EXTENDED ABSTRACT

DEVELOPMENT AND EVALUATION OF A CONSTRUCTED PILOT- SCALE HORIZONTAL SUBSURFACE FLOW WETLAND TREATING PIGGERY WASTEWATER

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INTRODUCTION

Intensive piggeries are predominating livestock production and there is rising concern of nutrient pollution from the use of floodplains and water bodies as convenient sinks for the disposal of untreated wastewater. Conventional systems are not suitable solutions in preventing water pollution in developing countries due to their prohibitive cost and highly mechanized system with high energy and minimum inflow requirements which cannot be afforded by farmers. Natural systems, such as constructed wetlands are less costly, and have low energy requirements. However, lack of information on their performance in the tropics is among the factors that hinder their adoption as alternative wastewater treatment system. Successful removal of nutrients in piggery wastewater by constructed wetlands has been reported in different climatic regions outside Nigeria and their optimal design, performance, effects of plants and climate change on performance and the prediction of these effects need verification. The objective of this study was design, construct and test and model the performance of a horizontal subsurface flow wetland for treatment of piggery wastewater;

METHODOLOGY

This study adopted research and development, and experimental approach. First order reaction kinetics with plug flow was assumed as design principle. Kikuth model was selected for the design of the wetland area and Darcy's model was used to determine the capacity of the wetland to conduct flow through it. Three concrete experimental wetland cells sized 7 m x 1.75 m x 0.60 m and lined with a 2.5 mm thick Texclear soil liner were created for experimental purposes.

Figure 1: Constructed wetland development and operation.

Each wetland cell was divided into two to give a 2 x 3 randomized experimental design. Both the wastewater inlet and outlet sections of the wetland basin were filled up to 0.60 m depth with 30 mm crushed granite rock extending one meter from the walls into the treatment area. The wetland basin was filled up to 0.60 m depth with coarse sand as substrate. Two of the wetland cells were then planted with *Pennisetum clandestinum* (PC) and *Pennisetum purpureum* (PP) and the control (C) was not planted. Thereafter, the wetland was left for about three months to consolidate before delivery of wastewater. Seven months of grab samples data were collected before and after the wetland detention time of three days. The data were analyzed for biological oxygen demand (BOD), total nitrogen (TN) and total phosphorus (TP). Meteorological data obtained with Weather eye model 22 were evaluated based on Food and Agriculture Organization (FAO-56) methods. Destructive and systematic sampling techniques were adopted for plant and soil, respectively. Wetland treatment performance was evaluated in terms of efficiencies in mass and concentrations reduction. Effect of browsing plants nutrient uptake on wastewater treatment efficiency was determined as the treatment difference between the planted and unplanted cells. Influence of ET on constructed wetland treatment efficiency was computed as the difference between mass and concentration removal efficiencies. Statistical analysis was performed with the SPSS version 16 and MINITAB Release 15 for windows which include descriptive statistics, analysis of variance (ANOVA) and multiple comparison tests. The conceptual model for nutrient removal included nutrient uptake, denitrification and retention in the wetland. Initial nitrogen and phosphorus concentrations (N_o, P_o), input rates (D) and wetland processes (γ) and retention time (t) were used to

formulate mathematical equations of wetland nutrient removal in MATLAB for periodic loading of wastewater to the wetland. The model was calibrated with data collected from February to March 2017, while data collected from April to August 2017 were used for validation.

RESULTS AND DISCUSSION

Six rectangular horizontal subsurface flow wetland cells sized 3.5 m x 1.75 m x 0.60 m were designed and constructed in the field with concrete blocks for treatment of piggery wastewater. The results of the treatment performance of the constructed experimental wetland for a retention time of three days and mean hydraulic loading rate of 0.26 m/day showed mean reduction of BOD by 66.53%, 64.95% and 60.27% for the three cells PC, PP and C, respectively. TN reduction was 62.49%, 58.89% and 50.14% for the cells PC, PP, and C respectively. TP was reduced by 48.53%, 44.91% and 41.27% for the cells PC, PP, and C, respectively. There was a positive correlation (R^2 = 0 .905) between planted cells and wastewater treatment efficiency. Treatment efficiencies based on mass removal due to evapotranspiration (ET), were higher than those based on concentration. Wetland mass removal efficiency for PC and PP increased by 7% and 8%, respectively for BOD; 2% and 6%, respectively for TN and 14% and 20%, respectively for TP. Wetland plant evapotranspiration (ET) correlated positively with effluent removal rate (R^2 = 0.2021). Total nitrogen (TN) correlated more positively with ET both in mass (R^2 = 0.509) and concentration (R^2 = 0.5031) than total phosphorus (TP) concentration (R^2 = 0392) and mass (R^2 = 0.0715). Nutrient reduction efficiency equations were determined for both N and P. The equations were simulated in MATLAB and the simulated and observed values for TN and TP were compared. Effluent TN content accounted for 33.75%, plant uptake of TN accounted for 28.14%, retention in wetland media was 20.34% and denitrification, 17.77%. For TP, effluent content accounted for 43.54%, retention in wetland media accounted for 36.72%, followed by plant uptake, 19 74%. There was a strong correlation between measured and simulated TN (R^2 = 0.741) and TP (R^2 = 0.6822) values.

CONCLUSION

This study shows that the pilot HSSFCW can effectively treat wastewater with respect to organic matter (BOD_5 and COD), TDS and nutrients (TN and TP) removal. The vegetated cells showed better performance in the removal process for all the investigated parameters than the non-vegetated cells, underlining the active role of macrophytes in the wastewater treatment. Although the best performance was obtained in the bed vegetated with PC, there was no significant difference between PC and PP, confirming that these plant species are suitable for use in constructed wetlands for wastewater treatment. For the parameters of concern, except TP, the effluent quality met the admissible standard for discharge into open water sources in Nigeria at fairly short hydraulic retention time. The short HRT time may not have provided adequate contact time between wastewater and wetland media responsible for the nutrient removal especially TP. Additionally, the short HRT in this study could have limited the nitrification/denitrification processes which enhance removal of nitrogen in HSSFCWs. Furthermore, the short monitoring period and probably high ET, for some part of the monitoring period may have increased pollutant concentration resulting in low TP effluent quality of 7.2, 15.8 and 22.4% above admissible value of 5 mg/l in the PC, PP and control wetland cells respectively. However, the removal efficiency compared favourably with results obtained in other studies in different countries with effluent values generally within acceptable limits. The study concludes that HSSF-CW is a viable on-farm alternative technology for conventional treatment of piggery wastewater in Nigeria. Given the minimal maintenance requirements, the ease of operation and optimal performance with little energy input, constructed wetland technology can help alleviate wastewater management problems in developing countries and in particular, Nigeria. For significant nutrient removal, longer detention time of wastewater in the wetland is necessary to allow for sedimentation, biotic processing and retention of more nutrients especially TP. Nevertheless, these results provide a starting point for the use of HSSF-CW and PC and PP in Nigeria and gives insight of the potential application of this technology for pollution control.

Keywords

Constructed wetland development, Piggery wastewater, *Pennisetum clandestinum*, Pollution *Pennisetum purpureum*, Removal efficiency.

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