APPLICATION OF AIRLIFT MEMBRANE BIOREACTOR FOR SLAUGHTERHOUSE WASTEWATER TREATMENT: 20 M^3/DAY PILOT STUDY IN HA NOI, VIET NAM

Do Tien Anh[1], Huynh Thi Lan Huong[1], Pham Hai Bang[2]
[1]Viet Nam Institute of Meteorology, Hydrology and Climate Change
[2]Ministry of Natural Resources and Environment

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Abstract: *Untreated wastewater from slaughterhouses has been contributing to the contamination of Day River due to its high concentration of COD, BOD, total nitrate (TN) and total phosphate (TP). Centralized wastewater treatment is not a good option at present due to lack of wastewater conveyance infrastructure and finance. On-site wastewater treatment has been emerging a better choice. This study evaluates an onsite wastewater treatment system using an airlift membrane bioreactor for a slaughterhouse in a suburb of Ha Noi. The system was designed to treat 20 m^3/day slaughterhouse wastewater. Wastewater from the Slaughterhouse contains 1060 ± 458 mg/L COD, 1060 ± 458 mg/L BOD and 451 ± 133 mg/L TN. Anaerobic and anoxic tanks were operated at the mixed liquor volatile suspended solid (MLVSS) of 1,500 mg/L. Cross-flow velocity, airlift flow rate and the transmembrane pressure (TMP) were maintained at 2 bar. The removal efficiencies of COD, TN were 89.1±4% and 85±8.7%, respectively. The results proved that AL-MBR could work well at pilot scale and be promising for upscaling along Nhue - Day River in future.*
Keywords: *wastewater, slaughterhouse, Nhue - Day River, membrane, airlift.*

1. Introduction

Nhue - Day River has been suffering from severe contamination due to human activities along its basin. The average concentration of organic matters in Nhue - Day River has been reported 2.2-9 times higher than Viet Nam´s discharge regulation standard (QCVN 08-MT: 2015/BTNMT) (Viet Nam Institute of Water Resources Planning, 2016). One of the sources which contribute to the pollution of the river is untreated wastewater from slaughterhouses located along the River's basin. Untreated wastewater from slaughterhouses contains high concentration of COD, BOD, total nitrogen (TN) and total phosphate (TP). Do et al. (2016), reported that the average concentration of COD, BOD, TN and TP in SHWW in Viet Nam was 1697±317 mg/L, 891±137 mg/L, 246±65 mg/L and 1,164 mg/L, respectively. Wastewater from the slaughterhouses along the basin is currently not adequately treated. Untreated slaughterhouse wastewater (SHWW) could cause pollution of natural reservoirs, environment, spreading diseases and health problems for residents along the riverside. With the rapid population growth along the riverside, these problems would become worse. The lack of conveyance infrastructure and finance are considered as major challenges for treating SHWW by centralized wastewater treatment systems in the basin in the near future. On-site treatment is being mentioned as a better option at this moment. However, the slaughterhouses along the basin are currently not equipped with the adequate wastewater treatment system.

Membrane bioreactors (MBR) has emerged as a popular application for onsite wastewater treatment (Choi et al., 2002; Daigger et al., 2005; Asatekin et al., 2006). The major advantages of MBR are: (i) efficient treatment; (ii) Particle-free effluent; (iii) small footprint; and (iv) The potential for remote monitoring and control (Van Dijk and Roncken, 1997).

Correspondence to: Do Tien Anh
E-mail: atdo1980@gmail.com

In practice, the efficiency of MBR for COD and TN removal could reach 90-97% and 44-90%, respectively (Do et al., 2016). Nevertheless, currently, the application of the MBR in developing countries, particularly in Viet Nam, is limited because of two barriers of the MBR which are high energy consumption and fouling of the membrane. Solutions for these two problems have been attracting huge attention from scientists. Thousands of studies have been reported in the past 20 years on this topic. Of which, a few studies on airlift MBR (AL-MBR) have shown very promising results. AL-MBR could reduce energy consumption and avoid the fouling of membrane (Do et al., 2016). The concept of the AL-MBR is to using air to sparge the membrane continuously to control better the build-up of cake-layer which would cause the membrane fouling and higher energy consumption (Futselaar et al., 2007; Prieto et al., 2013; Kijjanapanich et al., 2013). Few studies have shown that energy consumption could be reduced by up to 14-15% if using AL-MBR compared to conventional MBR system (Prieto et al., 2013; Do et al., 2016). Do et al. (2016) reports the AL-MBR could reduce 95±1.9% of COD and 70±3.3% of TN in SHWW at lab scale and concluded that AL-MBR could be a good option for on-site treatment of SHWW in Viet Nam. However, there have not been reported yet a study on the application of AL-MBR at practice for SHWW treatment.

This study will evaluate the operation of AL-MBR at a slaughterhouse at Nhue - Day River.

2. Materials and Methods

2.1. Activated sludge

Seed activated sludge was collected from a local wastewater treatment plant (Viet Ha Brewer Corporation, Bac Ninh province, Viet Nam). Prior to use, the sludge was sieved through a 3 mm mesh sieve to remove any debris that could clog the membrane lumen or block the reactor tubing. The TSS and pH of the seed sludge were 1.6±0.1 g/L and 7.24 ± 0.05, respectively.

2.2. Slaughterhouse location and SHWW

The slaughterhouse chosen for the study is located at Tri Thuy commune, Phu Xuyen district, Ha Noi. This commune is along the riverside of Day River and has around 30 slaughterhouses. The selected slaughter-house produces approximately 20 m^3/day of wastewater. The SHWW was discharged into an on-site septic tank before releasing into a water cannel nearby (Figure 1).

Figure 1. (a) Location of the selected slaughterhouse;
(b) A water cannel in front of the slaughterhouse

The effluent the septic tank was sampled in order to characterize wastewater from the slaughterhouse. The composition of the SHWW is described in Table 1.

Table 1. The SHWW characteristics in the slaughterhouse selected for this study

Parameters	SHWW (effluent of the septic tank)	Viet Nam Discharge Regulation Standard
BOD (mg/L)	640 ± 341	50
COD (mg/L)	1060 ± 458	150
NH4+-N(mg/L)	361 ± 106	10
TN (mg/L)	451 ± 133	40
TP (mg/L)	35±13	6
pH	6.8±0.4	5.5-9
TSS (mg/L)	540 ± 141	100

2.3. AL-MBR Fabrication

The AL-MBR was designed to treat the effluent from the current septic tank in the slaughterhouse. AL-MBR was constructed as a 60 m^3 biological reactor which includes both aerobic and anoxic functions coupled with two side stream tubular membrane modules. The membranes (length x inside diameter) were 3 m x 5.2 mm polyvinylidene fluoride modules (model code: MO 33G_I5, Berhof, Germany) with mean pore size of 0.03 µm and active filtration area of 4.8 m^2 per module. The SHWW was pumped from the septic tank to a 1 m^3 intermediate tank by a pump (Model CM100, Pentax, Italy) at a rate of 20 m^3/day. The wastewater from the 1 m^3 intermediate tank was designed to justify the pH or other parameters of the wastewater before transported into the biological reactor. The biological reactor consisted of anoxic and aerobic areas. The anoxic and aerobic areas were separated by adjustable metal baffles. The aerobic area in this study was set at 19 m^3. An air compressor was providing oxygen to keep DO in the aerobic area around 5 mg/L. The mixed liquor volatile suspended sludge (MLVSS) was kept at 1,500 mg/L. The mixed liquid-sludge from the bioreactor was pumped to the two membrane modules by a pump (Wilo PU 1500E, Korea). The Transmembrane pressure (TMP) was maintained at 2 bar. Cross-flow velocity and air flow rate through the membranes were kept consistently at 0.8 m/s and 0.2 L/min, respectively. The air was provided by a biogas from the slaughterhouse.

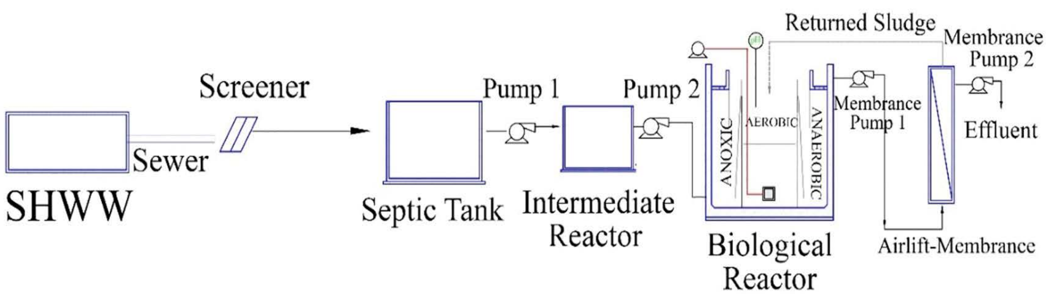

Figure 2. Flow scheme of the pilot airlift MBR for SHWW treatment at Tri Thuy, Phu Xuyen

2.4. Analytical Methods

Samples from the influent, mixed liquor in the aerobic and anoxic reactors, and permeate samples were taken daily to analyze the COD, NO_3--N, NH_4+-N, TN, MLSS and MLVSS according to Standard Methods for the Examination of

Water and Wastewater by APHA (APHA 2005). Samples for COD, NO_3^--N, TN and NH4+-N were filtered through a 0.45-µm glass microfibre filter before measurement. COD was determined by the closed reflux, colorimetric method (Method 8000). Total nitrogen (TN) was analyzed by the persulphate digestion method (Method 10071). Nitrate (NO_3^--N) was measured by the cadmium reduction method (Method 8039). Ammonia (NH_4^+-N) was measured by the salicylate method (Method 10031). Mixed-liquor suspended solids (MLSS) and mixed-liquor volatile suspended solids (MLVSS) were measured by using the methods 2540D and 2540E, respectively. The permeate flow rate was determined using a digital balance connected to a data logger.

During operation, energy consumption was monitored by using a kWh meter (EMIC Corp., Viet Nam). The energy consumption includes that for the feed pump, the recirculation pump, the internal recycle pump, the vacuum pump and the air blower. The specific energy consumption was estimated based on the flow rate of product water and the energy consumption recorded by the kWh meter.

3. Results and Discussion

3.1. Evaluation of Membrane Filtration Performance

It was observed that the highest permeate flux of the membrane was reached at 80 LMH/bar at the beginning and rapidly decreased to 40 LMH/bar after five days. The cake layer built up on the membrane surface would be the reason for the decrease. After five days, the cake layer would be stable, and the flux was consistently at 40-50 LMH/bar. This value was much higher than the value achieved at the lab scale system which was 18 LMH/bar (Do et al., 2016). The reason could come from differences in operation procedures for pilot and lab scale system. In lab scale system, there was no membrane cleaning procedure applied. However, in the pilot system, the membranes were operated for 20 minutes, then rested for 5 minutes. Of the 5 minutes rested, there were 3 minutes during which the membrane was cleaned with tap water. During a month of operation, there was no serious fouling of the membrane observed.

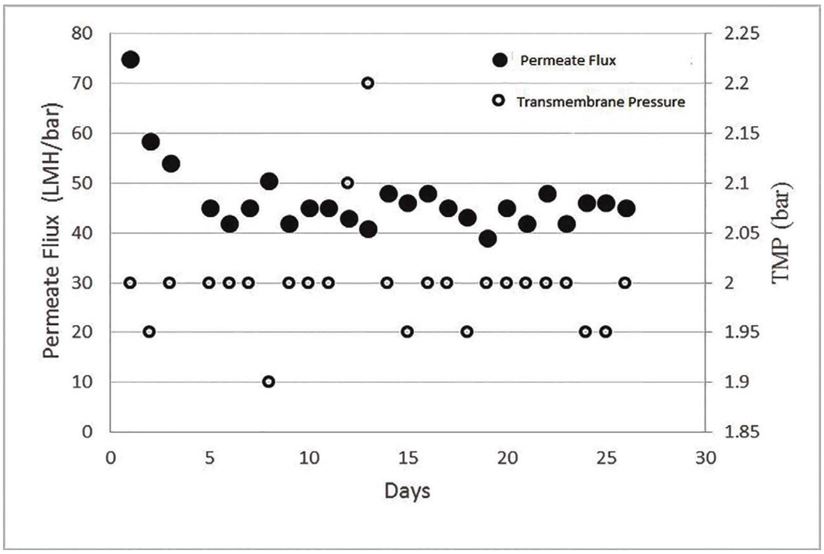

Figure 3. Membrane filtration performance

3.2. Organic matter reduction

Wastewater from the slaughterhouse contains various components which are blood, urine, meat and fat matters. The concentration of organic matters in SHWW is always high. The concentration of COD in SHWW sampled before the septic tank was 5000-6000 mg/L. The degradation of organic matters in the SHWW was observed after the septic tank. COD in the effluent of the septic tank was analyzed at 1060

± 458 mg/L. This value of COD was 6-10 times higher than the value permitted in Viet Nam discharged regulation standard. It is shown that a septic tank could help to reduce 90% of organic matters in the SHWW. However, the COD could not reach to regulation standard just by the septic tank. Therefore, the AL-MBR was installed to support the treatment of SHWW. It was observed that the COD could reach as low as 114±27 mg/L and 86±20 mg/L in the bioreactor and effluent, respectively (Figure 3). COD removal efficiency of the AL-MBR system had achieved 89.1±4%. Biological processes remove 85.5±5.41% and the membrane process contributed an addition of 3.61±1.35%.

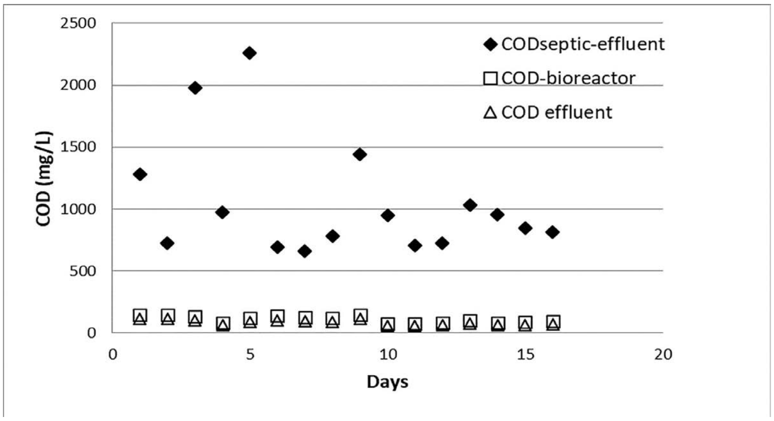

Figure 4. COD removal profile

3.3. Nitrogen Removal

The concentration of total nitrogen in SHWW in Viet Nam is quite high, around 246±65 mg/L. The concentration of total nitrogen in the effluent of the septic tank in the slaughterhouse at Phu Xuyen was much higher. The TN concentration was analyzed at 451±133 mg/L. Most of the nitrogen in the effluent of the septic tank was contributed by $NH4^+$. The concentration of the $NH4^+$ in the septic effluent was 356±101 mg/L and contributed to 80% of TN. Total nitrogen was removed 82%-94% by biological processes. Total nitrogen was reduced to 63.16±28.5 mg/L in the biological reactor. The concentration of TN in the membrane effluent was detected at 62±28.24 mg/L. The concentration of the TN was even lower in the effluent at 38±4 mg/L after the day 15^{th} of operation.

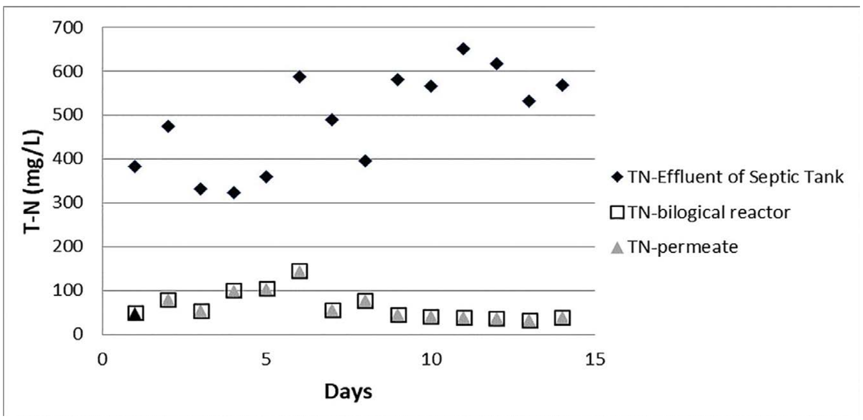

Figure 5. Profile of nitrogen removal

3.4. Energy consumption

Energy consumption of the whole AL-MBR system in the slaughterhouse was measured at 52 kWh/day which is equal to 2.6 kWh/m^3. This number is higher than the value reported for energy consumption of AL-MBR at lab scale which is 1.45 kWh/m^3 (Do et al., 2016). The equipment of the pilot system could be designed and operated higher than the practical demand which is needed to treat 20 m^3/day. It should also be noted that in the past 50 years, developments in MBR technology resulted in an energy demand reduction from about 5.0 kWh/m^3, needed for the first side-stream MBRs (Buer and Cumin, 2010). The energy requirement of the first tubular side-stream MBR installations was reported to be typically 6.0-8.0 kWh/m^3 (Van Dijk and Roncken, 1997), mainly due to energy-intensive cross-flow pumping of the liquid. The value of energy consumption of the pilot AL-MBR is lower than the same scale system for similar wastewater installed and operated in Viet Nam. A 30 m^3/day pilot Anaerobic Baffles Bioreactor (ABR) for pig farm wastewater treatment required 2.8 kWh/m^3 which is 7% higher than the energy consumption of the pilot AL-MBR (Tua et al., 2015).

4. Conclusions

The lack of finance for constructing centralized wastewater treatment plants and conveyance systems is the major reason for untreated slaughterhouse wastewater discharged into Nhue - Day River. Onsite treatment option is currently considered a good fit for SHWW management to prevent contamination of Nhue - Day River. It is proved that AL-MBR could work well to treat SHWW at pilot scale of 20 m^3/day. The system had achieved very promising results of removal of COD and TN. The removal efficiencies of COD and TN were observed at 89.1±4% and 85±8.7%, respectively. The AL-MBR in this study provided consistent permeate flux of 40 LMH/bar at 2 bar. This value is higher than the value recorded at lab scale. The energy consumption at pilot scale was higher than the energy consumption at lab scale due to over operation. It could be concluded that the AL-MBR could work well at both lab scale and pilot scale and could be considered as a good option for upscale for all slaughterhouses along Nhue - Day River or in Viet Nam in future.

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