Nutrient Removal in Hybrid Constructed Wetlands

A.M. Rasheed*, M.M.A. Mansoor, M.H.A. Ahmath, S.M. Shameer

Abstract— Discharge of nutrients rich wastewater directly to water bodies is a key environmental problem that leads to toxic, excessive algal growth/blooms and more importantly eutrophication. To address this concern this study is focused on use of constructed wetlands for nutrient removal in domestic wastewater. The experiments were conductedin four sets of hybrid constructed wetlands, containing VSSF and HSSF systems in series. Synthetic wastewater is fed intermittently to the VSSF constructed wetlands to achieve different hydraulic retention time of 0.5, 1, 2 and 4 days. Ammonia (NH3-N), Nitrates (NO3--N), Nitrites (NO2--N), Phosphate (PO43--P) concentrations and BOD5, D.O, pH, Electric conductivity, Temperaturewere measured at all influent effluent stations at two weeks interval.

The processes that affect the removal of Nitrogen with in a constructed wetland are manifold and NH3 volatilization, nitrification, denitrification and plant uptake/microbial uptake are the primer processes (However a few processes ultimately remove nitrogen from the wastewater). Removal efficiency of Ammonia-N studied in the hybrid system varied between 82.5% and 92.5%. Hybrid constructed wetlands could achieve higher removal of Ammonia due to the ability of provide both aerobic and anaerobic/anoxic condition at the same time. The treatment efficiency of the hybrid systems showed a linear increase with hydraulic retention times. Nitrates and Nitrites concentrations were increased in the treatment of VSSF wetlands by the potential nitrification process and HSSF wetlands showed a treatment efficiency of Nitrates and Nitrites between 30%-47% and between 9.5%-25% respectively. The main processes of NOX- removal in HSSF are denitrification and plant/microbial uptakes. The removal of Phosphorus typically the orthophosphate (PO43--P) is found moderate in all the HRTs. The hybrid system could treat Phosphates up to 37.7% to 46.3%. Organic treatment in the hybrid system was found very efficient even in smaller HRT with a range of mean treatment efficiency between 88.5% and 92.7%. The four day HRT hybrid system did the highest treatment among others considering all the wastewater parameters.

Index Terms— Denitrification, eutrophication, hybrid constructed wetlands, nitrification, plant uptake, treatment, volatilization.

1 Introduction

CONSTRUCTED wetlands are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soil and their associated microbial assemblages to assist in treating wastewater. They are designed to take advantage of many of the processes that occur in natural wetlands, but do so within a more controlled environment. The potential use of constructed wetlands for nutrient treatment is substantially efficient and eco-friendly (Brix, 1989). Combination of these two or more basic types of constructed wetlands in order to get higher treatment efficiency is known as Hybrid Wetlands. Hybrid Systems comprised with VSSF and HSFS systems arranged in a staged manner have proven to be effective in nutrient removal (Vymazal, 2007).

2 Literature Review

The mechanisms that ultimately remove nitrogen from wastewaters include ammonia volatilization, denitrification, plant uptake (with biomass harvesting), ammonia adsorption and organic nitrogen burial. Other processes (ammonification or nitrification) "only" convert nitrogen among various nitrogen forms but do not actually remove nitrogen from the wastewater (Vyzamal, 2007).

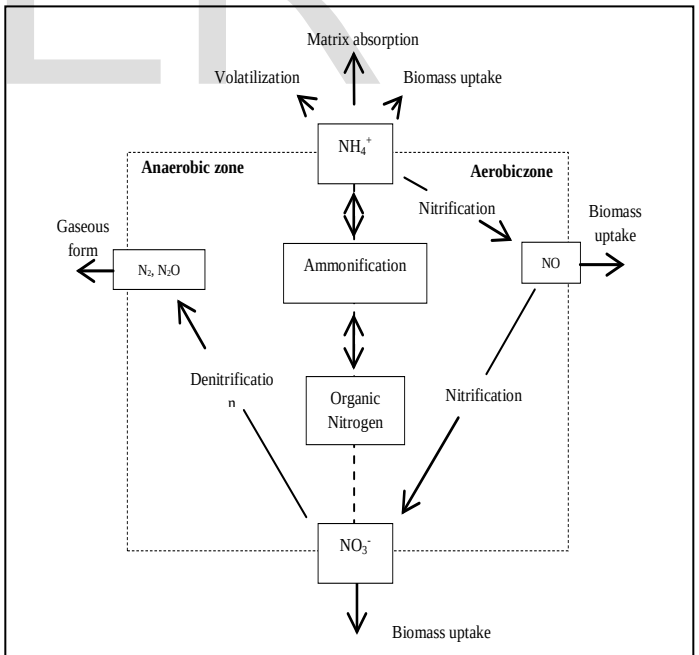

Fig. 1. Nitrogen transformation cycle in constructed wetlands (Sim, 2003).

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Adsorption and precipitation of phosphorus is effective in systems where wastewater gets in contact with filtration substrate. It means that constructed wetlands with sub-surface flow have the major potential for phosphorus removal via these mechanisms. Horizontal-flow systems have higher potential as the substrate is constantly flooded. Vertical-flow systems, where wastewater is fed intermittently, may not be as effective because the oxygenation of the bed may cause desorption and subsequent release of phosphorus (Vymazal, 2007).

Settleable organics are rapidly removed in wetland system under calm conditions by deposition and filtration. Attached and suspended microbial growth is responsible for removal of soluble organics. Organic compounds are degraded aerobically as well as anaerobically.

4 EXPERIMENT METHOD

The experiment was conducted in four sets of hybrid constructed wetlands of VSSF-HSSF combination with four different retention times of 0.5, 1, 2 and 4 days as shown in the figure 3.1.

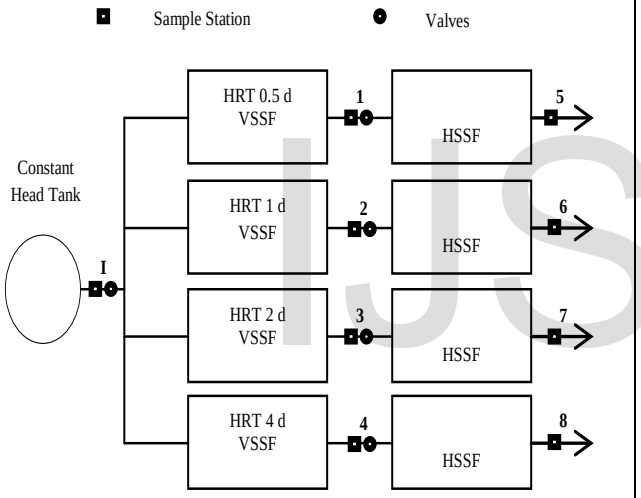


Fig. 2. Layout of the hybrid constructed wetland system

The influent flow is set thus it fills the required volume of wastewater in the VSSF for a determined period. The effluent of VSSF was set with a valve to control the flow concurring the hydraulic retention times of the particular constructed wetland system. Samples were collected from the influent and eight effluent stations at two weeks interval. Ammonia (NH_3-N), Nitrates (NO_3^--N), Nitrites (NO_2^--N), Phosphate (PO_4^{3-}-P) concentrations and BOD_5, DO, pH, Conductivity, Temperature were measured in all samples. Further, plant growth with respect to plant height, No. of leaves, shoots per plant were also monitored throughout the study period.

4 RESULT AND DISCUSSION

4.1 Nitrogen Removal

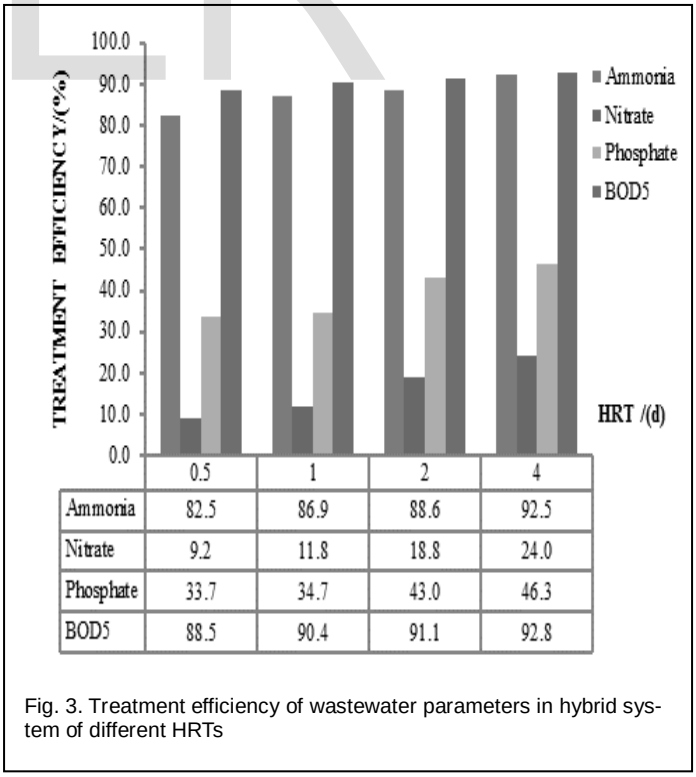
The VSSF wetland systems showed an average of 76.0 to 87.6% NH_3-N treatment efficiency, whereas HSSF system showed an average removal of 27.0 to 39.4%. However, the VF-HF hybrid arrangement showed an NH_3-N a removal efficiency of 82.5 and 92.5% from 0.5d to 4d HRTs. The mean DO concentrations were varied between 4.2 to 5 mg/L in VSSF systems and 1.0 to 2.1 mg/L in HSSF system. The higher DO concentration in VSSF systems could have been enhanced the NH_3-N removal through nitrification in VSSF systems. According to Hammer and Knight (1994) nitrification of NH_3-N is substantially reduced at places where DO concentration is less than 2.0 mg/L. It was observed that in all HSSF system DO concentration is below 2.0 mg/L and this could the reason for lower NH_3-N removal in HSSF systems.

In this study, it was observed that NH_3-N in both VSSF and HSSF systems as well as the hybrid systems has a linear increase of treatment efficiency with HRT (from 0.5 to 4days) increase.

The system showed treatment efficiency of 30.2 to 47.0% and of 9.5 to 25.0% for nitrate and nitrite respectively in HSSF. In VSSF systems, there was an increase in NO_x^--N concentration in the effluent than the influent due to nitrification process.

4.2 Phosphorous Removal

The VSSF wetland systems showed phosphate removal efficiency of 7.9 to 18.0% whereas the HSSF systems showed 28.0 to 34.5%. Consequently the hybrid system could treat phosphorus up to 33.7 to 46.3%. However, treatment efficiency has increased with hydraulic retention time. The plant uptake, adsorption and precipitation are the phosphate removal mechanism in wetland systems. Horizontal flow systems have higher potential adsorption as the substrate is constantly in contact than of VSSF system. These phenomena would have resulted higher phosphate removal efficiency in the HSSF systems than VSSF systems.



	0.5	1	2	4
Ammonia	82.5	86.9	88.6	92.5
Nitrate	9.2	11.8	18.8	24.0
Phosphate	33.7	34.7	43.0	46.3
BOD5	88.5	90.4	91.1	92.8

Fig. 3. Treatment efficiency of wastewater parameters in hybrid system of different HRTs

4.3 BOD_5 Removal

The hybrid system of resident time 0.5, 1, 2, 4 days shows BOD_5 treatment efficiency between 88.5and 92.7%.

5 Conclutions

Hybrid constructed wetland containing VSSF and HSSF in series are viable alternative for wastewater treatment for small source of pollution especially when organics, ammonia and phosphates are the treatment targets.

The hybrid systems has a linear increase of NH_3-N treatment efficiency with HRT (from 0.5 to 4days) increase. Ultimately, the study revealed that the 4 day HRT hybrid constructed wetlands was found very efficient in nutrient removal considering all the wastewater parameters measured.

Acknowledgment

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