



Feasibility Study of Fish Farm Effluent Treatment by Sequencing Batch Membrane Bioreactor

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ABSTRACT

In this study, the treatment of fish farm effluent by SBR (sequencing batch reactor) operation type MBR was conducted to evaluate the system performance. Two aerobic/anoxic durations (aeration/stirring-settling), 100/45-45 min (run 1) and 60/60-70 min (run 2), were adopted for the evaluation of system performance. High DO concentration was maintained in aerobic phase to enhance nitrification in this study as well as to evaluate the effect of anoxic duration on system performance. The results showed that the average MLSS concentration for run 1 and run 2 is 1560 mg/L and 1890 mg/L, respectively. The results indicated that the performance of run 2 was much better than that of run 1. The experimental results indicated that both nitrogen and organic removals were significant during run 2 due to its shorter aeration and longer anoxic phase. The average removal of COD and BOD₅ of run 2 was 81 % and 90 %, respectively. Nitrification and denitrification were significant during run 2, the effluent nitrite was down to a range of 0.5-1.0 mg/L and most of the time, nitrate was non-detectable.

Keywords: Fish farm effluent, Sequencing batch membrane bioreactor, COD, Nitrogen compounds

1.0 INTRODUCTION

Pond culture is one of the major contributors to aquaculture industry in Taiwan (Chen et al., 2003). However, the rapid expansion of pond culture has resulted in adverse effects on the environment such as land subsidence and water pollution (Chen et al., 2006). The wastewaters mainly derive from the leftover feeds and creatures' excrements. Differing from the running-flow-type culture which causes significant pollution by direct discharge of waste water into the natural water body, recirculation culture is one of the most

efficient improvements on the aquaculture wastewater treatment (Lyssenko and Wheaton, 2006). In addition to decrease in expenditure of effort, finance and manpower, it can also create high density aquaculture only by regular addition of small amount of water lost due to evaporation (Timmons and Losordo, 1994). Recently, membrane bioreactor (MBR) has been applied for aquaculture effluent reuse (Pulefou et al., 2008). MBR systems have high organic removal performance, tolerate bulking sludge conditions, and effectively remove suspended solids (SS) and pathogenic micro-organisms from wastewaters. Such plants typically operate at high sludge ages and reduced sludge yields. The chief advantage of MBRs, however, is the ability to

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maintain high MLSS concentration in the mixed liquor, thus it is possible to employ smaller HRTs and reactor volumes (Brindle and Stephenson, 1996).

Sequencing batch reactor (SBR) systems are cost-effective and well established in the domain of municipal sewage and industrial wastewater treatments. SBR plants use intermittent aeration, thus can remove both carbon and nitrogen from wastewater with lower energy requirements (Suresh et al., 2011; Wisaam et al., 2007). Basically, SBR can discharge the effluent fairly well without sludge washout. However, additional filtration is generally needed to get adequate water quality for water reuse (Wisaam et al., 2007). Zhang et al. (2006) demonstrated a comparative study on the performance between a sequencing batch membrane bioreactor (SBMBR) and a conventional membrane bioreactor (CMBR) for enhancing nitrogen and phosphorus removals. The results illustrated that the SBMBR system demonstrated good performance on nitrogen and phosphorus removal at different COD/TN ratios. Although applying SBR type operation for MBR systems to treat domestic wastewater and industrial wastewater have been studied (Yang et al., 2010; Zhang et al., 2006), the combination of SBR type operation with MBR to treat fish farm wastewater is barely explored.

In this study, a membrane bioreactor with a sequencing batch type operation was experimented to treat fish farm effluent. An optimum duration of aeration/anoxic phases is necessary in order to achieve good nitrification and denitrification in a SBR type operation (Boopathy et al., 2005; Chang et al., 2006; Fontenot et al., 2007). The aim of this study focused on the effect of anoxic duration on nitrogen and organic removals under a highly aerated condition prior to the anoxic phase. Two operating modes were evaluated in this study to estimate the treatment feasibility of

fish farm effluent by a laboratory scale SBR operating type MBR.

2.0 MATERIALS AND METHODS

2.1 Experimental Design of MBR

A submerged membrane bioreactor (MBR) with a working volume of 6.0 L was inoculated with fresh activated sludge from a municipal wastewater treatment plant to give an initial biomass concentration of 2900 mg VSS L⁻¹ (VSS stands for volatile suspended solids). The experimental MBR set up is shown in Figure 1. The hollow fiber membrane with a pore size of 0.4 μm used in this study is made of high density polyethylene (Mitsubishi Rayon Co., Ltd, Japan). The reactor was maintained at 25° C in a temperature room. Effluent was discharged at a volumetric exchange ratio of 60%. The total surface area of the hollow fiber membrane used in this study was 0.108 m² to provide an average flux of 50 Lm⁻²h⁻¹ for 3.6 L permeate within 40 min. During the suction, the membrane module was partially submerged in the sludge blanket. Transmembrane pressure difference was not evaluated in this study, the membrane was cleaned with chemicals once 3.6 L permeate within 40 min could not be reached. An average chemical cleaning frequency of 23 days was obtained in this study. Fine air bubbles for aeration were supplied through a dispenser at the reactor bottom at an airflow rate of 8 L min⁻¹ to maintain a dissolved oxygen concentration above 4 mg L⁻¹ during aeration period. In this study, high DO concentration was maintained in aerobic phase to enhance nitrification as well as to evaluate the effect of anoxic duration on system performance.

2.2 Operating Mode of MBR

Experiments were carried out in two runs corresponded to different aerobic/anoxic dura-

tion ratio. For each run, the reactor was initially operated sequentially by influent filling-aeration-stirring-settling-effluent withdrawal with the total cycle duration of 4 h. The sludge retention time (SRT) was 20 days throughout the experiments. In this study, 10 min of influent filling and 40 min of effluent withdrawal were fixed, different aeration on/off modes (aeration/stirring-settling) were adopted for the evaluation of removal performance, and the operation of aeration/stirring-settling for run 1 and run 2 in minute were 100/45-45 and 60/60-70 respectively. Operational conditions according to aeration on/off time are presented in Table 1. Wastewater used in this study was taken from a multiple fish species breeding pond in Tainan, Taiwan. In that pond, several creatures including Milkfish, Tilapia and *Penaeus monodon* were bred. The detailed characteristics of the wastewater are presented in Table 2.

2.3 Analysis

The DO (dissolved oxygen), ORP (oxidation-reduction potential) were measured by putting the DO and ORP probe inside the tank, while samples were taken from MBR reactor for analyses of MLSS (mixed liquid suspended solid), MLVSS (mixed liquid volatile suspended solid), COD (chemical oxygen demand), DCOD (dissolved chemical oxygen demand), TCOD (total chemical oxygen demand), BOD₅ (biochemical oxygen demand), TKN (total Kjeldahl nitrogen), ammonia-N, nitrite and nitrate.

3.0 RESULTS AND DISCUSSION

In this study, the treatment of fish pond wastewater by SBR (sequencing batch reactor) type MBR reactor was conducted at two different operating modes to evaluate the system performance. The temperature of

influent was in the range of 27.5 to 31 °C since the sampling was taken in summer. Influent pH values from 7.8 to 8.5 were observed while the effluent pH averaged 8.2. Throughout the experiments the effluent from the MBR had turbidity less than 0.5 NTU which is important if the effluent is to be recirculated back to the pond system.

Figure 2 shows the DO and ORP profiles for run 1 and run 2. As is the normal case, DO and ORP has positive correlation and both profiles showed the same trend. For run 1, during aerobic condition, DO and ORP both increased and both decreased as aeration was stopped. The slightly slow decrease in DO and ORP just after aeration was turned off as compared to the faster DO depletion and as a consequence, a reduction in the ORP of the anoxic period, could be explained by the microbiological acclimatization to sudden change in DO level. A different ORP trend of run 2 was observed while a sharp drop occurred when aeration was ceased and the lowest ORP with a value of -21 mV was obtained when anoxic stage was terminated. Also, the level of DO and ORP towards the end of the anoxic period where the ORP values are more negative than run 1. In this study, the air flow rate for aeration was the same. The higher consumption of oxygen in run 2 due to the higher biomass concentration resulted in a better performance of COD removal. The longer duration of anoxic operation may provide an adaptable circumstance for denitrifiers in run 2.

Results of MLSS, BOD₅ and COD measurements during the experiment are presented in Table 3. During the experiment, the average MLSS concentration for run 1 and run 2 is 1560 mg/L and 1890 mg/L, respectively. No SS is detected in the effluent. It is apparently that the average BOD₅ and COD removals of run 2 are higher than those of run 1.

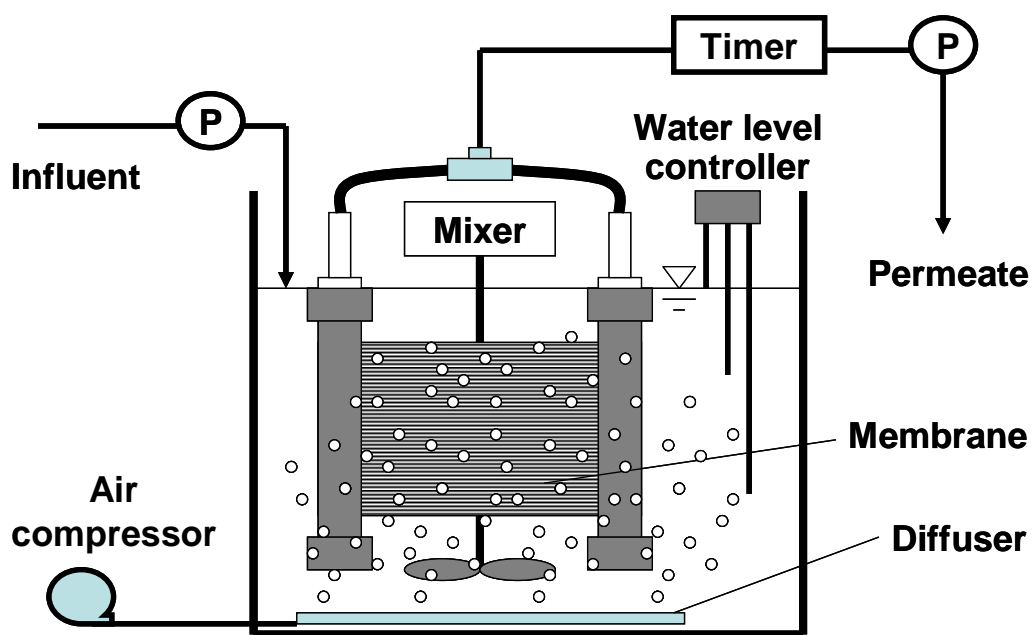


Figure 1 Schematic diagram of the experimental MBR reactor

Table 1 Scheme of operating modes

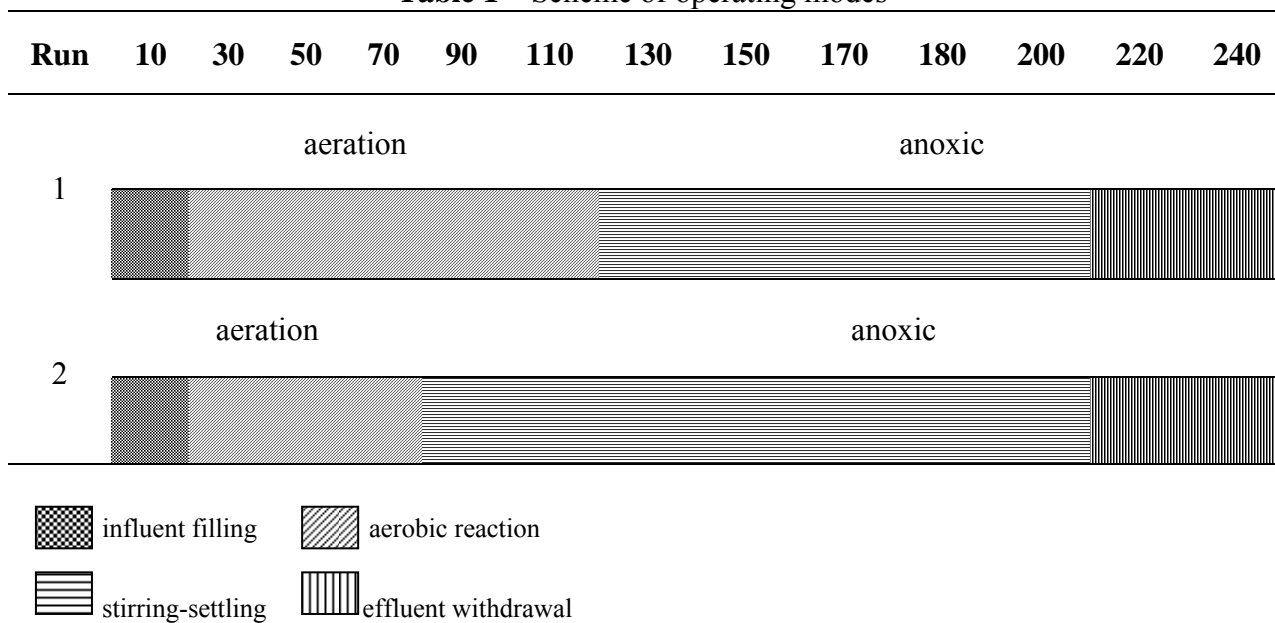


Table 2 Characteristics of influent

Item	pH	TCOD (mg/L)	TKN (mg/L)	NO ₂ -N (mg/L)	NO ₃ -N (mg/L)	Turb. (NTU)
Range	7.8-8.5	180-300	23-43	<5	<18	80-120

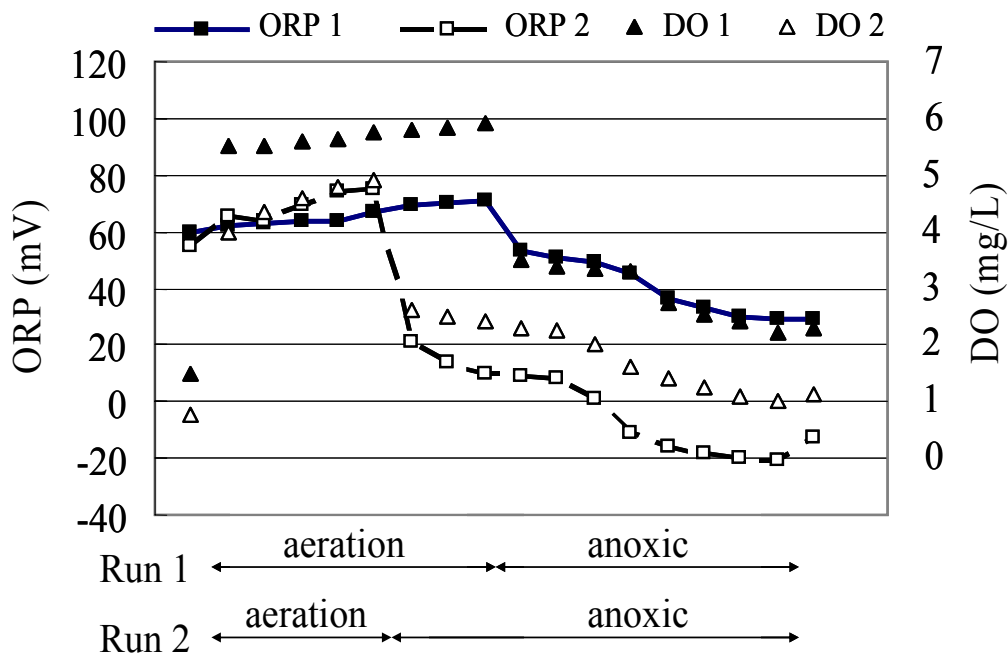


Figure 2 Relationship of ORP and DO for run 1 and run 2

Table 3 MLSS, BOD₅ and COD concentrations during the experiment

Mode	MBR		Influent (mg/L)		Effluent (mg/L)		Average Removal (%)	
	MLSS (mg/L)	VSS/SS	BOD ₅	TCOD	BOD ₅	DCOD	BOD ₅	TCOD
Run 1	1560	0.85	60-80	260-300	10-18	60-80	75	79
Run 2	1890	0.8	80-90	180-200	6-10	10-20	81	90

COD and BOD₅ variations within a SBR cycle were performed to investigate the effect of aerobic/anoxic duration on system performance. Figure 3(a) show that the BOD₅ profiles for both runs have a general decreasing trend, however, it was observed for run 2, the BOD profile steadily decreases as opposed to the BOD profile for run 1 in which the profile showed noticeable phases of slow and fast rate of BOD removal during the entire cycle of SBMBR operation. While the BOD removal of run 2 showed a much stable profile. It can be said that the performance of both run 1 and run 2 in terms of BOD removal are fairly the same as shown by the two

profiles almost having the same permeate quality.

Figure 3(b) shows the COD profile during the entire cycle of the SBMBR operation both for run 1 and run 2. For run 1, during aeration period, a noticeable slow initial rate of BOD removal which picked up towards the end of the aerobic phase was observed. COD removal for the aerobic and anoxic periods of Run 1 is 63% and 57% respectively. This greater COD removal rate during the aerobic versus the COD removal during the anoxic period of run 1 could be attributed to a longer aeration period where oxygen continuously available for nitrification, while the slight

decrease of COD removal during anoxic period could be attributed to a shorter anoxic duration prior to withdrawal of effluent.

For run 2, however, a reverse in the COD removal during the aeration period was observed as compared to that of run 1. During the aeration period of run 2, there is a fast initial rate of COD removal which slightly decreased towards the end of the aeration period. COD removal during aeration period is 44%. The COD removal of the anoxic period of Run 2, however, started out slowly with a slight increase towards the end of the anoxic period. COD removal for the anoxic period of run 2 is 88%.

The much higher COD removal during the anoxic period of run 2 as compared to its aeration period's COD removal could be attributed to the longer anoxic period duration for the denitrification reaction to proceed prior to withdrawal of the sample. While BOD removal as shown by Figure 3a for both runs are fairly the same, comparing the COD removal for run 1 and run 2 showed a different trend as discussed above, and in general run 2 with a shorter aeration period and longer anoxic period proved to be more efficient in COD removal with an overall COD removal of 94% as compared to about only 70% COD removal of Run 1.

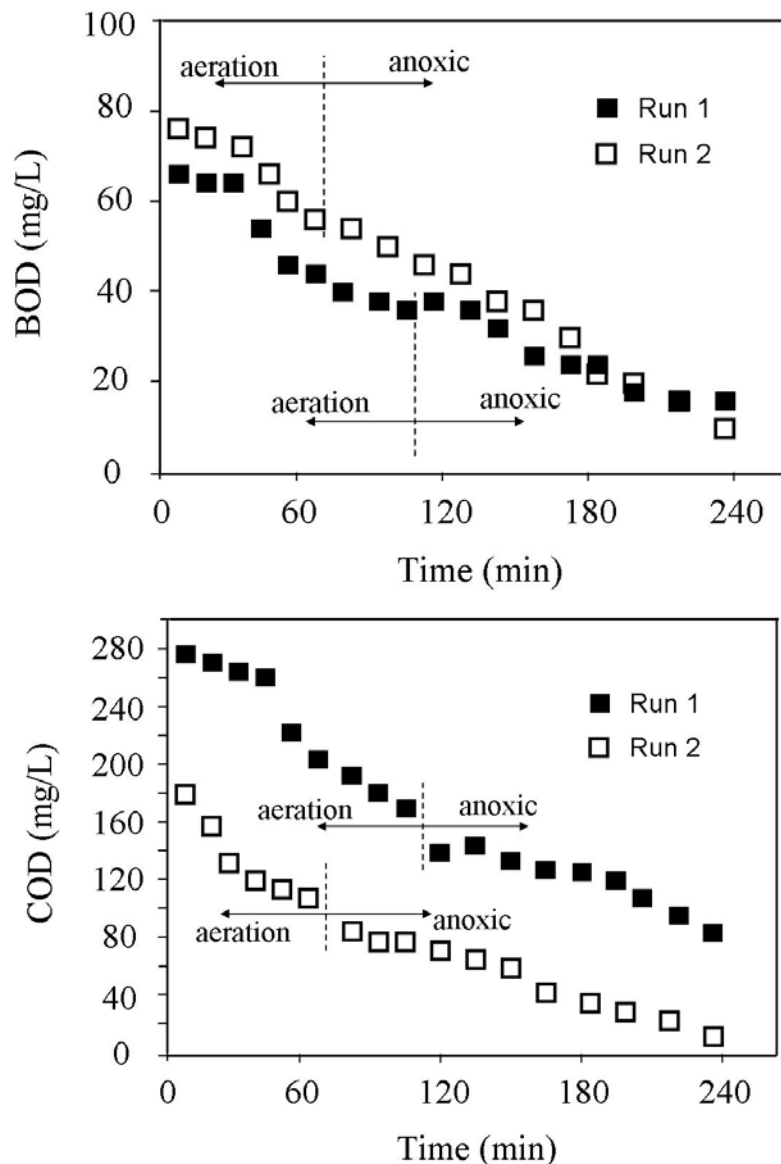


Figure 3 COD and BOD₅ variations within a SBR cycle (a) run 1 (b) run 2

Figure 4 illustrates the concentration profiles of nitrogen compounds through the experiments. As for nitrogen removal, the efficiency of run 2 was higher than run 1. The concentration of TKN of run 2 can be reduced significantly from 40 mg/L to 5 mg/L. The influent of ammonia-N was in the range of 4-7 mg/L, the effluent concentration of ammonia-N was in the range of 0.5- 1 mg/L. It clearly indicates that almost 90% of ammonia-N was removed in run 2. The effluent nitrite concentration was down to a range of 0.5-1.0 mg/L and most of the time,

nitrate was non-detectable. The results obtained from Figure 4 led to a conclusion that nitrification was dominant in run 1 and both nitrification and denitrification were significant in run 2.

In order to investigate the effect of aerobic/anoxic duration on nitrogen compounds and COD removals, one SBR cycle experiment were carried out. The relationships among TKN, ammonia nitrogen, nitrite, nitrate and COD are illustrated in Figure 5.

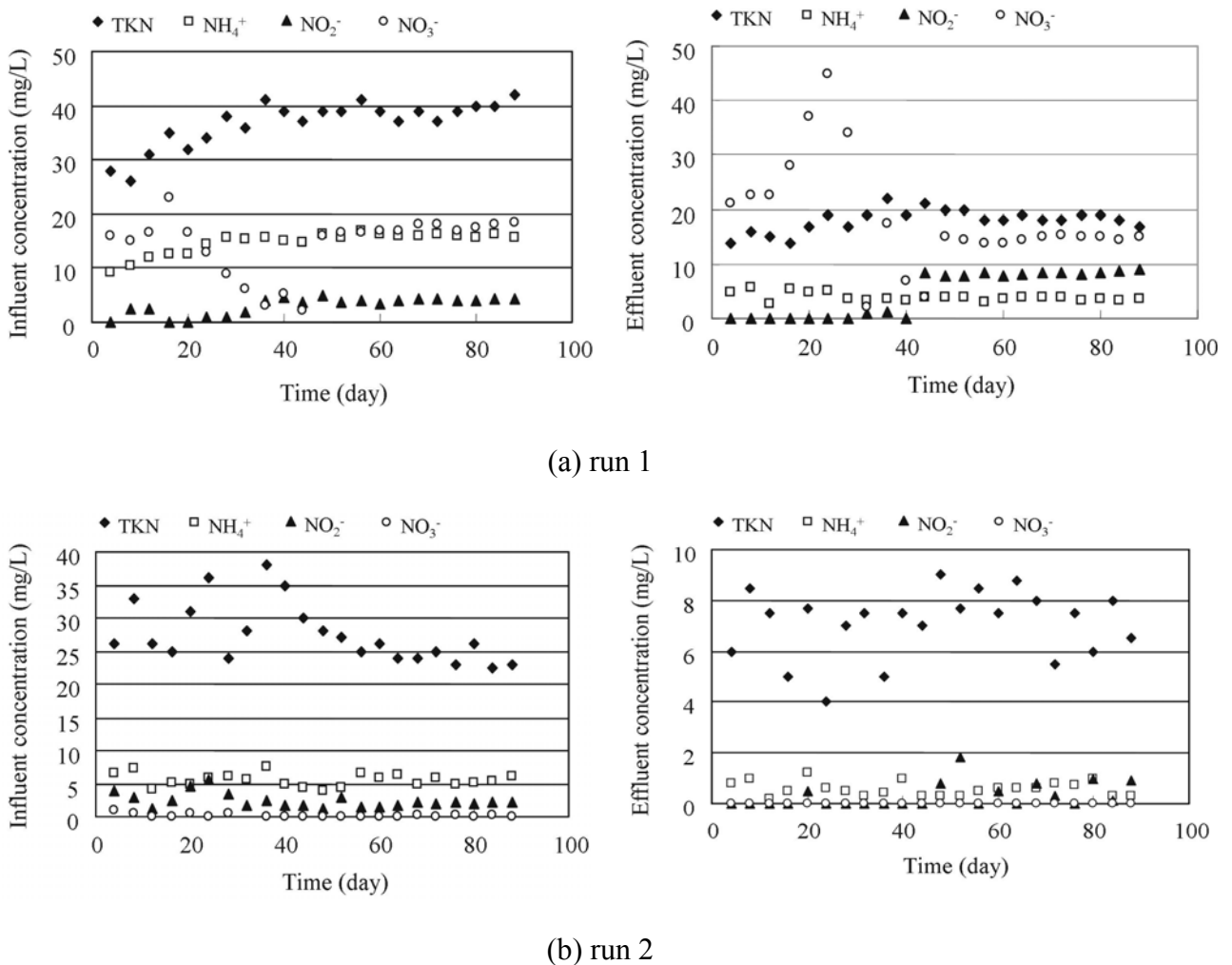


Figure 4 Profiles of nitrogen compounds through the experiments (a) run 1 (b) run 2

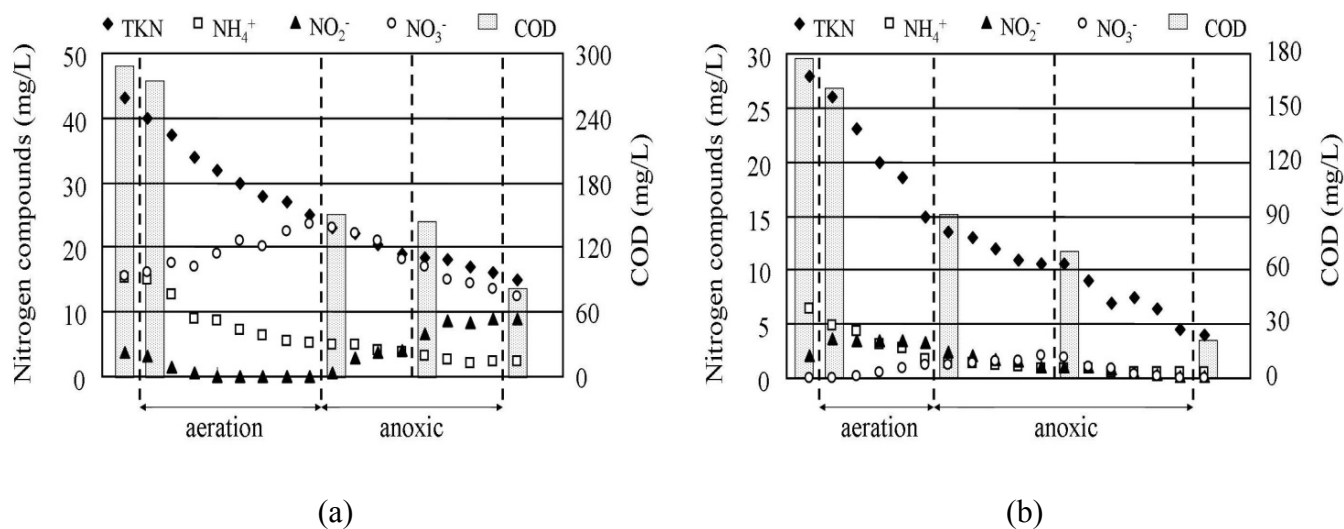


Figure 5 Profiles of nitrogen compounds and COD (a) run 1 (b) run 2

High COD/NH₄⁺-N (C/N) ratios were found in this system. As shown in Figure 5, the initial C/N ratio in the beginning of anoxic for run 1 and run 2 is 5 and 6, respectively. The results showed that the high C/N ratio contributed to enhanced removals of COD and nitrogen compounds. For run 1 as shown in Figure 5 (a), a steady decrease in TKN concentration was observed throughout the duration of the cycle. From the initial TKN concentration of 43 mg/L, the TKN value was decreased to 14 mg/L translating to 67% conversion. Generally, NH₄⁺-N concentration was also observed to have a decreasing trend throughout the cycle of operation with a sharper decrease in concentration during the early stage of the aeration process and decreasing at a fairly constant rate thereafter.

For run 2, Figure 5(b) shows that TKN and NH₄⁺-N showed a decreasing trend as in the case of run 1 but with slight differences. TKN profile for run 1 showed a smoother decreasing profile than that of Run 2 throughout the entire cycle. While it can be observed the TKN and NH₄⁺-N removal for run 1 appears to be faster than that of run 2, run 2 still performed better in the overall removal of the said nitrogen species. TKN

and NH₄⁺-N removal efficiency for run 1 are 65% and 80% respectively while TKN and NH₄⁺-N removal efficiency for run 2 are 82% and 92% respectively.

Figure 5(a) also shows the nitrite and nitrate concentration profiles during the different periods in the SBMBR cycle. During the aeration period, nitrite concentration decreased while the nitrate concentration increased. This inverse relationship of the nitrite/nitrate species signifies that nitrification was in progress and was the result of the coupled reaction of the AOB (ammonia oxidizing bacteria) conversion of ammonia nitrogen to nitrite which is then converted by NOB (nitrite oxidizing bacteria) bacteria to nitrate. During the anoxic period, the concentration of nitrite increased and showed a net increase of 5.5 mg/L from the influent to the effluent while the nitrate concentration decreased as denitrification took place, with a faster rate at the start which can be attributed to an initial high C/N ratio of 2.7 at the onset of denitrification then gradually decreasing as the carbon source is depleted towards the end of the anoxic period.

For run 2, Figure 5(b) shows the nitrite and nitrate concentration profiles during the

different periods in the SBMBR cycle. There is however a noticeable difference in the rates by which nitrite and nitrate are depleted. For run 1, nitrite concentration was almost negligible by the middle of the aeration period as compared to its slow depletion during the aeration period of run 2. Nitrate concentration on the other hand for run 1 reached its maximum concentration of 24mg/L, right after aeration was stopped and then followed a faster rate for decrease.

For run 2 which had its maximum at a much later time which coincided at the end of the stirring period. However, in terms of efficiency in converting nitrate to nitrogen gas, the longer duration of anoxic period for run 2 may have contributed to a better denitrification efficiency as compared to that of run 1 as the nitrate concentration was almost near zero at the end of the anoxic period versus the final nitrate concentration of 13mg/L for run 1. It should also be noted from Figure 5 that at the onset of anoxic period, the COD/N ratio for run 1 and run 2 are 2.7 and 7.5 respectively, making run 2 more favorable to denitrification. In fact, ORP profiles for run 2 showed that denitrification is more significant as compared to that of run 1 as shown in Figure 2. As shown in Figure 2, the ORP values of run 2 are more negative and thus indicating a reduction environment favorable for denitrification than the more positive ORP values of run 1. This difference could be attributed to the longer duration of the anoxic period for Run 2.

4.0 CONCLUSIONS

A laboratory scale SBR (sequencing batch reactor) operation type MBR was conducted to evaluate the system performance for the treatment of fish farm effluent. In this study, DO concentration above 4 mg/L was maintained in aerobic phase of both run 1 and run 2 to enhance nitrification. The

experimental results indicated that nitrification was significant in both run 1 and for run 2. However, nitrogen and organic removals were effective during run 2 due to its shorter aeration and longer anoxic phase. The average removal of COD and BOD₅ of run 2 was 81 % and 90 %, respectively. Effluent nitrite was down to a range of 0.5-1.0 mg/L and most of the time, nitrate was non-detectable. The results of this study revealed that SBR type MBR is efficiently as well as it can provide an alternative for the treatment of fish farm effluent.

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