American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-02, Issue-12, pp-450-454
www.ajer.org

Research Paper Open Access

Efficiency Assessment of a Constructed Wetland Using Eichhornia Crassipes for Wastewater Treatment

David O. Olukanni and Kola O. Kokumo
Department of Civil Engineering, Covenant University, P.M.B. 1023, Ota, Ogun State, Nigeria.

Abstract: - The practice of treating municipal wastewater at low cost prior to its disposal is continually gaining attention in developing countries. Among the current processes used for wastewatere treatment, constructed wetlands have attracted interest as the unit process of choice for its treatment due to their low cost and efficient operation in tropical regions. The aim of this study is to assess the efficiency of a constructed wetland that uses water hyacinth for wastewater treatment and to investigate the impact of the hydraulic structures on the treatment system. This study also involves determining the efficiency of water hyacinth in polishing biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), phosphate, magnesium, zinc, nitrate, chloride, sulphate, potassium, pH and fecal coliform. Two samples each were collected and tested from the six WHRB reactors available at Covenant University. The wetland achieved a performance of 70% of BOD-, 68% of COD-, 41% of Total Solids (TS)-, 100% of zinc, 30% of nitrate, 38% of chloride, 94% of sulphate, and 2% of potassium-removal, respectively. The result also shows a 6%, 29% and a significant increase, in pH, phosphate and magnesium, respectively. The study shows that constructed wetlands are capable of treating wastewater and also emphasizes the sustainability of the technology.

Keywords: - *Wastewater, Developing Countries, Low Cost, Constructed wetland,* Eichhornia Crassipes,

I. INTRODUCTION

Conventional wastewater treatment technologies used in most industrialized nations are currently not potential options in many developing countries to provide environmental and public health protection [1]. Also, in these developing countries, the treatment of wastewater has been a great concern and it is well known that most of the projected global population increases will take place in the third world countries that already suffer from land, water, food and health problems. The greatest challenge in the water and sanitation sector over the next two decades would be the implementation of low cost wastewater treatment that would at the same time permit selective reuse of treated effluents for agricultural and industrial purposes [2]. In most developing countries, especially in Africa, wastewater is simply too valuable to waste [3]. Its water and nutrients (nitrogen and phosphorus) are needed for crop irrigation and fish culture [4] [5]. However, the construction cost for conventional wastewater treatment plant has been a major barrier for the implementation of conventional technologies by local authorities in many African countries [6]. Although, these technologies are very effective, they are expensive to build and maintained, coupled with the fact that they also require skillful personnel and technical expertise to be operated [7]. Consequently, while water borne diseases such as cholera and diarrhea have persisted because of inadequacies in wastewater treatment systems, developing nations are unable to incorporate these technologies as part of a wastewater treatment master plan. It is therefore imperative that a treatment system that is economical and sustainable be put in place.

As a result of this development, decision makers are looking for alternatives that could be used as complementary methods to reducing treatment costs. Among the current processes used for wastewater treatment in tropical regions, constructed wetland has attracted interest as the unit process of choice for wastewater treatment due to their low cost in energy consumption, low maintenance, high level sustainability, efficient operation and being an ecosystem that uses natural processes [8] [9] [10]. Constructed wetlands are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils and associated microbial assemblage to assist in treatment of wastewater. Constructed wetlands are based upon the symbiotic relationship between the micro organisms and pollutants in the wastewater [11].

Some of the different wastewater treatment processes which are in use globally are; activated sludge, biological filter, oxidation ditch, aerated lagoon, waste stabilization Pond (WSP) and Constructed wetlands. In developing countries, the number of choices may be higher as a result of the more diverse discharge standards encountered. Wetlands serve thousands of communities around the world. They are effective in wastewater treatment and offer potentials for resources recovery through the production of biomass, which can be used as human and animal foods. The growing interest in wetland system is due in part to recognition that natural systems offer advantages over conventional systems.

Various wetland systems incorporate the use of different plants as a source of nutrient and pathogenic organisms' removal. Wetland plants have the ability to transport atmospheric oxygen and other gases down into the root to the water column. Within the water column, the stems and roots of wetland plants significantly provide the surface area for the attachment of microbial population. Water hyacinth (Eichhornia crassipes), Duck weed (Lemna spp), Spirodela spp, Wolffia spp, totora and cattails, among others are plants that are very efficient in removing vast range of pollutants, from suspended materials, BOD, nutrients, organic matter to heavy metals and pathogens [12]. Eichhornia Crassipes can be distinguished from others by its highly glossy leaves. Water hyacinth has demonstrated that it is an excellent pollutant removal for wastewaters [13] [14]. This study is aimed at assessing the efficiency of the constructed wetland that uses water hyacinth [water Hyacinth reed bed (WHRB)] as pollutant removal in Covenant University and to investigate how the system can be improved if necessitated.

II. MATERIALS AND METHODS

2.1 Description of the study area

Covenant University, within Canaan land in Ota town, is in close proximity to the city of Lagos, Nigeria. The institution has undergone an increasing population since its inception in 2002 with a current population of over 9,000 people. Wastewater from septic tanks in isolated locations within the Canaan land is taken by water tankers (Plate 1) for discharge into a primary clarifier which subsequently flows into a secondary clarifier and then into the CW (water hyacinth reed bed). The geometry of the primary clarifier was measured to have a volume of 720 m^3 i.e. 15 x 13.7 x 3.5 meters. The secondary clarifier has an area of 261 m^2 i.e. 17.41 m x 15 m and a depth of 5m. These tanks functions like anaerobic ponds within which the biochemical oxygen demand (BOD) and total solids are substantially reduced by sedimentation and anaerobic digestion before the partially treated effluent enters a diversion chamber. It is from this point that the wastes are fed into the hyacinth beds (Plate 2).

The constructed wetland is a Free Water Surface (FWS) type. As shown in Figure 1, the reed beds consist of six units of concrete facultative aerobic tanks 1.2m deep and each partitioned into four cells with an internal surface area 5.70 m by 4.80 m with influx of wastewater into each cell at alternate ends of the partition walls (Plate 3). The effective depth of each cell is about 0.9 m and has a volume of 23.16 m^3 with a free board of 0.30m. The final effluent discharges into an outfall (Plate 4) that is about 8m long and empties into a perennial stream that drains the campus and forms a tributary that discharges into River Atuara, a few kilometers from the Campus.

Plate 1

Plate 2

Plate 1 shows tanker dislodging wastewater into the treatment chamber while Plate 2 is the water hyacinth (Eichhornia Crassipes) beds showing baffle arrangement at opposing edges.

Plate 3

Plate 4

Plate 3- shows water hyacinth treating wastewater and Plate 4 shows effluent discharging through the outfall into the thick vegetation valley.

Grab samples of the raw influent and treated effluent from the existing water hyacinth reed bed were collected and analyzed in the laboratory for its BOD_5, Faecal coliform, pH, temperature, COD, Suspended Solids, Total Solids, Nutrients and Heavy Metals. Variation of influent and effluent parameters (physical, chemical, bacteriological and physico-chemical characteristics) was determined.

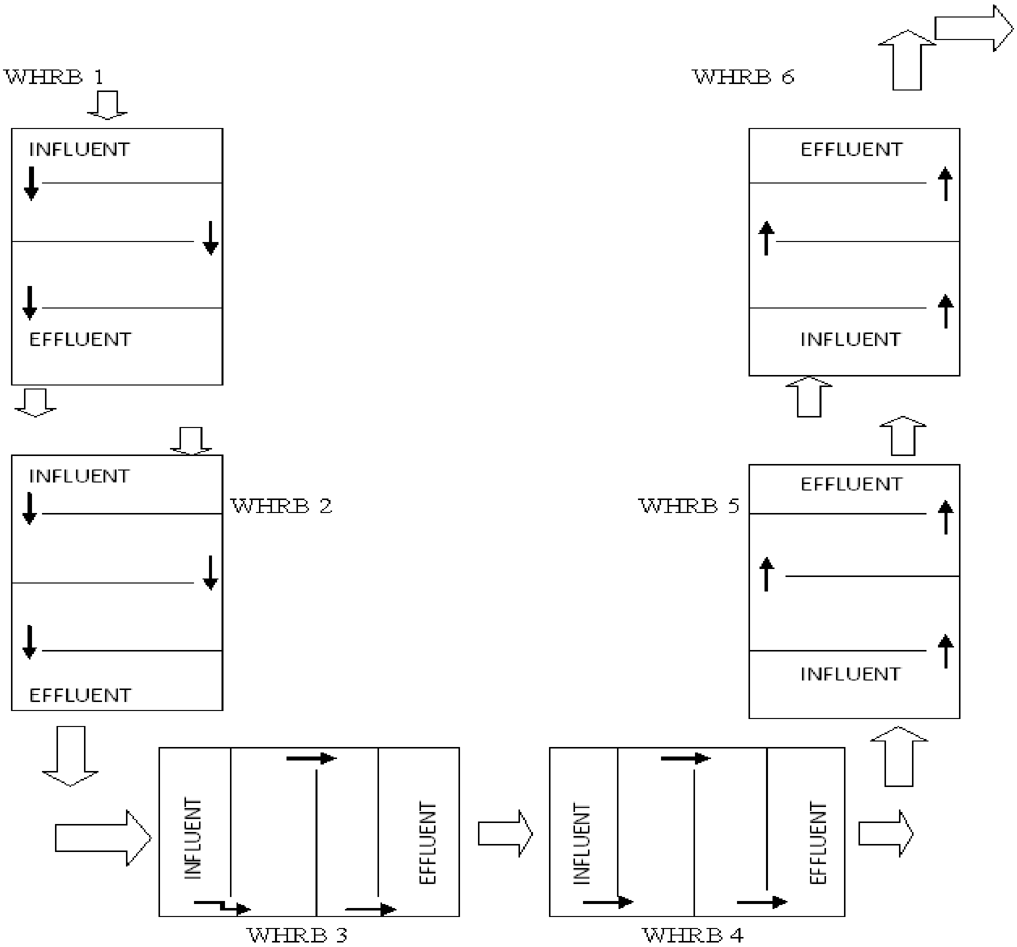

Figure 1- Layout of the Constructed Wetland [Water Hyacinth Reed Beds (WHRB)] in Covenant University and the wastewater collection points.

III. RESULTS AND DISCUSSION

3.1 Physico-Chemical Parameters

Table 1 shows the performance evaluation of the constructed wetland. There was a significant reduction in turbidity level with a performance of 40 % reduction. Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. There was an increase in the pH value which range from 6.16-6.59 with a constant temperature of 27^0C across all the reactors. Though optimum pH for bacteria to function is between 7.5 and 8.5 but most treatment plants are able to effectively nitrify with a pH of 6.5 to 7.0. The Total Suspended Solids (TSS) was reduced by 56% at the outlet of the final reactor. However, this does not meet with the Federal Environmental Protection Agency (FEPA) [15] now named "National Environmental Standards and Regulations Enforcement Agency" (NESREA) standard, recommending a limit of 30 mg/L for TSS. This means that the TSS concentration in the system is high and should be further reduced. The TSS includes silt, clay, plankton, organic wastes, and inorganic precipitates.

The treatment plant had little effect on the total dissolved solids (TDS). Though the TDS concentration is way below the standard limit given by FEPA, 2000 mg/L, it's composition in the effluent can still be reduced. It can also be deduced that most of the TDS concentration has been treated in the primary and secondary clarifiers. The Total Solids (TS) was considerably reduced. Though there is no specification to the amount of solids expected in wastewater. The treatment system gave a significant performance on reducing the total solids by 41.18% in pollutant level. A 37% reduction in chloride concentration was achieved by the treatment system. However the effluent chloride concentration is way below the 600 mg/L standard recommended by FEPA. It is a known fact that the chloride content of wastewater usually increases as its mineral contents increases and vice versa. The phosphate concentration increases very slightly but it is way under the 5mg/L recommendation. The slight increase in phosphate concentration could be as a result of the dead and decayed water hyacinth plant in the reactors.

The nitrate and sulphate content was reduced by 30% and 90%, respectively, an amount that is acceptable for discharge into natural water bodies. The BOD and COD ratio reveals the treatability of wastewater, so if the ratio is above 0.5 the wastewater is considered to be highly biodegradable and if lower than 0.3 the wastewater is deemed to undergo a chemical treatment before the routine biological treatment. For the University treatment plant, the BOD to COD ratio is 0.85. Therefore it is concluded that the wastewater generated in the campus is highly biodegradable.

The CW and its associated water hyacinth plants were considered to have little or no effect on the concentration of magnesium and potassium. In fact, a highly significant increase in the magnesium content was observed in the wastewater. Magnesium and potassium content could slow down the COD removal at certain concentration but a fair decrease in their level could rapidly enhance COD removal. Though the magnesium content increases, it is still way below the 200mg/L limit in wastewater as recommended by FEPA. The zinc element in the CW system was effectively removed in the wastewater.

Table 1. Overall performance of treatment between influent into WHRB 1 Influents and WHRB 6 Effluents on the Parameters Tested

Parameters	WHRB 1 Influent	WHRB 6 Effluent	Percentage (%) increase	Percentage (%) decrease
Turbidity	136	82		39.70
pH	6.16	6.56	6.49	
Total Solids mg/L	255.00	150.00		41.18
Total Suspended Solids mg/L	168.00	74.00		55.95
Total Dissolved solids mg/L	87.00	76.00		12.64
Chloride mg/L	259.93	162.45		37.50
Phosphate mg/L	0.113	0.146	29.20	
Nitrate mg/L	0.04	0.028		30.00
Sulphate mg/L	0.20	0.012		94.00
Chemical Oxygen Demand mg/L	330.50	105.19		68.17
Biochemical Oxygen Demand mg/L	298.35	90.43		69.69
Magnesium mg/L	9.00	26.00	188	
Zinc mg/L	0.04	ND		100.00
Potassium mg/L	25.41	24.67		2.91

IV. CONCLUSION AND RECOMMENDATION

The Constructed Wetland with hydrophytes (water hyacinth plant) is capable of removing pollutants and the hydrophytes have shown its ability to survive in high concentration of nutrients with significant nutrient removal. It has reliable nutrient stripping value for the removal of the trace elements tested for in the study. The use of water hyacinth plant aquatic system can help reduce eutrophication effects in receiving streams and also improve water quality. It would be recommended that more reactors are added to the treatment plant to enhance further settling of solids and give the wastewater more exposure to bacteria and water hyacinth, so that more nutrients are removed from the wastewater. Improvement can also be possible by increase in retention time of the wastewater in each compartment of the constructed wetland and possible means of aeration at the final discharge point.

REFERENCE

[1] D.O. Olukanni, J. J., Ducoste, Optimization of Waste Stabilization Pond Design for Developing Nations using Computational Fluid Dynamics. Ecological Eng, 37, 2011, 1878–1888.
[2] P. S. Navaraj, Anaerobic Waste Stabilization Ponds: A Low-cost Contribution to a Sustainable Wastewater Reuse Cycle. 2005 navaraj678@sify.com.
[3] World Health Organization, UNICEF. Global Water Supply and Sanitation Assessment Report. Geneva. 2000
[4] D. Ghosh, Turning Around for a Community-based Technology-Towards a Wetland Option for Wastewater Treatment and Resource Recovery that is Less Experience, Farmer-centered and Ecologically Balanced. Environment Improvement Programme, Calcutta Metropolitan Development Authority, Calcutta. 1996.
[5] D. D. Mara, Appropriate wastewater collection, treatment and reuse in developing Countries, Proceedings of the Institutions of Civil Engineers, London. 2001, 299-303.
[6] D.O. Olukanni, S. A. Aremu, Water hyacinth based wastewater treatment system and its derivable bye-product. Journal of Research Information in Civil Engineering, 5(1), 2008, 43-55.
[7] D. O. Olukanni, Evaluation of the Influence of Reactor Design on the Treatment Performance of an Optimized Pilot-Scale Waste Stabilization Pond. IJET, 3(2), 2013, 189-198.
[8] A. Al-Omari, M. Fayyad, Treatment of domestic wastewater by subsurface flow constructed wetlands in Jordan. Desalination, 155, 2003, 27-39
[9] E. A. Korkusuz, M. Beklioglu, G. N. Demirer, Comparison of the treatment performances of blast furnace slag-based and gravel-based vertical flow wetlands operated identically for domestic wastewater treatment in Turkey. Ecological Engineering, 24, 2005, 187-200.
[10] A. Yasar, Rehabilitation by constructed wetlands of available wastewater treatment plant in Salkhnin, Ecological Engineering. 29, 2007, 27-32.
[11] M. Stomp, K. H. Han, S. Wilbert, M. P. Gordonand, S. D. Cunningham, Genetic strategies for enhancing phytore mediation, Ann. New York Acad. Sci. 721,1994, 481-491.
[12] S. Dhote, S. Dixit, Water Quality Improvement through Macrophytes: A Case Study, Asian J. Exp. Sci., 21(2), 2007, 427-430.
[13] M. A. Maine, Nutrient and metal removal in constructed wetland for wastewater treatment from metallurgical industry. Ecological Engineering, 26 (4), 2006, 341-347.
[14] K. Skinner, Mercury uptake and accumulation by four species of aquatic plants. Environmental Pollution, 145 (1), 2007, 234-237.
[15] Federal Environmental Protection Agency (FEPA) Guidelines to Standards for Environmental Pollution Control in Nigeria. FEPA, Lagos, Nigeria, 1991, 90-91.