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Study of Aeration Rate Effects on Total Nitrogen Removal from Domestic Wastewater

Izzati Izwanni Ibrahim[1,*], Rafidah Hamdan[2]

Department of Water and Environment Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400 Batu Pahat, Johor, Malaysia,[2]Department of Civil Engineering Technology, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400 Batu Pahat, Johor, Malaysia
[*]Email: izzatiibraka@gmail.com

Abstract

Nitrogen removal from wastewater often requires a highly cost of chemical treatment to prevent over loading of nutrient in effluent discharge to the surface water body. Therefore, an alternative low-cost treatment method for removing nitrogen from wastewater is urgently needed. Hence, the present study of a pilot-scale vertical aerated rock filter (VARF) was principally design to remove ammoniacal nitrogen from domestic wastewater. To develop the most favorable environment for nitrification to take place, the influence of aeration flow rate at different filters depth of 0.5m, 0.75m and 1.0m has been studied. Wastewaters from Universiti Tun Hussein Onn Malaysia wastewater treatment plant have been collected to operate the VARF. Throughout the experimental period, the VARF influent and effluent samples have been sampling and analyzed for total nitrogen, ammoniacal nitrogen, biochemical oxygen demand, chemical oxygen demand, suspended solid, turbidity, dissolved oxygen and pH to monitor the filter effectiveness. From this, it was indicated that most of ammoniacal nitrogen were converted to nitrate-nitrogen in the highly aerated VARF system. More than 90% of ammoniacal nitrogen were converted to NO3-N in the system at the filter depth of 0.75m and 1.0 m. Results from this study show that at the filter depth of 0.75m and air flow rate of 10 L/min has efficiently remove 50.4%, 51.9%, 74.7%, 99.2%, 96.2%, and 97.1% of chemical oxygen demand, biochemical oxygen demand, total nitrogen, ammoniacal nitrogen, suspended solid, and turbidity respectively compared to the air flow rate of 20 L/min at the same filter depth which is remove 42%, 72.1%, 54%, 95.1%, 92.4%, and 83.5% respectively. For pH and dissolved oxygen profiles, the effluent values was found to be higher at the air flow rate of 10 L/min, which is range between 8.4 to 9.5 and 7.6, 8.3 and 8.5 mg/L respectively. Meanwhile at air flow rate of 20 L/min is about 8.2 to 8.4 and 7.3, 8.1 and 7.0 mg/L respectively. By complying with Malaysian Environment Quality (sewage) Regulations 2009, the sample treated for all parameters are within permissible limit of standard B.

Introduction

Water is the most important source to all living things in the world. Human need clean and fresh water to survive their life, therefore the quality of water is very important to be cared in order to supply clean and fresh water. But today, increasing rate of global population growth, urbanization and industrial development causes many challenges and contamination to ours wastewater discharges on surface water quality (Dan, *et al*., 2011). Therefore, the wastewater needs to be treated before it can be discharged into rivers or lakes.

Total nutrient, nitrogen and phosphorus are recognized eutrophic nutrients as they could cause eutrophication in which excessive growth of organisms such as algae will decrease the soluble oxygen concentration in waters, causing detrimental effects on the aquatic life as indicated in Henry and Heinke (1989) and Foy and Withers (1998) cited in

(Alamdari and Rohani, 2007) even at an increase in phosphorus as low as 0.1 mg P/l. Eutrophication are made more eutrophic through an increase in their nutrient supply due by excessive nitrogen and phosphorus. Although this eutrophic commonly applied to lakes and reservoirs, it can also be applied to flowing waters, estuaries and coastal marine waters (Smith, *et al.*, 1999). To remove total nutrient from wastewater conventionally it requires an additional cost for chemical salt and sludge handling and treatment. Furthermore, the new stricter effluent requirements for nutrient removal in wastewaters are now applicable in Malaysia under the Environmental Quality Act (Sewage) Regulations, 2009.

Therefore, the demand of low-cost technology and an economic effective system are crucial as an alternative to the conventional treatment method for treating high nutrient wastewater and towards the new effluent discharge compliance. Hence, this study will be carried out to develop a pilot-scale aerated rock filter system using a low-cost filter media in Environmental Laboratory of FKAAS, UTHM with the rate of aeration is 10 L/min and 20 L/min to enhance nitrification within the system which will be the main focus of the present study.

Material and Methods

Generally, this project is to study the parameters in all type of nitrogen removal which are BOD, COD, ammonia nitrogen, nitrate, nitrite, suspended solid, dissolved oxygen, pH, turbidity and total nitrogen. The VARF pilot-scale consists of pipe with diameter 0.3m and 1.0m height, one storage tank, three tap, one peristaltic pump and compressor, one porous disc followed by one fine bubble air diffuser, and master flex hose.

VARF Pilot-Scale System

Schematic diagram of the VARF pilot-scale set up as shown in Figure 1. The height of filter is 1.5m and there have three discharged which are 0.5m, 0.75m and 1.0m. The experiments have been conducted at two different air flow rates, 10 L/min and 20 L/min. The system has been aerated by using a compressor and the effluent samples have been sampled at three different depths as stated above. The domestic wastewater flows from the storage tank into the bottom of the VARF through the peristaltic pump and has been controlled the flow according to the calculation. However, the flow of inlet has been controlled by the required hydraulic retention time (HRT) is set at 23ml/min. Table 1 shows the characteristics and operating conditions of VARF system whilst Table 2 shows the wastewater sampling parameters, standard method and frequency.

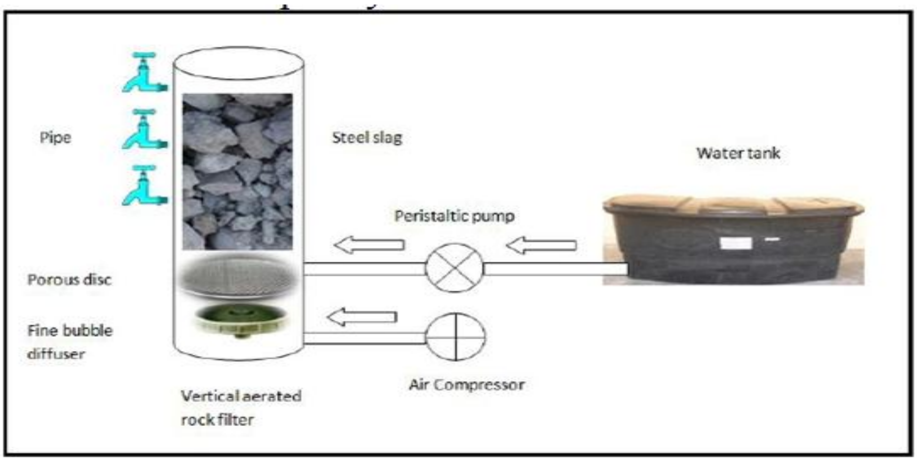

Figure 1: Schematic Diagram of the Pilot Scale of Vertical Aerated Rock Filter

Table 1: The VARF characteristics and operating conditions

No	Parameter	Unit	Value	Reference
1	Total Height	m	1.5	
2	Internal Diameter	m	0.3	
3	Filter Bed Depth / Liquid Depth	m	1.0	
4	Media Volume, V	m^3	0.11	
5	Hydraulic Loading Rate	$m^3/m^3.d$	0.3	Mara, D.D (2004)
6	Flow Rate, Q	ml/min	23	
7	Q Working Volume	L/min	10 & 20	
8	Sampling Point	m	0.5, 0.75, 1.0	

Table 2: Wastewater Sampling Parameters, Standard Method and Frequency

Parameter	Standard Method for Examination Water and Wastewater (APHA)	Frequency
BOD	5210 b	Twice a week
COD	8000-DR/4000	
NO_3	10020-NO_3 DR/4000	
NO_2	8153-NO_2, DR/4000	
Ammonia	8038-NH_3, DR/4000	
pH	pH meter	
Suspended Solid	2540 G	
Dissolved Oxygen	DO meter	
Turbidity	2100P TURBIDEMETER	
Total Nitrogen	10071-Nitrogen, Total, DR5000	

Results and Discussion

Biochemical Oxygen Demand (BOD_5) Removal

The removal efficiencies of BOD_5 as well their concentrations in domestic wastewater are provided in Figure 2. From the figure above, the result shows that the removal efficiency of BOD_5 was influenced by the filter depth of VARF system. The higher removal percentage is 83.8% for air flow rate of 10 L/min at 0.5m of filter depth whilst 72.1% for air flow rate of 20 L/min at filter depth 0.75m. From this observation, it is indicated that the air flow rate of 10 L/min has a minimum filter depth in removing organic matter compared to the other filter depth 0.75m and 1.0m meanwhile for the air flow rate of 20 L/min, the percentage removal were high at filter depth 0.75m.

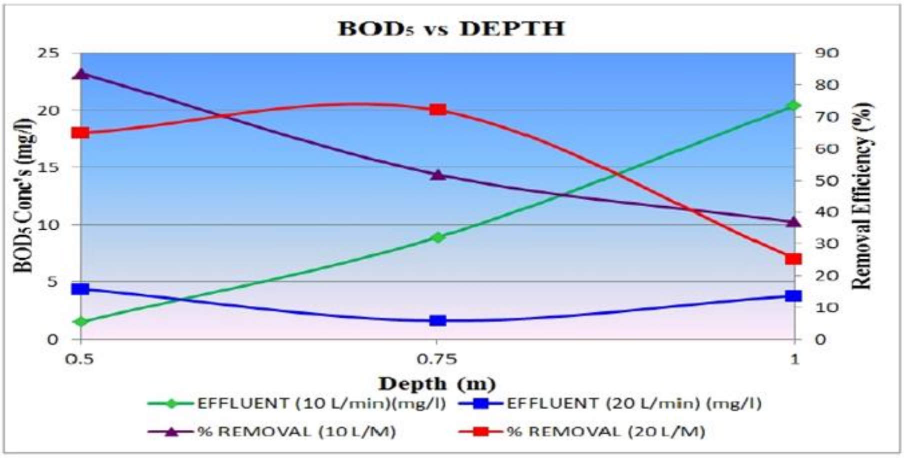

Figure 2: BOD_5 Concentrations and Removal Efficiency

Total Nitrogen (N_{Tot}) Removal

The effluent concentrations for air flow rate of 10 L/min ranges from 12.5 to 23 mgN/l, meanwhile for air flow rate of 20 L/min is around 7 to 10 mgN/l as illustrated in Figure 3. This figure also shows the removal efficiency of N_{Tot} in the VARF system. The removal efficiencies values at air flow rate of 10 L/min were slightly higher than air flow rate of 20 L/min. It is between 54.8% to 74.7% and 5.4% to 54% respectively at air flow rate of 10 L/min and 20 L/min.

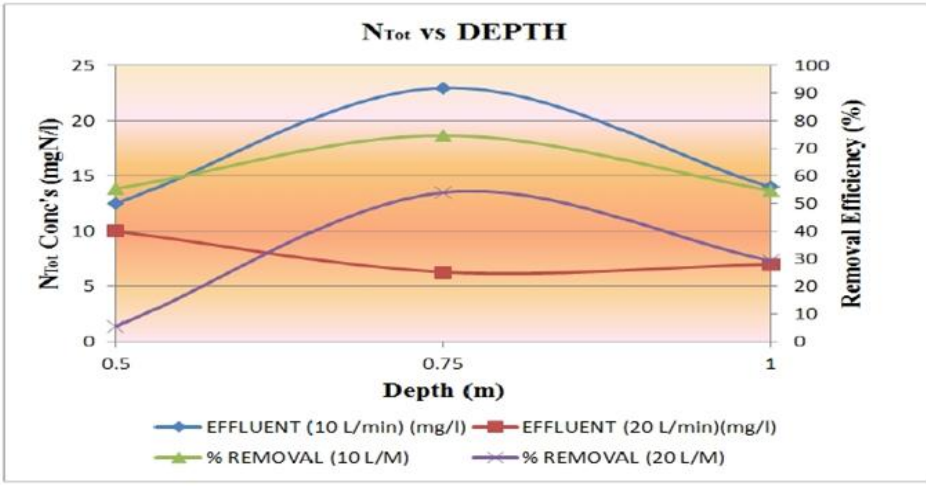

Figure 3: N_{Tot} Concentrations and Removal Efficiency

Ammonia Nitrogen (AN) Removal

The removal efficiency of AN at flow rate of 10 L/min at filter depth 0.5m, 0.75m and 1.0m were 81.3%, 99.2% and 95%, respectively meanwhile at 20 L/min of air flow rate the removal efficiencies at the above mentioned filter depth were 92.5%, 95.1% and 91.1% as shown in Figure 4. Therefore, the air flow rate of 10 L/min more suitable than air flow rate of 20 L/min as their capabilities in removing ammonia nitrogen.

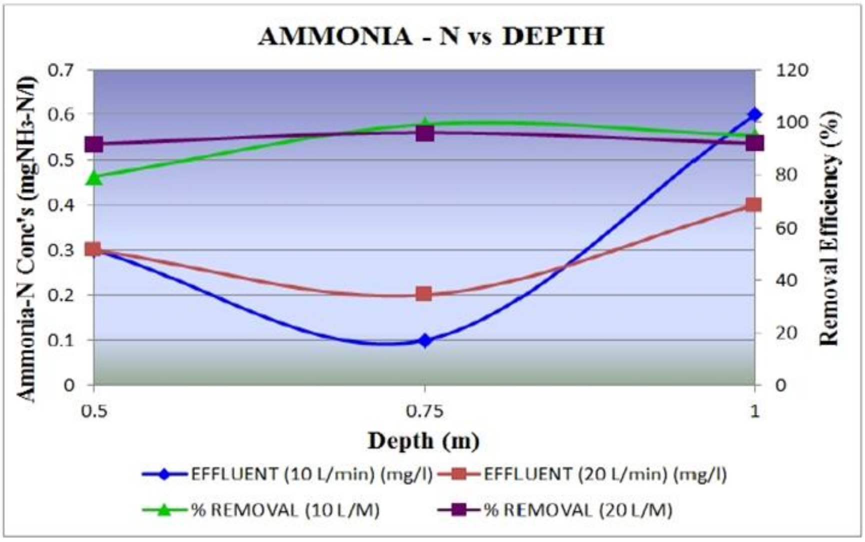

Figure 4: Ammonia-N Concentrations and Removal Efficiency

The concentrations of nitrate-N in the VARF system effluent ranged from 5.7 to 11.4 mgNO_3-N/L at air flow rate of 10 L/min whereas the concentration of effluent at air flow rate of 20 L/min was between 3.7 to 5 mg NO_3-N/L, as shown in Figure 5. That is, the air flow rate of 10 L/min is oxidized more free AN ions to nitrate-nitrogen in comparison with the air flow rate of 20 L/min. Therefore, the air flow rate of 10 L/min is more effective than 20 L/min. Moreover, free ammonia in the form of ammonium ions (NH_4^+-N) was oxidized to nitrate through the bacterial nitrification process in the VARF system.

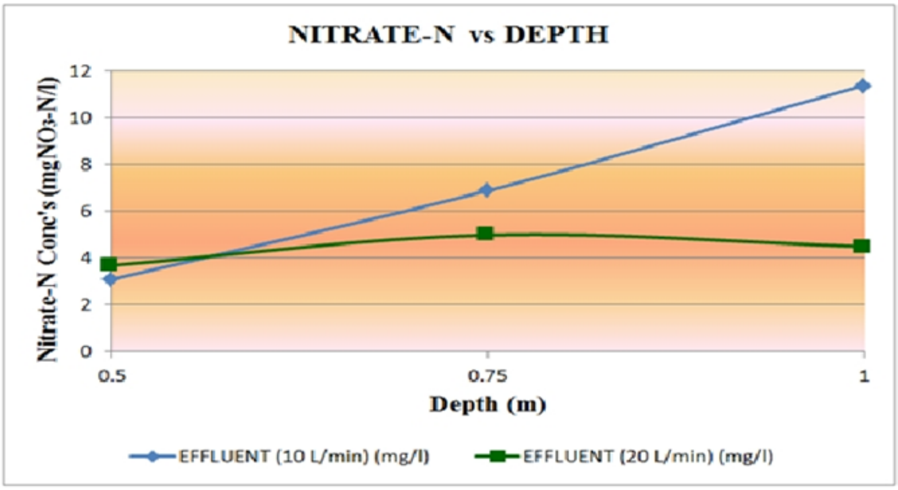

Figure 5: Nitrate-N Concentrations

Dissolved oxygen was found to be higher in the air flow rate of 10 L/min which is 7.6, 8.3 and 8.5 mg/L, whilst 7.3, 8.1 and 7.0 mg/L was determined in the air flow rate of 20 L/min as illustrated in Figure 6 below. According to the increasing level of DO in the systems, the VARF pilot scale system provides more favorable conditions for nitrification to occur as well as further removal of biodegradable organic matters. The consumption of the DO is needed to oxidize ammonia to nitrite and later to nitrate (Hamdan and Mara, 2011). From this study, it was found that the DO levels at 10 L/min were significantly higher than the 20 L/min.

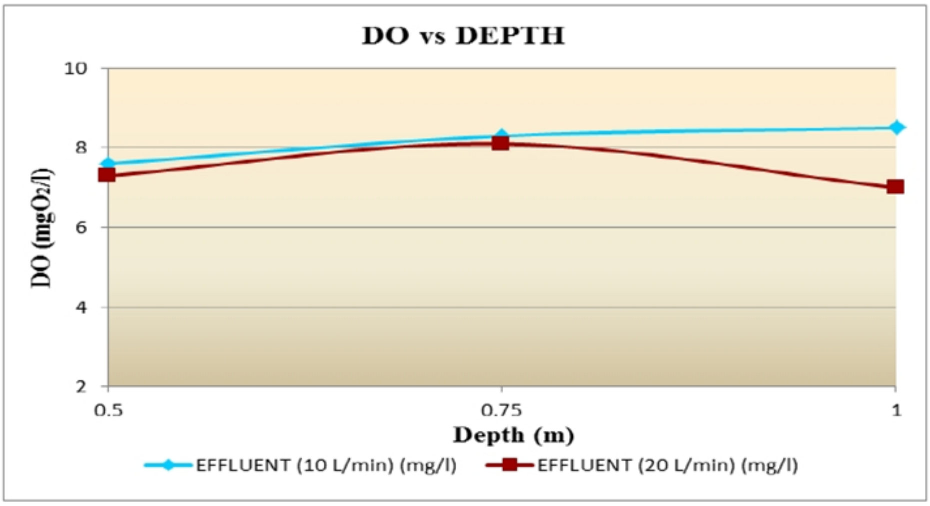

Figure 6: Dissolved Oxygen Profiles

Suspended Solid (SS) Removal

Figure 7 shows the percentage of removal efficiency of suspended solid. The higher percentage removal efficiency of suspended solid is 97.8% at 1.0m filter depth with air flow rate of 20 L/min meanwhile the minimum removal efficiency is 56.9% at filter depth 0.5m with 10 L/min air flow rate. From the observation it can be conclude that the VARF pilot scale is appropriate system to remove the suspended solid.

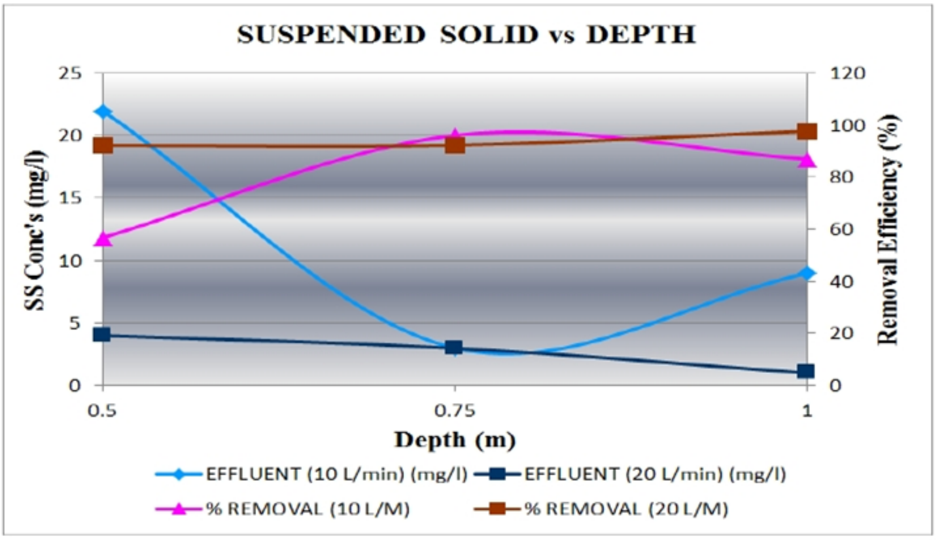

Figure 7: SS concentrations and Removal Efficiency

pH Profile

The effluent pH for air flow rate of 10 L/min is range 8.4 to 9.5 whilst at air flow rate of 20 L/min is about 8.2 to 8.4. This occurred most probably due to consumption of alkalinity since the nitrification of nitrogen within the treatment process. It was found that at air flow rate of 20 L/min, VARF effluent pH is more stable in comparison to the pH at air flow rate of 10 L/min as provided in Figure 8. Besides that, the effluent is comply to the effluent permissible limit for 'standard B' from Environmental Quality (Sewage) Regulations 2009, where for effluent discharge design for standard B is 5.5 - 9.0. However, the observed pH value is not harmful to aquatic life because of the natural water has a pH range of 4.5 to 8.5.

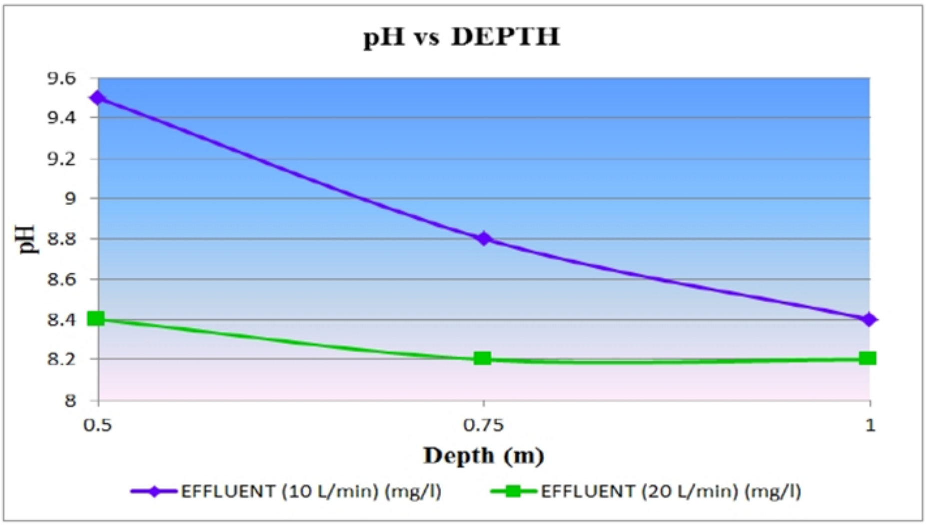

Figure 8: pH Profile

As a conclusion, effective aeration systems designed for domestic wastewater treatment process must be adequate and comply with the biochemical oxygen demand (BOD) Standard required by the regulators satisfy the oxygen demand of nitrification. It is already proven in the analysis where the percentage of reducing BOD_5 is around 80%. All result from the effluent fulfills all the criteria in Malaysian Environmental Quality (sewage) Regulation 2009 which is in standard B.

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