLUSION

Phragmites karka as a macrophyte in Constructed Wetland was found to be efficient in dye-rich wastewater treatment. The design and construction of this treatment facility does not entail the use of any mechanical component and, thus, the maintenance requirement is minimal.

REFERENCES

Akratos C., Tsihrintzis V. 2007. Effect of Temperature, HRT, Vegetation and Porous Media on Removal Efficiency of Pilot-Scale Horizontal Subsurface Flow Constructed Wetlands, *Ecological Engineering*, 29: 173 – 191.

Ayaz, S.C 2008. Post-treatment and reuse of tertiary treated wastewater by constructed wetlands. *Desalination* 226, 249–255.

Calheiros, C., Rangel, A., Castro, P. 2007. Constructed wetland systems vegetated with different plants applied to the treatment of tannery wastewater. *Water Resources* 41 (8), 1790–1798.

Carty, A., Miklas, S., Kate, H., Fabrice, G., Atif, M. 2008. The universal design, operation and maintenance guidelines for farm constructed wetlands (FCW) in temperate climates. *Bioresource Technology*.

Davies, L., Caries, C., Novais, J., Matins-Dias, S. 2005. Phytoremediation of Textile Effluents containing azo dye by using *Phragmites australis* in a Vertical Flow Intermittently Feeding Constructed Wetland. *Ecological Engineering* 25, 594-605.

Federal Environmental Protection Agency, (FEPA) 1991. National Guidelines and standards for industrial effluents, gaseous emissions and hazardous waste management in Nigeria. Government notice. P. 49.

Frazer-Williams R. 2007. Constructed Wetlands for advanced treatment and re-use. Centre for Water Science Sustainable Systems Department, School of Applied Science. Cranfield University.

Kadlec, R., Knight, R. 1996 Treatment Wetlands. CRC Press, Inc. Boca. In LaFlamme. C 2005 Nutrient Removal using a Constructed Wetland in Southern Quebec, Unpublished M.Sc. Thesis; McGill University, Montreal.

Ogunfowokan, A., Okoh, E., Adenuga, A., Asubiojo, O. 2005. An Assessment of the Impact of Point Source Pollution from a University Sewage Treatment Oxidation Pond on a Receiving Stream - A Preliminary Study, *Journal of Applied Sciences* 5 (1): 36-43.

O'Sullivan, A., Conlon, R., Moran, B. Otte, M. 2005. Characteristics of Constructed Wetlands Substrates by Chemical Sequential Extraction and X-ray Diffraction Analysis. Biology and Environment. Proceedings of the Royal Irish Academy. 105B 87-94.

Poe, A., Pichler, M., Thompson, S., Paerl, H. 2003. Denitrification in a constructed wetland receiving agricultural runoff. *Wetlands* 23: 817–826.

Wagner, S., Truong, P., Vietitz, A., Smeal, A. 2004. Response of Vetiver Grass to Extreme Nitrogen and Phosphorus Supply. Conference Proceeding; Vetiver and Water 3rd International Conference China pg. 61-72.

WHO, 2004. Guidelines For Dinking Water Quality. 3rd Ed. Vol. 1 Recommendation, Geneva, 515.

Windham, L., Weis, J., Weis, P. 2001. Lead Uptake, Distribution and Effects in Two Dominant Salt Marsh Macrophytes. *Marine Pollution Bulletin*. 42(10): 811 – 816.

Windham, L., Weis J., Weis P. 2003 Uptake and Distribution of Metals in Two Dominant Salt Marsh Macrophytes, Spartina alterniflora (Cordgrass) and Phragmites australis (Common reed). *Estuarine, Coastal and Shelf Science*. 56: 63-72.

(Manuscript received: 7th August, 2012; accepted: 27th May, 2013).