

# Determination of Operation Factors in Treating Piggery Wastewater by Membrane Bioreactor

Nguyễn Sáng<sup>1,\*</sup>, Chu Xuân Quang<sup>1</sup>, Trần Văn Quy<sup>2</sup>, Trần Hùng Thuận<sup>1</sup>

<sup>1</sup>Center for Advanced Material Technology – National Center for Technological Progress,  
C6 Thanh Xuân Bắc, Hanoi, Vietnam

<sup>2</sup>VNU University of Science, 334 Nguyễn Trãi, Hanoi, Vietnam

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**Abstract:** An investigation into the treatment efficiency of real piggery wastewater of a bench-scale aerobic membrane bioreactor was performed. The experiments were aimed to evaluate the effects of hydraulic retention time and activated sludge concentration. The piggery wastewater having high chemical oxygen demand, ammonium and total phosphorus concentrations (about 4200 mg/l, 320 mg/L and 48 mg/L, respectively) was employed. It was found that the removal efficiency of COD reached up to 94% even at operation conditions of HRT = 24 hours and MLSS = 6000 mg/L, but the HRT need to be increased twice in order to obtain the removal of 99% NH<sub>4</sub><sup>+</sup>-N and 85% T-P. The similar efficiency was also achieved by reduced HRT to 8 hours but increased MLSS to 12000 mg/L.

**Keywords:** Membrane bioreactor (MBR), piggery wastewater, microfiltration, activated sludge, eutrophication.

## 1. Introduction

Due to containing high amount of organic matter, nitrogen, phosphorus and suspended solids, piggery wastewater created an important environmental impact. The free ammonia is toxic to fish and many other aquatic organisms; moreover, both ammonium ion and ammonia are oxygen-consuming compounds which deplete the dissolved oxygen in receiving water. In addition, all forms of nitrogen can be made available to aquatic plants and can consequently

contribute to eutrophication [1]. However, it is difficult to treat nitrogen by the conventional activated sludge process. The organic matter oxidation microorganism has a high yield value than the nitrification microorganism. Therefore, if sludge retention time (SRT) gets shorter, it is hard to stabilize the nitrification microorganism. In this study, the membrane bioreactor (MBR) was used to make high mixed liquor suspended solids (MLSS) and long SRT for advanced nitrification. Comparison with conventional activate sludge processes, the MBR process offers several advantages. The membrane is an absolute barrier to suspended solids and thus offers the possibility to operate

\* Corresponding author. Tel.: 84-435544821.  
Email: amt.met@gmail.com

the system at high sludge concentration. The treatment process run at longer SRT so that the slow-growing microorganisms can be enriched. This leads to better removal of organic matter as well as efficiency of nitrification [2], higher effluent quality, complete disinfection, high reliability compactness and minimized sludge production [3]. Therefore, treatment of high contaminated wastewater by using MBR with consistance conditions might have promising many potential [4].

In Vietnam, the MBR technology used test few years ago and main applied in the treatment of domestic sewage, industrial wastewater and hospital wastewater [5]. Research publications in the MBR applying for piggery wastewater treatment are limited. Therefore, the study of factors affecting the operation factors of MBR systems in piggery wastewater treatment is necessary to make a precondition for the application of this technology for piggery wastewater treatment in Vietnam.

## 2. Materials and methods

### 2.1. Materials

- Piggery wastewater was collected from a pig farming households (Thuong Tin, Hanoi). The wastewater was taken at the discharged drainage of breeding facilities. The wastewater which removed coarse garbage (>5 mm in size) was having COD around of 4200 mg/l, ammonium of 320 mg/L and total phosphorus concentrations of 48 mg/L.

- Concentrated activated sludge was taken from the aerobic tank of an existing biological treatment system which was operating with synthesis wastewater. Activated sludge was then

grew with real piggery wastewater in one month as starting-up phase.

- Membrane used in this study was polyvinylidene fluoride (PVDF) hollow fiber (Motimo, China). It has pore size of 0.1  $\mu\text{m}$  and membrane surface area is 0.065  $\text{m}^2$  per module.

### 2.2. Methods

+ Analysis method: analysis method of COD parameter follow by TCVN 6491:1999 (ISO 6060: 1989)  $\text{NH}_4^+\text{-N}$ : follow by TCVN 6620 – 2000 (ISO 6778:1984); MLSS follow by TCVN 6625:2000 (ISO 11923:1997), and T-P follow by TCVN 6202:2008 (ISO 6878:2004).

+ Experiment design: A hollow fiber membrane module was submerged in a process tank with a working volume of 50 L. An air-diffuser was set up at the beneath the membrane module in order to provide oxygen for biological oxidation and reduce membrane fouling. The rate of aeration was controlled by using a valve and measured by flow-meter. Membrane transport pressure was taken by pressure meter. The range of DO value is 3 – 6 mg/L. MBR process was operated at constant permeate flux 12  $\text{L}/\text{m}^2\cdot\text{h}$ .

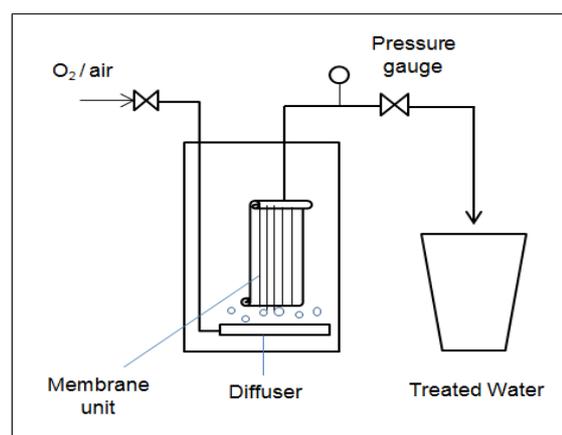


Figure 1. Schematic of the submerged membrane bioreactor system.

### 3. Results and discussion

#### 3.1. Characterization of activated sludge

MLSS, MLVSS and SVI parameters were measured in order to observe the growth rate of sludge.

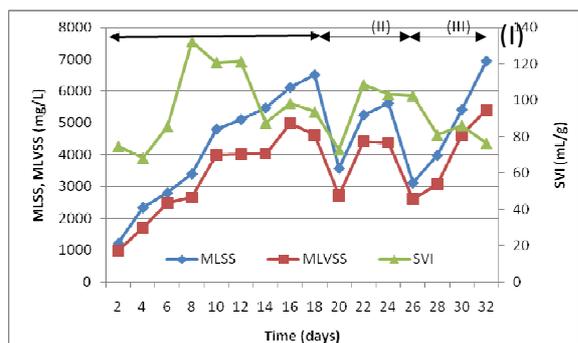


Figure 2. The change of MLSS, MLVSS and SVI with the time.

From results in Figure 2, after 18 days, the amount of biomass increased from 1217 mg/L to 6513 mg/L. From the beginning to sixth day, microorganisms in sludge were in the period of adaptation to the environment cause low growth of activated sludge. At growth stage of microorganism with piggery wastewater is rich in substances and nutrients, sludge grew upto 6000 mg/L and was settling well. Settling ability of sludge (solid – liquid separation ability in reactor) is performed by SVI indicator. The sludge with low SVI is good settling and concentrated. SVI of sludge in the tank was fluctuated in range of 68 – 132 mL/g. Thus, the feed sludge has good settling ability. However, there were some period that settling ability of sludge was not good (for example from 22<sup>nd</sup> to 26<sup>th</sup> SVI > 100 mL/g), because the large of air flow provided; sludge floc break out and became finer. Low DO made sludge float on the top and took long time to settle down. At the next stage, sludge developed well, but slows

settling, had sticky smell. When microelement substances added, SVI fluctuated in range of 80 – 98 mL/g, in optimal range 80 – 120 mL/g [6]. Comparison with Truong Thanh Canh study [6] which activated sludge feed by piggery wastewater had SVI of 77 mL/g, was lower than sludge in this study.

In order to access microorganism concentration in activated sludge, the ratio MLVSS/MLSS was examined. The results on Figure 2 shown that when solid retention time increase, the concentration of both MLSS and MLVSS in tank increase, so bacteria was good growth. Besides, the ratio MLVSS/MLSS was quite stable, fluctuate in 0.71 – 0.84. It could conclude that sludge had high degree of activity.

#### 3.2. The effect of hydraulic retention time on treatment efficiency

##### 3.2.1. The effect of hydraulic retention time on removing organic matter

Study was carried out at 6000 mg-MLSS/L, aerated rate 15 L/min with different hydraulic retention time (HRT): 2, 4, 6, 8, 24 and 48 hours.

The efficiency of COD removal is shown in Figure 3.

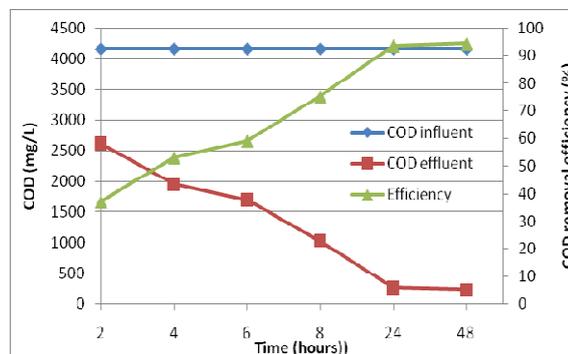


Figure 3. Effect of HRT on removal COD.

The results on Figure 3 shown that the concentration of organic matter in the influent was very high, average COD parameter was 4160 mg O<sub>2</sub>/L. After 2 hours of aeration, efficiency of COD removal process achieved 37.1% corresponding to 2620 mg/L of COD in the effluent. When the aeration time increased to 4, 6, 8 hours, the efficiency of COD removal increased by 53% to 75.2%. After 24 hours of aeration, the efficiency of COD removal achieves 93.6%. When the time of aeration increased to 48 hours, COD removal efficiency increased slightly to 94.3%. The results shown that after 24 hours in aeration, the biodegradable organic matter was almost completely treated, only remained hard or non-biodegradable organic substances in wastewater.

### 3.2.2. The effect of hydraulic retention time on removal ammonium

The efficiency of ammonium treatment is shown in Figure 4.

The concentration of ammonium in the influent was very high, 320 mg/L in average. After 8 hours of aeration, almost of ammonium had not changed into nitrate or nitrite form, as a result was only 39 % (shown in Figure 4). Because both of oxidation process of ammonium and COD occur in the aerobic condition by two

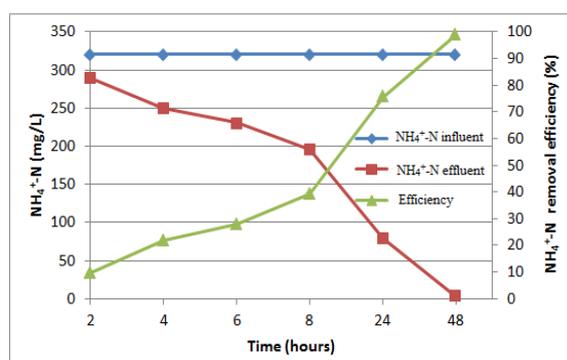


Figure 4. Effect of HRT on removal ammonium.

types of autotrophic and heterotrophic microorganisms, there was a competition for factors joining in two processes, example such as dissolved oxygen. The autotrophic organism (*Nitrosomonas* and *Nitrobacter*) could not compete with heterotrophic microorganisms because its concentration normally too small in total biomass. Moreover, ammonium oxidation rate by autotroph (the amount of ammonium is oxidized in unit of time and biomass) is too smaller than that one by heterotrophic organisms (only equal 40 – 50%) [7]. That means scale of equipment for oxidation of ammonium process is double than oxidation of ammonium with the same loading rate [7]. As a result, in order to *Nitrosomonas* and *Nitrobacter* bacteria convert totally NH<sub>4</sub><sup>+</sup> to NO<sub>2</sub><sup>-</sup> and NO<sub>3</sub><sup>-</sup>, longer time is needed. The time of aeration increase to 24 and 48 hours, ammonium treatment efficiency increased to 75.5 % and 99.0 %, respectively, indicating that nitrification occurred almost completely. So, in compared with COD removal process need only 24 hours for oxidation of simple organic matter, then ammonium oxidation needs a longer time by 48 hours. Therefore, the objective that needs to study in the aerobic treatment process is ammonium oxidation process, COD oxidation is a minor factor. Having solved ammonium oxidation process then COD oxidation process will be solved automatically [7].

From results above, HRT of 48 hours was selected for the next step in the study.

### 3.2.3. Effect hydraulic retention time on removal phosphorus

Piggery wastewater contains large amount of phosphorus (45 – 140 mg/L) which is the main cause of eutrophication.

T-P removal efficiency with time is shown in Figure 5.

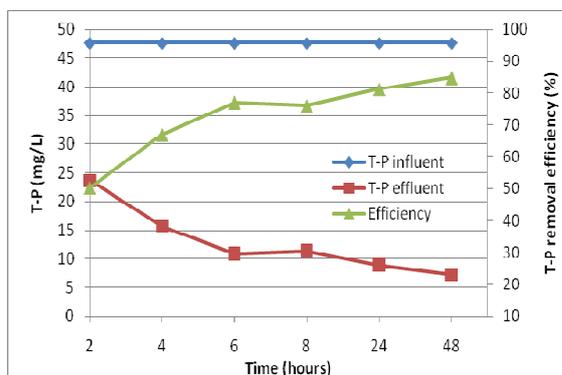


Figure 5. Effect of HRT on T-P removal efficiency.

T-P removal efficiency increased with the increased of HRT (shown in Figure 5). These efficiencies after 24 hours and 48 hours achieved 81.3% and 84.9%, respectively. Due to the increased and got predominant of the number of bacteria- P. This type of bacteria has low degradable rate but has ability to absorb large amount of phosphorus in sludge and deposition so T-P removal efficiency increase [8]. Besides, by good at sludge separation of membrane bioreactor, the amount of phosphorus in effluent was also reduced [7]. The average T-P concentration in the effluent was smaller than 10 mg/L.

### 3.3. The effect of the activated sludge concentration (MLSS) on treatment efficiency

#### 3.3.1. Effect of MLSS on COD removal

Study was carried out in two activated sludge tanks at the same time with concentrations of 6000 and 12000 mgMLSS/L.

The effect of MLSS on efficiency of COD removal is shown in Figure 6.

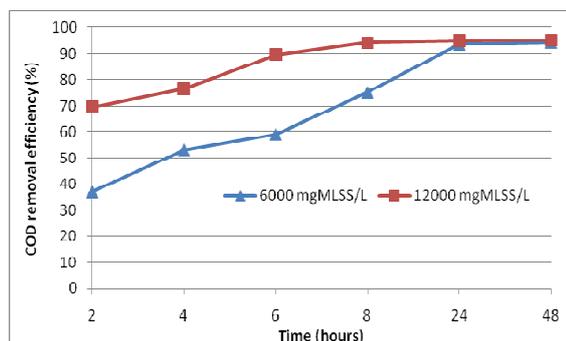


Figure 6. Effect of MLSS on removal COD.

Because piggery wastewater is rich in nutrients, so the biological system still operates as well as when increase of MLSS (demand of using substrate of microorganisms increase). The aeration tank in the MBR system could cultivate and maintain a higher biomass concentration than one of the conventional activated sludge process. Results on Figure 6 shown that when increased MLSS in tank to 12000 mg/L, COD removal efficiency increased to 70% after 2 hours, which is higher significantly than one's of system with 6000 mg/L (only achieve 37%). Due to larger biomass should absorption substrate taken place faster. After 8 hours, the efficiency of COD removal of the system with 12000 mg/L was equivalent with one's of the system with 6000 mg/L after 24 hours (94,1% and 93,6%, respectively).

#### 3.3.2. Effect of MLSS on ammonium removal

The effect of MLSS concentration on efficiency of ammonium removal is shown in Figure 7.

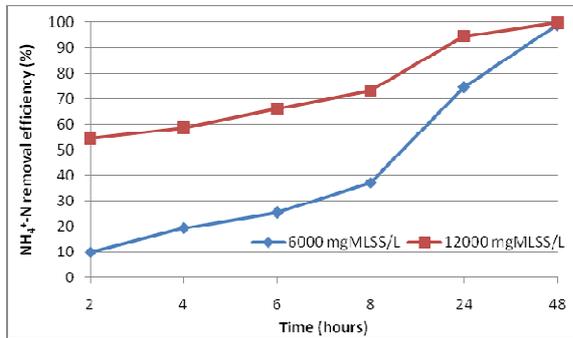


Figure 7. Effect of MLSS on removal ammonium.

When high MLSS make an increase in number of *Nitrosomonas* and *Nitrobacter* bacteria, so enhance nitrification in aerobic process [9]. Indeed, the efficiency of ammonium removal of sludge system with 12000mg/L is higher significantly than that one of the system with 6000mg/L. Results on Figure 7 shown that efficiencies of ammonium removal of systems with 12000 mg/L and 6000 mg/L after 2 hours reached 54,4% and 9,8%, respectively. These efficiencies after 24 hours and 48 hours achieved 94.6% and 99.8%, respectively. Base on high MLSS for advanced nitrification, ammonium is completely converted to nitrate in the aeration tank, so treatment process was saved time and energy.

### 3.3.3. Effect of MLSS on phosphorus removal

The effect of MLSS on T-P removal efficiency is shown in Figure 8.

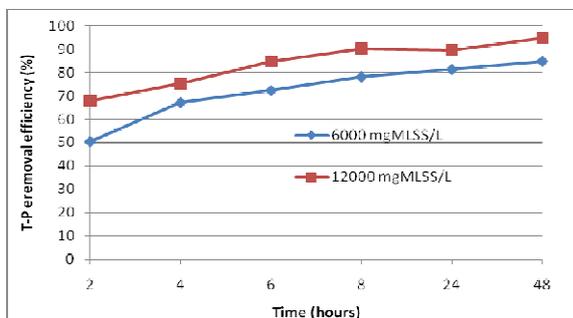


Figure 8. Effect of MLSS concentration on T-P removal efficiency.

The efficiency of T-P removal of activated sludge system with 12000 mg/L achieved 94.6%; it is higher than that one with 6000 mg/L (84.9%). High MLSS make increase in number of bacteria-P and predominant when increase retention time [8]. Moreover, T-P may be removed by the filtering of membrane [7]. When MLSS increased, the efficiency of T-P removal increased. The T-P concentration in effluent was smaller than 6 mg/L, which meet Vietnam's standard for livestock wastewater discharge (QCVN 40:2011/BTNMT).

Finally, high biomass concentration in a bioreactor is one of the most important conditions to remove COD,  $\text{NH}_4^+\text{-N}$ , T-P in swine wastewater treatment.

## 4. Conclusions

The effect of HRT and the activated sludge concentration on contaminant treatment was defined through operate system of aerobic tanks integrate membrane bioreactor at different retention time and different from sludge concentration. The results shown that with HRT 24 hours, activated sludge system 6000 mg/L treated nearly completely simple organic substances, biodegradable, achieved 94% in efficiency. When extended HRT, the efficiency of COD removal increased slightly, the efficiency of ammonium removal increased to 99%, and for TP achieved 84.9%. When increased the activated sludge concentration to 12000 mg/L, the time for organic matter decompose reduced to 8 hours, efficiency achieved 94.2% and efficiency of ammonium and T-P removal achieved 99.8% and 94.6% after 48 hours. The MBR is an efficient treatment technology for COD and nutrient removal, capable of achieving effluent with very low  $\text{NH}_4^+\text{-N}$ , T-P concentrations from piggery wastewater.

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# Khảo sát ảnh hưởng của một số yếu tố ảnh hưởng đến hiệu quả xử lý nước thải chăn nuôi lợn khi sử dụng bể sinh học kết hợp lọc màng (MBR)

Nguyễn Sáng<sup>1</sup>, Chu Xuân Quang<sup>1</sup>, Trần Văn Quy<sup>2</sup>, Trần Hùng Thuận<sup>1</sup>

<sup>1</sup>*Trung tâm Công nghệ Vật liệu - Viện Ứng dụng Công nghệ, C6 Thanh Xuân Bắc, Hà Nội, Việt Nam*

<sup>2</sup>*Trường Đại học Khoa học Tự nhiên - Đại học Quốc Gia Hà Nội, 334 Nguyễn Trãi, Hà Nội, Việt Nam*

**Tóm tắt:** Nghiên cứu hiệu quả xử lý nước thải chăn nuôi lợn thực tế của bể sinh học hiếu khí tích hợp lọc màng quy mô phòng thí nghiệm đã được thực hiện. Mục tiêu của nghiên cứu nhằm đánh giá ảnh hưởng của thời gian lưu thủy lực và nồng độ bùn hoạt tính. Nước thải chăn nuôi lợn có nhu cầu oxy hóa học, hàm lượng amoni và phốt pho cao (tương ứng 4200 mgO<sub>2</sub>/L, 320 mg/L và 48 mg/L) đã được sử dụng trong nghiên cứu. Kết quả cho thấy hiệu suất loại bỏ COD đạt được khoảng 94% ở điều kiện làm việc thời gian lưu 24 giờ và nồng độ bùn 6000 mg/L, tuy nhiên cần tăng thời gian lưu gấp đôi để đạt được hiệu suất loại bỏ NH<sub>4</sub><sup>+</sup>-N và T-P tương ứng 99% và 85%. Hiệu suất tương đương cũng đạt được khi rút ngắn thời gian lưu xuống 8 giờ nhưng tăng nồng độ bùn lên 12000 mg/L.

**Từ khóa:** Xử lý sinh học kết hợp lọc màng (MBR), nước thải chăn nuôi lợn, vi lọc, bùn hoạt tính, phú dưỡng.