PERFORMANCE OF SUBSURFACE FLOW CONSTRUCTED WETLANDS IN DOMESTIC WASTEWATER TREATMENT AND THEIR POTENTIAL FOR INCREASING GREENHOUSE GAS EMISSIONS AT BUGOLOBI SEWAGE TREATMENT PLANT, KAMPALA

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Abstract

Uganda is grappling with public health and eutrophication challenges of its water bodies, owing to persistence of microbial pathogens, excess nutrients and organic matter content in domestic and industrial wastewater effluents. In addition, the country is also faced with emerging climate change challenges as a result of increasing greenhouse gas emissions (especially carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20) from several sources, such as industrial activities and natural processes taking place in various ecosystems, with wetlands. The overall objectives of this study was to assess the performance of horizontal (HF) and vertical (VF) subsurface flow (SSF) constructed wetlands (CWs) (planted with Cyperus papyrus) in domestic wastewater treatment and their potential as Carbon and Nitrogen sinks in increasing greenhouse gas (GHG) emissions. The system was operated under batch hydraulic loading in Kampala, Bugolobi. Both HF and VF CWs exhibited high efficiency for remediation of organic matter (OM), nitrogen (N), phosphorus (P) and faecal coliforms in effluent pollution loads. Notably, the highest percentage reduction was observed in the VF CWs, probably attributable to optimal oxygen supply within the system. Moreover, the VF CWs were most important for the removal of faecal coliforms (99.7%), 5-day biological oxygen demand (85.5%), total suspended solids (77.2%), ammonium-nitrogen (71.3%),

chemical oxygen demand (67%), total nitrogen (55.9%), total phosphorus (55.9%) and ortho-phosphate (53.7%). The highest recorded mean CH_4 flux (in mg CH_4-C m^{-2} h^{-1}) was 38.3 $\pm$ 3.3 in unplanted HF, compared to (3.3 $\pm$ 0.4), recorded in planted VF CWs. However, CO_2 fluxes (mg ^{CO2}-C m^{-2} h^{-1}) were significantly higher ($P< 0.05$) in planted CWs, with no significant difference ($P> 0.05$) between the planted HF (2213.5 $\pm$ 122.4) and VF (2272.8 $\pm$ 191.0) CWs. The COs flux attained in the planted CWs was attributable to the presence of roots and rhizomes for which their exudates in the planted beds, may have increased microbial activity which eventually could have increased CO_2 emission rates. However, N_2O fluxes were relatively low and their variations were insignificant (P> 0.0.05) in all treatments. Nevertheless, the unplanted HF mesocosms registered the highest N_2O fluxes of 0.24 $\pm$ 0.07 mg N_2O-N m^{-2} h^{-1} differing to the planted HF, unplanted VF and planted VF treatment systems that registered N_20 fluxes of 0.19 $\pm$ 0.05, 0.07 $\pm$ 0.02 and 0.08 $\pm$ 0.02 mg N_20-N m^{-2} h^{-1} respectively. Low N20 fluxes, could be attributed to the inhibition of denitrification under aerobic conditions, which on the other hand promoted nitrification, particularly in the planted CWs. The VF systems according to the observations, have shown low CH4 and N_20 emissions, therefore making them an appropriate technological option for low carbon development targets concerning sanitation and wastewater management in Uganda.

On the other hand, harvesting of the above ground biomass (AGB) removed 19.6% and 17.5% N and 23.8% and 25% P of the total N and P from planted VF and HF CWs respectively. Further, this would imply that SSF CWs are significant removal routes for nutrients, i.e., nitrogen and phosphorus and indeed, significantly more removal was recorded in the VF wetland systems planted with Cyperus papyrus. Therefore, SSF CWs are recommended for adoption, as suitable and less costly technology that may be used for interventions at local levels, to increase the adaptation and resilience for receiving environments through lessening the impact of intermittent and pulse pollution loads from wastewater treatment plants (WWTPs).

Key words: Aboveground biomass; constructed wetland; gas fluxes; nitrogen; nutrient uptake; organic matter; subsurface flow.