PERFORMANCE EVALUATION OF MEMBRANE BIOREACTOR FOR POLLUTANT REMOVAL FROM DOMESTIC WASTEWATER

ĐÁNH GIÁ HIỆU QUẢ CỦA BỂ LỌC SINH HỌC MÀNG TRONG VIỆC XỬ LÝ CÁC CHẤT Ô NHIỄM TỪ NƯỚC THẢI SINH HOẠT

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ABSTRACT

*The main aim of this investigation was to evaluate the capability of Membrane Bioreactor (MBR) for removal of nutrient and organic compounds from domestic wastewater. A laboratory study with a continuous stream was conducted using an experimental model of 36 liters (24*20*75 cm) and the submerged membrane module has 0.4 µm pores. The experimental model maintains pH at 6.5-8.0 and operates in 4 months with different hydraulic retention time (HRT) modes in order to evaluate the ability to treat Biological Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD). The high biomass concentration lead to increase wastewater treatment efficiency more than traditionally activated sludge methods. The MBR showed a good performance to remove pollutant matters. The average BOD_5 and COD removal were 94.6 and 92.6%, respectively. Besides, the average removal efficiency of TN, TP are 64.6 and 79.2% respectively. MBR as an advanced process had a proper nutrient as well as organic compounds removal efficiency from domestic wastewater.*

***Keywords*: Organic compounds; nutrient; COD; domestic wastewater; MBR.**

TÓM TẮT

*Mục đích chính của khám phá nhằm đánh giá khả năng xử lý các hợp chất hữu cơ và dinh dưỡng trong nước thải sinh hoạt bằng công nghệ màng lọc sinh học. Nghiên cứu quy mô phòng thí nghiệm với dòng liên tục được thực hiện với mô hình thực nghiệm 36 lít (24*20*75 cm) và module màng chìm có kích thước lỗ lọc 0,4 µm. Mô hình thí nghiệm duy trì pH ở 6,5-8,0 và vận hành trong thời gian 4 tháng với các thời gian lưu thủy lực (HRT) khác nhau để đánh giá khả năng xử lý nhu cầu oxi sinh học (BOD_5) và nhu cầu oxi hóa học (COD). Nhờ nồng độ MLSS cao nên gia tăng hiệu quả xử lý nước thải so với phương pháp bùn hoạt tính truyền thống. Công nghệ MBR cho thấy khả năng tốt trong việc loại bỏ các chất ô nhiễm. Hiệu quả trung bình xử lý BOD_5 và COD lần lượt tương ứng 94,6 và 92,6%. Bên cạnh đó, trung bình hiệu quả xử lý TN, TP tương ứng lần lượt 64,6 và 79,2%. MBR là quá trình tiên tiến loại bỏ hiệu quả các hợp chất hữu cơ cũng như các chất dinh dưỡng từ nước thải sinh hoạt.*

Từ khóa: *Hợp chất hữu cơ; chất dinh dưỡng; COD; nước thải sinh hoạt; MBR.*

1. INTRODUCTION

Membrane Bioreactor (MBR) is the combination of bioactive activated sludge process and membrane [1]. This is an advance method which can treat many types of wastewater from domestic wastewater to industrial or medical wastewater whose compositions are complicated and hard to be treated. MBR is the combination of activated sludge process and membrane to separate the sludge from wastewater flow. By using the membrane having pore sizes from 0.01-0.04 μm, the microorganisms, the pollutants and sludge are kept on the membrane's surface. Because bioactive sludge is kept in the reaction tank, with high concentration of microorganism, pollutant treatment ability is improved stimulaneously [2].

Previous studies have shown the superiority of MBR in the treatment of medical, industrial or domestic wastewater. According to the study on wastewater from seafood treatment process of Porntip *et al.*, 2006 [3], the ability to treat BOD_5, COD and TOC is great, with 99%, 85% and 85% accordingly. MBR is also efficient in the treatment of wastewater from petrochemical industry (Qin *et al.*, 2007) [4]. Studies on the treatment of domestic wastewater from Vietnamese researchers such as Uan *et al.*, (2010) [5], Ha *et al.*, (2012) [6] have also had good results.

In this study, the study model of MBR is the combination of two basic processes (biodegradation of organic matters and biomass separation from membrane) in order to evaluate the domestic wastewater treatment efficiency.

2. METHODS

2.1. An experimental model

A laboratory-scale system has a working volume of 36 liters (sizes L.W.H = 24.20.75cm) and the submerged membrane module has 0.4 μm pores and 0.9 m^2 surface (Mitsubishi, Japan). Sludge retention time (SRT) is controlled every 25 days. Permeation cycles are 10 min ON/1.0 min OFF. To maintain DO ≥ 2.0 mg/l during operation, the researchers used an air supply equipment with 1.7 m^3/h flow. Membrane filter performance is 15-20 l/(m^2.h). Air is supplied so that the microorganisms can degrade organic substances, promote nitrate process and reduce membrane fouling. Initial MLSS concentration in the reaction tank is maintained at 10,000 mg/l. The study maintains pH at 6.5-8.0 and operates in 121 days with different HRT modes in order to evaluate the ability to treat BOD_5 and COD. During operation, the membrane is only washed with clean water and aerated on the surface.

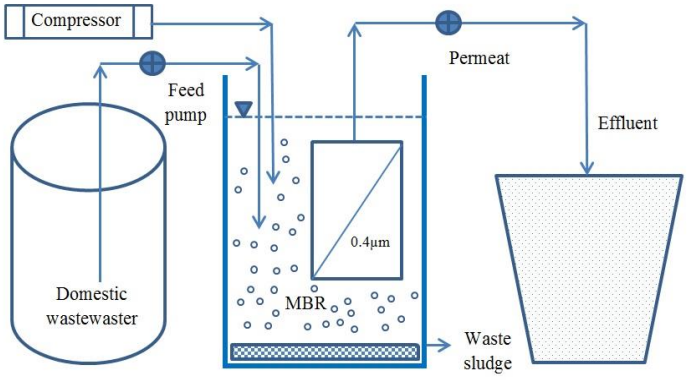

Figure 1. Diagram of experimental model

Table 1. Parameters and operating phases

Period	Day	Volume (Q, liter/hour)	HRT (hour)	SRT (day)	OLR (kgCOD/m^3.day)
1	1-30	4	9.0	25	1.7
2	31-60	8	4.5	25	3.4
3	61-90	12	3.0	25	5.1
4	91-121	16	2.25	25	6.8

In the studying of Stefan & Walter (2001) [7], the authors maintained membrane bioreactor experiment at the lowest HRT and equal to 1.5 hour for domestic wastewater. While, Ren *et al.,* 2001 conducted HRT evaluation in period from 1 to 3 hours [8]. For domestic wastewater, the HRT setting is usually chosen in the range from 1.5 to 7.5 hour (Defrance & Jaffrin, 1999 [9]; Huang *et al*., 2000 [10]; Shim *et al.,* 2002 [11]). In this study, in order to evaluate the ability to nutrient and organic compounds removal at diffirent OLRs, MBR tested wastewater flows: 4, 8, 12, 16 liters/hour corresponde to hydraulic retention time (HRT) of 9.0, 4.5, 3.0 and 2.25 hours accordingly. Organic loading rate (OLR) is from 1.7 to 6.8 kgCOD/m^3.day.

2.2. Analytical methods

Samples were analyzed as described in standard methods (APHA-AWWA-WEF, 2005) [12]. The waters were sampled 3 times per week. The pH values and the oxygen concentration were analyzed using pH-meter and oxymeter (WTW 340i) respectively. The BOD_5 value is measured in during 5 days of incubation at 20°C. UV-VIS spectrometer was used to measure COD level fllowing MEWW 5220-D:2005 method. TN and TP concentration were measured regularly according to standard methods. Mixed Liquor Suspended Solid (MLSS) and Mixed Liquor Volatile Suspended Solids (MLVSS) were measured by gravimetric method (Samples filtered through 0.45 μm filter paper, the residue left on the filter is dried to a constant weight at a temperature 105 and 550°C).

3. RESULTS AND DISCUSSION

3.1. An operating parameters and advantages of MBR technology

Studied wastewater is taken from some residential area in Ho Chi Minh City. The composition and pollutant concentration of the studied wastewater is shown in Table 2.

Table 2. Results of domestic wastewater quality and allowable limits

No.	Parameters	Unit	Result		QCVN 14:2008/BTNMT (Column A)
			Mean	SD	
1	pH	-	7.6	0.4	5-9
2	DO	mg/l	1.1	0.13	≥2[a]
3	BOD_5	mg/l	312	14.5	30
4	COD	mg/l	630	27.8	75[b]
5	TN	mg/l	33	4.7	20[b]
6	TP	mg/l	21	3.2	4[b]

Notes: QCVN 14:2008/BTNMT - National technical regulation on domestic wastewater
[a]QCVN 39:2011/BTNMT - National technical regulation on quality of water for irrigation
[b]QCVN 40:2011/BTNMT - National technical regulation for industrial wastewater (A)

Level of pH is maintained at 6.7-8.4 with the average value of 7.5 (SD = 0.44; n = 41). Meanwhile, dissolved oxygen concentration (DO) varies from 3.7 to 6.5 mg/l with the average value of 4.8 mg/l (SD = 0.92; n = 41). Average reaction surface temperature is 35.2^{0}C (SD = 1.84; n = 41) with minimum and maximum values are 28.7^{o}C and 44.3^{o}C accordingly. In general, MLSS concentration in the reaction tank is maintained at 10913.1 ± 2089.7 mg/l. MLSS concentrations at each period in the operation process are 10431.1 ± 1114.5 (OLR_1); 11092.5 ± 1887.0 (OLR_2); 11403.5 ± 2501.9 (OLR_3) and 10773.4 ± 2756.8 mg/l (OLR_4). High MLSS concentration improves the pollutant treating ability.

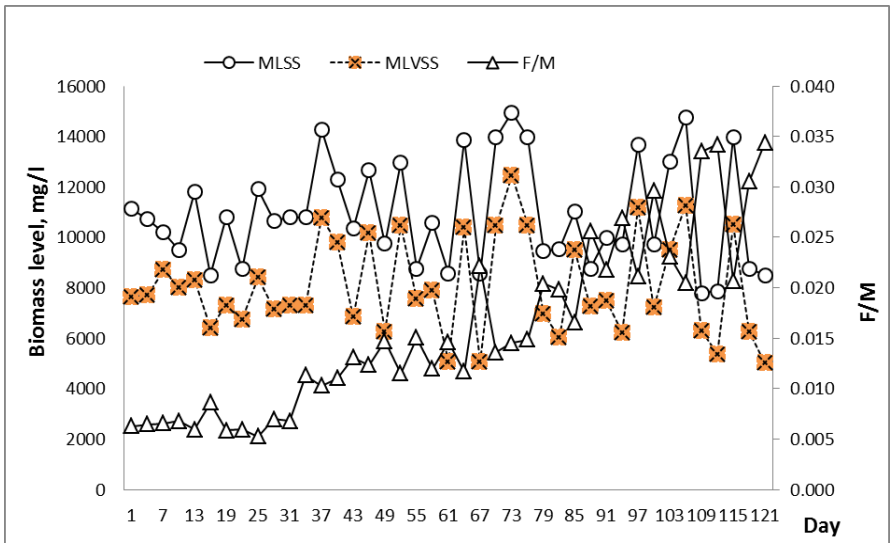

Figure 2. Biomass level and F/M in membrane bioreactor under OLRs

In addition, the variable values of MLVSS concentration are also shown in Figure 2, which are 7603.8 ± 712.4 (OLR_1); 8202.5 ± 1968.5 (OLR_2); 8603.5 ± 2370.5 (OLR_3); 7873.4 ± 2463.3 mg/l (OLR_4) at each period in the operation process. Operation activities have low F/M ratio, from 0.005 to 0.034 (day^{-1}). Low sludge formation in low F/M condition is confirmed in the study of Huang *et al.*, 2001 [13]. Normally, F/M value is low because the biomass is kept for the maintenance of high MLSS concentration (Metcalf & Eddy, 2003) [14]. The application of MBR is advantageous and can be used to treat domestic wastewater (Rosenberger *et al.*, 2002) [15].

3.2. Efficiency of pollutants treatment from domestic wastewater

The ability to remove organic substances is mostly due to the activated sludge in the reaction tank and also the membrane filter process [16]. Air supply flow for the reaction tank is an important factor which greatly affect to BOD_5 and COD eliminating biochemical activities. Average BOD_5 and COD eliminating efficiency is 94.6% and 92.6% accordingly. Detailed values of BOD_5 and COD before and after treatment in 121 days are shown in Figure 3. BOD_5 concentration varies from 250 – 361 mg/l before treatment and 8.7 – 29.0 mg/l after treatment. Initial COD concentration is high (from 468 to 702 mg/l) but become low after treatment (≤57.0 mg/l). Meanwhile, according to QCVN 14:2008/BTNMT – National standards in domestic wastewater (Column A), upper limit of BOD_5 and COD is 30 and 75 mg/l accordingly. This show the potential of MBR technology in the treatment and recycling of wastewater.

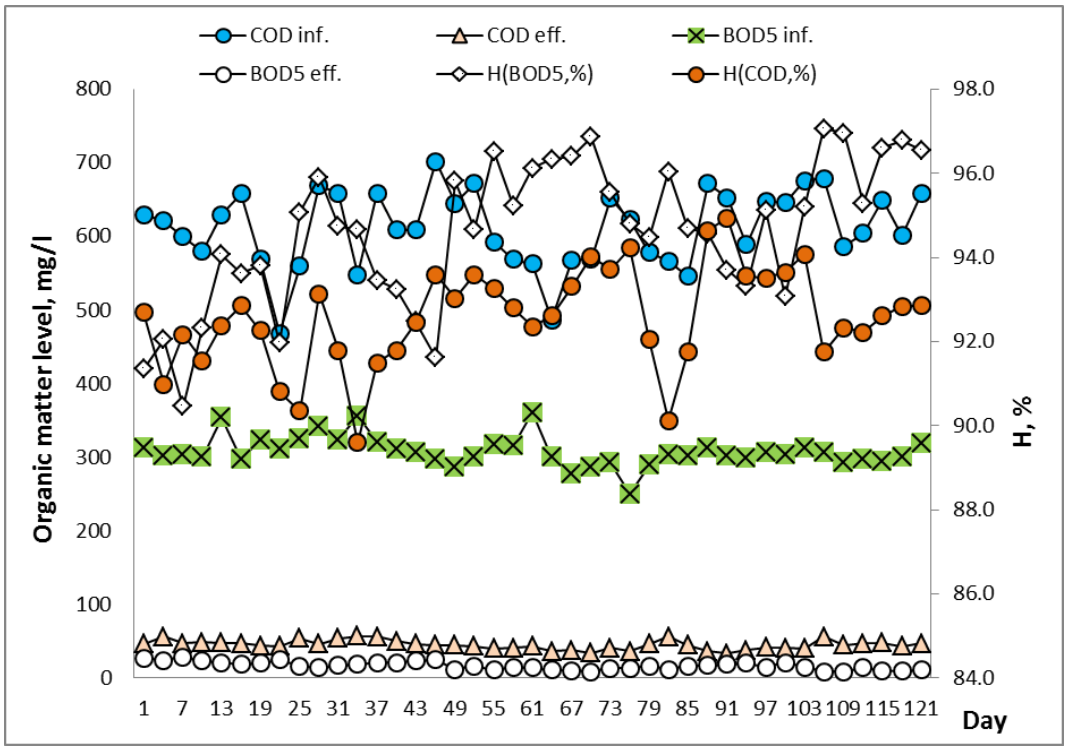

Figure 3. Changes in contents and organic matter removal efficiency

High sludge age due to long SRT (25 days) allow complete mineralization of raw organic substances in wastewater. High COD treating efficiency lead to high MLSS concentration in reaction tank. MLSS concentration plays an important part in the degradation process of organic substances (Xing *et al.*, 2000) [16]. BOD_5 treating efficiency raises when the organic load rises from 1.7 (corresponding to 93.2% efficiency) to 6.8 kgCOD/m^3.day (corresponding to 95.6% efficiency). In the case of COD concentration, the efficiency tends to rise slightly from 91.9% (1st period) to 93.1% (3rd period) and then reduce slightly in 4th period (92.9%). Detailed BOD_5 and COD treating efficiency for different loads is shown in Table 3.

Table 3. Removal efficiency BOD_5 and COD under OLRs

OLR	Result	BOD_5			COD		
		$BOD_{5\ inf.}$	$BOD_{5\ eff.}$	H, %	$COD_{inf.}$	$COD_{eff.}$	H, %
OLR_1=1.7 kgCOD/m^3.day	Mean	317.7	21.4	93.2	604.0	48.5	91.9
	SD	18.0	4.7	1.7	58.4	4.3	0.9
OLR_2=3.4 kgCOD/m^3.day	Mean	317.2	17.7	94.4	616.9	46.6	92.4
	SD	24.0	4.8	1.6	51.1	5.9	1.2
OLR_3=5.1 kgCOD/m^3.day	Mean	291.6	13.6	95.3	591.5	40.1	93.1
	SD	17.7	3.3	1.0	57.5	7.1	1.5
OLR_4=6.8 kgCOD/m^3.day	Mean	303.3	13.4	95.6	633.8	44.7	92.9
	SD	8.1	4.4	1.5	35.3	5.2	0.7

Study results in Figure 3 show the organic substance treating efficiency of MBR technology is more than 89%. The study of Xing *et al.*, 2001 [17] on domestic wastewater also has good COD eliminating efficiency (95%). BOD_5 eliminating efficiency is lowest (90.5%) in the 7^{th} day and highest in the 106^{th} day (97.1%). Meanwhile, COD eliminating efficiency varies from 89.6% (34^{th} day) to 94.9% (91^{st} day). In the aerobic MBR reaction tank, the reduction of COD concentration is the result of the formation of volatile substances and their volatilization in aerobic condition [18].

3.3. Efficiency of nutrient removal from domestic wastewater

The membrane bioreactors technology has gained great attention in wastewater treatment due to nutrient pollution. The MBR removal efficiencies of TN, TP are shown in Table 4. An indicate removal of nutrient with 64.6% total nitrogen and 79.2% total nitrogen, respectively. The results from the phases indicate good phosphorus and nitrogen removal. Nitrogen and phosphorus removal is one of the main concerns in modern wastewater treatment. The total phosphorus removal efficiency for the four phases were 78.0; 79.6; 78.0 and 81.2%, respectively.

Table 4. Removal efficiency nutrient (TN, TP) under OLRs

OLR	**Result**	**TN**			**TP**		
		$TN_{iff.}$	**$TN_{eff.}$**	**H, %**	**$TP_{iff.}$**	**$TP_{eff.}$**	**H, %**
OLR_1=1.7 $kgCOD/m^3.day$	Mean	30.6	12.5	59.0	17.3	3.7	78.0
	SD	1.5	1.3	5.3	3.5	0.3	5.2
OLR_2=3.4 $kgCOD/m^3.day$	Mean	27.0	9.2	65.9	12.6	2.4	79.6
	SD	2.2	2.5	9.0	3.2	0.6	7.7
OLR_3=5.1 $kgCOD/m^3.day$	Mean	27.4	8.3	69.7	14.4	3.1	78.0
	SD	4.0	2.3	8.0	3.2	0.4	3.9
OLR_4=6.8 $kgCOD/m^3.day$	Mean	33.2	11.7	64.4	16.5	3.0	81.2
	SD	2.9	1.8	6.9	3.5	0.4	2.6

The MBR achieved stable and efficient nutrient removal performance with good quality effluent and can be suitably used to satisfy the demand national standards for domestic wastewater. Additionally, TN and TP removal are found to increase with high MLSS concentration. Simply due to the high number of microorganism in MBR, the substrate uptake and reaction rate can be increased. The MBR effluent TN concentrations were as low as 12.5 mg/l. The TN concentration in the tank reduced, indicating the existence of simultaneous nitrification and denitrification here, which may be relevant to high MLSS (Peng & Ge, 2011) [19]. When moving from OLR_1 to OLR_2 and OLR_3 of the study, the removal efficiency of TN improved (Table 4).

During phase OLR_4, the phosphorus removal was achieved by biomass growth mechanisms and the average removal was 81.2%, corresponding to an average of 3.0 mg/l total phosphorus in the effluent. A part of the phosphorus is always removed

biologically because phosphorus is one of the essentials needed for bacterial growth. The phosphate accumulating organisms (PAO) which can build up a polyphosphate storage under aerobic conditions resulting in accumulated phosphorus levels. The total phosphorus ultimately removed through sludge discharge process in MBR.

4. CONCLUSION

The study has shown that the efficiency of BOD_5 and COD elimination on domestic wastewater by MBR technology is more than 90%. The average removal efficiency of TN, TP are 64.6 and 79.2% respectively. This meets the requirement in the National standards in domestic wastewater QCVN 14:2008/BTNMT. The efficiency tends to raise when the organic load increases. The advantage of MBR technology is the maintenance of high and stable MLSS concentration and the facilitation for microbiological treatment of the pollutants as well as small pore filtration. This is the suitable technology for the construction of domestic wastewater treatment system in order to control pollution and to protect the environment.

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