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EFFECT OF ORGANIC LOADING RATE ON SIMULTANEOUS REMOVAL OF NITROGEN AND PHOSPHORUS FROM AQUATIC PRODUCT PROCESSING WASTEWATER BY ADVANCED A^2/O – BAF SYSTEM

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ABSTRACT

Combined system of Anaerobic/Anoxic/Oxic reactor with Biological Aerated Filter (A^2/O – BAF) is used to enhance simultaneous removal of nitrogen and phosphorus on aquatic product processing wastewater treatment. A^2/O reactor was operated with short solids retention time employed mainly for removal of organic matter and phosphorus together with denitrification and BAF with long solids retention time employed mainly for nitrification. The model of combined A^2/O – BAF system made from polyacrylic with the capacity of 49.5 liters was operated with hydraulic retention time decreased from 19.2 to 9.6 hours and organic loading rates increased from 0.50 to 1.0 kgCOD/m^3/day. The results showed that the model not only treated organic matter well but also removed nearly completely both nitrogen and phosphorus. For loading rate of 0.75 kgCOD/m^3/day, treatment efficiencies of COD, NH_4^+-N, TN, TP of the model were the highest as 91.02, 96.82, 84.08, 86.66 %, respectively and output values of these parameters were within the limits of QCVN 11:2008/BTNMT, column A.

Keywords: combined A^2/O – BAF system, aquatic product processing wastewater.

1. INTRODUCTION

Wastewater with excessive nitrogen and phosphorus can result in serious environmental problems – eutrophication. To decrease such environmental pollution, the effluent requirement for nutrient discharges (especially for nitrogen and phosphorus) is becoming more and more stringent. Along with this growth of aquatic product processing industry, a huge amount of wastewater from aquatic product processing has caused serious problems with environmental pollution [1]. Major types of wastes found in aquatic processing wastewaters are blood, offal products, viscera, fins, fish heads, shells, skins and meat "fines." The characteristics of the wastewater are rich of nutrients, nitrogen and phosphorus. To aquatic product processing wastewater, traditional biological treatment processes such as activated sludge (suspended growth) or biological filter (attached growth) are often implemented. However, these processes have not yet treated thoroughly nitrogen and phosphorus from aquatic product processing wastewater to meet QCVN 11:2008/BTNMT (Vietnam National Technical Regulation on Aquatic Product Processing Wastewater) [2].

In this study, a combined Anaerobic/Anoxic/Oxic (A^2/O) reactor and biological aerated filter (BAF) system were applied to treat high – mid concentration wastewater. The A^2/O process was operated in a short aerobic sludge retention time (SRT) for restraining nitrification, and mainly used for organic pollutants, phosphorus removal and denitrification. The A^2/O reactor have two recyles: one is an nitrate recirculation from the aerobic zone to the anoxic zone for denitrification, the other is the sludge recycled from the settler to the anaerobic zone. In anaerobic zone, the intracelular β-polyhydroxybutyrate (PHB) accumulation extent of Phosphorus Accumulating Organisms (PAOs) determined its capacity of taking up phosphorus in aerobic or anoxic zone. However, A^2/O reactor is a single sludge system with the only line for excess sludge discharge at the secondary clarifier so there has been limitation to satisfy an proper solids retention time for both nitrifiers and PAOs in one aerobic zone of A^2/O reactor. On the other hand, nitrifiers need long solids retention time and PAOs need short solids retention time. To solve this problem, a new biological reactor will be seperated from the oxic compartment of A^2/O reactor. The new biological reactor with short hydraulic time contains attached growth organisms with long solids retention time for nitrification of NH_4^+-N and recirculation of NO_3^--N. Combined system of A^2/O – Attached Growth Biological Reactor including A^2/O reactor employed mainly for removal of organic matter and phosphorus together with denitrification and attached growth biological retention reactor employed mainly for nitrification is used to enhance simultaneous removal of nitrogen and phosphorus from wastewater. Weitang Zhang et al., 2013 studied simultaneous removal of nitrogen and phosphorus from domestic wastewater by a combined system of A^2/O – BAF. The results showed that treatment efficiencies of COD, TN, PO_4^{3-}-P achieved very high values as 89±4, 83±3, 99±1 %, respectively [5]. Biological Aerated Filter Reactor (BAF) using media made from polyethylene which have weight lighter than water and large specific surface area in fluidized state for microbial attachment and biofilm formation has been a new wastewater treatment technology researched and developed by Swedish scientists since 1986 and it can reach complete nitrification [6]. Thus, BAF was selected as attached growth biological reactor in combined system. In this paper, combined A^2/O – BAF system was used to evaluate efficiencies of removing nitrogen and phosphorus simultaneously from aquatic product processing wastewater.

2. MATERIALS AND METHODS

2.1. Waste water and sludge

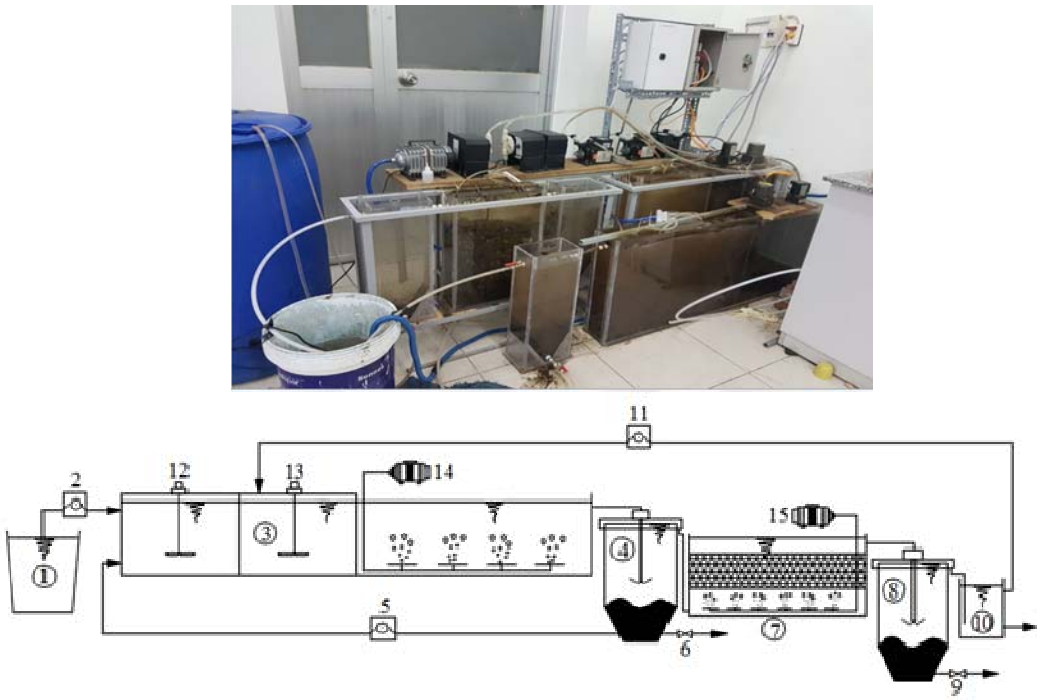
The influent of the experimental system was similar to aquatic product processing wastewater after primary and anaerobic treatment was created by taking catfish and by-products bought from supermarkets into a grinder. After being coarsely ground, they were fed to a water tank in 15 days to decompose. Then the solution from this tank was gone through a filter to remove fish bone and suspended solid. The filtrate was considered as raw wastewater. The major characteristics of the influent are shown in Table 1.

Table 1. Characteristics of influent wastewater (mg/l).

Parameter	pH	COD	TN	NH_4^+-N	TP
The range	6.8 – 7.8	230 – 445	64 – 96	50 – 82	8 – 15
Average	7.5	420	82	61	12

Seed sludge for the model of combined A^2/O – BAF system was taken from Wastewater Treatment Plant of Binh Hung, Ho Chi Minh City. Seed sludge was light brown, well-settled with SVI of 89 and MLVSS/MLSS ratio of 0.72.

2.2. Experimental system



1/Wastewater tank: 250 liters (PE, Vietnam); 2/Quantitative pump: 11 liters/hour (Hana, Rumani); 3/A_2O reactor with three compartments: 36.0 liters (Polyacrylic, Vietnam); 4/Secondary settler 1: 7.2 liters (Polyacrylic, Vietnam); 5/Return sludge pump: 11 liters/hour (Blue White, United State); 6/ Sludge valve 1: ∅21 (PVC, Vietnam); 7/BAF with FXP media: 13.5 liters (Polyacrylic, Vietnam); 8/Secondary settler 2: 7.2 liters (Polyacrylic, Vietnam); 9/Sludge valve 2: ∅21 (PVC, Vietnam); 10/Middle tank: 20 liters (PE, Vietnam); 11/Return effluent pump: 30 liters/hour (Blue White, United State); 12/Mixing 1: (IWAKI, Japan); 13/Mixing 2: (IWAKI, Japan); 14/Blower 1: 38 liters/min (RESUN, Ap 001, China); 15/Blower 2: 38 liters/min (RESUN, Ap 001, China).

Figure 1. Schematic representation of the experimental system.

Polyacrylic model included A^2/O reactor having an approximate dimension of 800 mm L × 100 mm W × 500 mm H with the corresponding volume of 36.0 liters which was divided by baffles to creat three compartments in ratio of 2:2:4 and BAF having an approximate dimension of 300 mm L ×100 mm W × 500 mm H with the corresponding volume of 13.5 liters. Total volume of the model of combined A^2/O – BAF system was 49.5 liters. The amount of FXP media (FXSINO Co Ltd., China) used in the BAF was about 3.6 liters accounted for 40 % volume of the reactor. FXP media made from polyethylene with 16 mm in diameter and 9 mm in length, having surface area of 590 m^2/m^3 and specific weight of 970 kg/m^3. Secondary settlers had an approximate dimension of 150 mm D x 300 mm H with the working volume of 7.2 liters. Schematic representation of the experimental system was represented in Figure 1.2.3.

2.3. Experimental set-up

Seed sludge was given to 50 % volume of the model with MLSS concentration about 4500 mg/L. Raw wastewater with average COD concentration of 420 mg/L diluted in ratio of 1:1 with tap water was pumped into the model. Organic loading rates increased little by litte from 0.2 to 0.4 $kgCOD/m^3$/day correspond to hydraulic retention time decreased from 42.6 to 24 hours and wastewater flow rates increased from 28 to 84 liters/day. DO concentrations of the aerobic compartment and the BAF were determined by DO meter and controlled from 2 to 4 mg/L. Return effluent ratio of 200 % and return sludge ratio of 100 % were fixed. The adaptation stage ended when COD removal efficiency achieved over 85 %. At that time, biomass available in the aerobic compartment was more than 2000 mg/L and biofilm was formed on media surface of the BAF. Then raw wastewater was pumped continously with wastewater flow rates increased from 62 to 124 liters/day corresponding to hydraulic retention time decreased from 19.2 to 9.6 hours and organic, nitrogen, phosphorus loading rates increased from 0.5 to 1.0 $kgCOD/m^3$/day, 0.11 to 0.21 $kgTN/m^3$/day, 0.014 to 0.028 $kgTP/m^3$/day, respectively as in Table 2. Excess sludge from the secondary settlers were discharged to maintain solids retention time in the A^2/O reactor and the BAF from 5 to 7 days and from 15 to 20 days, respectively.

Table 2. Operating parameters at different organic loading rates.

Wastewater flow (liter/day)	**Organic loading** ($kgCOD/m^3$/day)	**Nitrogen loading** ($kgTN/m^3$/day)	**Phosphorus loading** ($kgTP/m^3$/day)	**Return effluent ratio** (%)	**Hydraulic retention time** (hour)
62	0.50	0.11	0.014	200	19.2
93	0.75	0.16	0.021	200	12.8
124	1.00	0.21	0.028	200	9.6

2.4. Analytical methods

Samples were collected regularly from different zones of the A^2/O – BAF reactor as well as the feed for offline measurement. pH, COD, MLSS, NH_4^+-N, NO_2^--N, NO_3^--N, TN, TP and PO_4^{3-}–P were measured according to Vietnam National Standards (QCVN) together with Standard Methods for the Examination of Water and Wastewater (APHA, Eaton DA, and AWWA) at the Laboratory of Environmental Technology of Institute for Environment and Resources, and the Laboratory of Hoa Sen University - Ho Chi Minh City. All samples were filtrated by 0.45 µm filter before analysis. For each loading rate, the model was operated for 15 days to achieve a steady-state condition and the samples were collected over a 5-day period during 80 successive days. The results below were based on average value and standard deviation by using Microsoft Office Excel software.

3. RESULTS AND DISCUSSION

3.1. Organic removal efficiency

The results from this study confirmed this intergrated system achieved good COD removal efficiency. COD concentrations at different positions in the model were revealed in Figure 2 for loading rates of 0.50, 0.75, 1.00, 1.25 kgCOD/m^3/day and COD removal efficiencies at various loading rates were revealed in Figure 3.

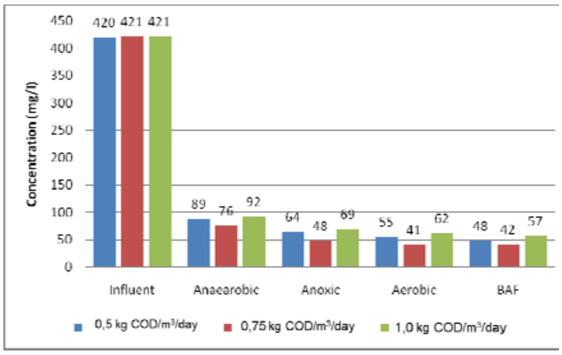


Figure 2. Change of COD concentration at various loading rates.

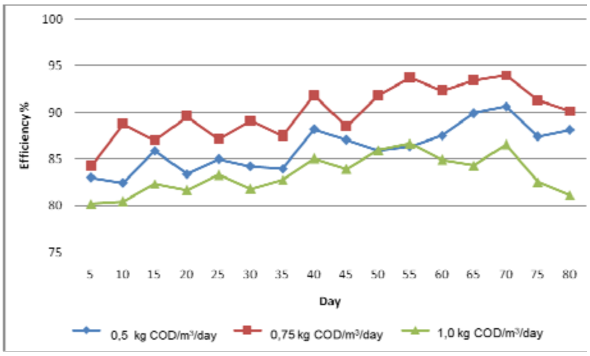


Figure 3. COD removal efficiencies at various loading rates.

The results showed that a large proportion of COD (approximately 81%) was utilized in the anaerobic zone of the A^2/O process by PAOs and 10 % of COD was consumed in the anoxic compartment by denitrifiers. The amount of COD changed slightly in the aerobic zone and BAF process [7]. Among the percentage of COD removal, more than 80% COD was removed in the anaeobic phase, while 28 ≈ 46 % COD was utilized in the anoxic zone, with very low COD available in the aerobic phase. It was condidered to be advantageous for nitrification because of non-inhibitory effects. Phosphorus accumulation by PAOs happened mostly in the aerobic compartment and nitrification of NH_4^+-N by nitrifiers also happened mostly in the BAF. Therefore, the growth of nitrifiers was favourable and nitrification was enhanced as well. COD removal efficiencies at various loading rates of the model were represented in Figure 3. For loading rates of 0.50, 0.75, 1.00 kgCOD/m^3/day, average COD removal efficiencies of the model were 90.02, 96.82, 84.08 %, respectively. It could be seen that COD removal efficiency reached the highest value at the proper loading rate of 0.75 kgCOD/m^3/day. For loading rates of 0.50 and 0.75 kgCOD/m^3/day, output values of COD were within the limits of QCVN 11:2008/BTNMT, column A. For loading rate of 1.00 kg COD/m^3/day, output values of COD were within the limits of QCVN 11:2008/BTNMT, column B.

3.2. Nitrogen removal efficiency

In the A^2/O – BAF system, the nitrat recycling stream from the BAF to the anoxic zones of the A^2/O acts as a typical pre – denitrification process. Nitrogen concentrations at different positions in the model were revealed in Figures 4, 5, 6 and 7 for loading rates of 0.50, 0.75, 1.00 kgCOD/m^3/day, respectively. The results showed that TN and NH_4^+-N concentrations decreased significantly in the anaerobic and anoxic compartments. It also showed that TN at the aerobic compartment was mostly NH_4^+-N and TN at the BAF was mostly NO_3^--N. Nitrification hardly occured in the aerobic compartment. Nearly all of NH_4^+-N was completely transformed by nitrification in the BAF. Only a small amount of NH_4^+-N was metabolized for the growth of microorganisms in the A^2/O reactor. Very low NO_3^--N concentration in the aerobic compartment indicated that denitrification happened as much as possible in the anoxic compartment [8]. The anoxic denitrification capabilities play a prominent role in TN removal. Because anoxic zones are the only place that all or part of NO_3^--N are reduced to nitrogen gas. TN removal was positively associated with the anoxic denitrification capabilities. Removal efficiencies of nitrogen at various loading rates of the model were represented in Figure 7. For loading rates of 0.50, 0.75, 1.00 kgCOD/m^3/day, average TN and NH_4^+-N removal efficiencies of the model were 80.05 and 93.41, 96 and 84, 67.9 and 87.27 %, respectively. Nitrogen removal efficiency also reached the highest values at the proper loading rate of 0.75 kgCOD/m^3/day. For all three loading rates, output values of TN and NH_4^+-N were within the limits of QCVN 11:2008/BTNMT, column A.

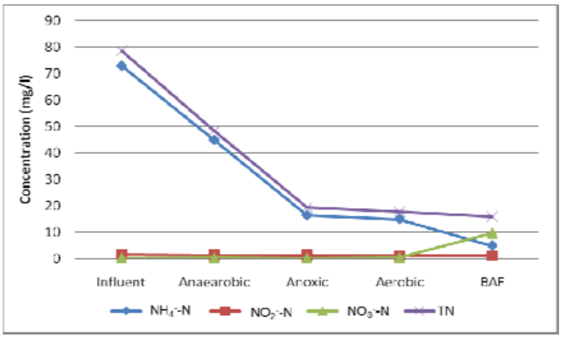


Figure 4. Conversion of nitrogen concentration for a loading rate of 0.50 kgCOD/m^3/day.

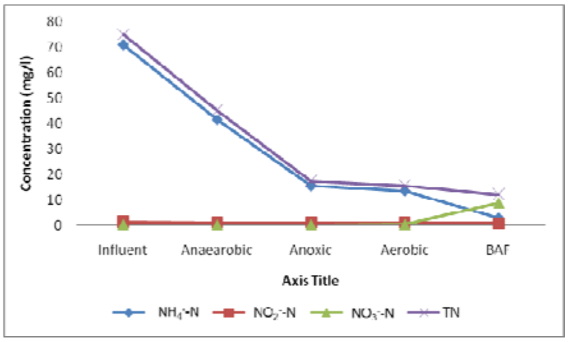


Figure 5. Conversion of nitrogen concentrationfor a loading rate of 0.75 kgCOD/m^3/day.

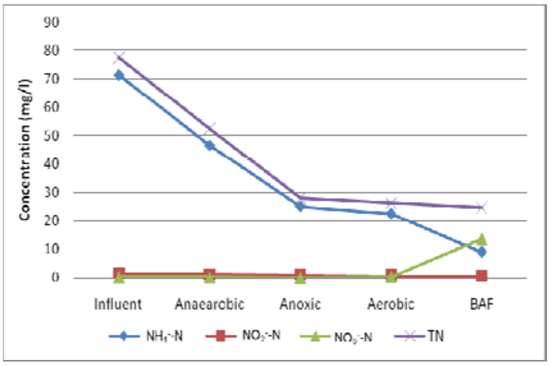


Figure 6. Conversion of nitrogen concentration for a loading rate of 1.00 kgCOD/m^3/day.

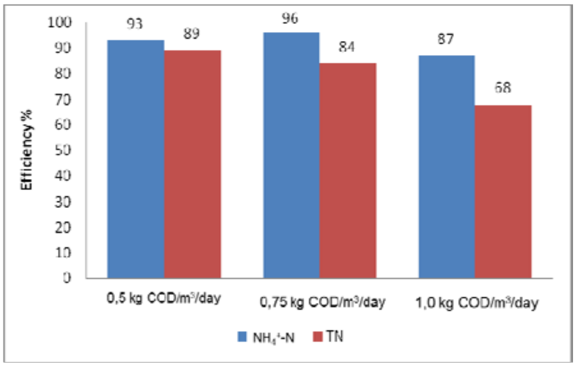


Figure 7. Nitrogen removal efficiencies at various loading rates.

3.3. Phosphorus removal efficiency

Phosphorus concentrations at different positions in the model were illustrated in Figure 8 for loading rates of 0.50, 0.75, 1.00 kgCOD/m^3/day. The results showed that TP concentration increased to the maximum level in the anaerobic compartment when PAOs released phosphate by utilizing 81 % of COD in wastewater as stated above and decreased in the anoxic compartment by the dilution of the return effluent flow from the BAF to the anoxic compartment. In the aerobic compartment, TP was further accumulated by PAOs to reach complete biological phosphorus removal. Phosphorus removal efficiencies at various loading rates of the model were represented in Figure 9. For loading rates of 0.50, 0.75, 1.00 kgCOD/m^3/day, average TP removal efficiencies of the model were 87.27, 88.66, 83.96 %, respectively. Phosphorus removal efficiency also reached the highest values at the proper loading rate of 0.75 kgCOD/m^3/day. For all three loading rates, output values of TP were within the limits of QCVN 11:2008/BTNMT, column A.

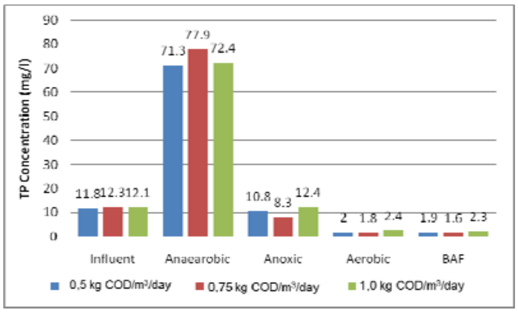


Figure 8. Conversion of TP concentration at various loading rates.

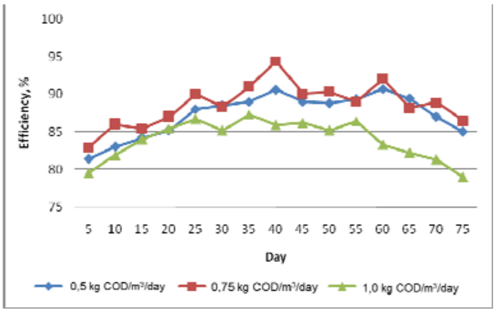


Figure 9. TP removal efficiencies at various loading rates.

4. CONCLUSIONS

In this study, the model of combined A^2/O – BAF system was operated well and treatment efficiencies of nitrogen and phosphorus at four loading rates were very high. It was capable of achieving effluents with very low nitrogen and phosphorus concentrations from aquatic product processing wastewater. For a loading rate of 0.75 kgCOD/m^3/day, treatment efficiencies of COD, NH_4^+-N, TN, TP of the model were the highest as 90.02, 96.82, 84.08, 86.66 %, respectively and output values of these parameters were within the limits of QCVN 11:2008/BTNMT, column A. In conclusion, A^2/O reactor with short solids retention time and BAF with long solids retention time could remove simultaneously nitrogen and phosphorus from aquatic processing wastewater to prevent eutrophication in natural water resources.

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