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# Study on treatment performance of low cost membrane based septic tank at various fluxes

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***Abstract*** — The objective of this study was to evaluate the performance and fouling behavior of membrane based septic tank (MBST).Woven Fiber Microfiltration (WFMF) introduced in the chamber of a septic tank as a submerged membrane for domestic wastewater treatment. Concentrations of black water stored in the third chamber were 125 ± 15 mg/L COD, 124 ± 28 mg/L SS and 59 ± 9 mg/L TKN. Results showed that COD removal was 54-78 % of which effluent achieved less than 50 mg/L. In addition, the withdrawal was mostly non-performed suspended solids. TMP level increased gradually, indicated low membrane fouling rate (dTMP/dt) of 0.4-1.0 kPa/day at flux as low as 2.5 LMH. While at the flux greater than 3.4 LMH the fouling rate increased rapidly with the fouling rate of 13 kPa/day.

***Keywords*** — *membrane based septic tank; domestic wastewater; fouling; septic tank (ST); Woven Fiber Microfiltration (WFMF).*

## I. Introduction

Septic tank is a popular partial treating system in Vietnam and many countries across the world. This construction officially has two or three chambers in series. The treatment does not perform well (only 50% of SS removal and 30-50 % of COD removal) and the effluent does not meet the Vietnamese standard limits. Septic tanks are still widely applied for domestic wastewater treatment in Viet Nam because of several advantages such as wide range of loading, low cost and less maintenance fee. In fact, it is suitable for developing countries where the centralized wastewater treatment plants are expensive and/or hard to link to sewage systems.

There are many types of septic tank (ST), including conventional ST, anaerobic/aerobic filters ST, baffled ST, etc. Many researchers reported that conventional ST are able to remove contaminants through sedimentation and anaerobic decomposition, approximately 25-45% of $BOD_5$ or COD, 50-70% of SS [1]. The improved septic tanks, including anaerobic filter (AF) and baffled septic tank (BAST), could achieved better removal efficiencies (70 – 85% of COD, $BOD_5$ and SS) at the hydraulic retention time (HRT) of 48 hrs [2].

Despite the improved septic tanks could perform much better compared to the conventional ones, those systems required the modification of the tank structure such as installing a new anaerobic chamber and/or filter media chamber. These additional structure required schedule maintenance and cost investment. To avoid the complicated modification, this study aimed to improve the treated effluent from conventional septic tank by inserting a flat sheet woven fiber microfiltration membrane (WFMF) module into the last chamber of the septic tank. The membrane has pore size of 1-3 µm and functioned similar a sieving mechanism.

The membrane based septic tank could improve the treatment performance due to the possible accumulation of microbes inside the tank. Some research reported the treatment performance of various anaerobic membrane bioreactors in Table 1. This study evaluates the treatment performance and fouling behavior of membrane based septic tank (MBST).

## II. Materials and Methods

### *2.1. Reactor set-up and operation*

MBST system has three chambers with dimensions of 1.5 m length, 2 m width and 1.2 m height. The membrane module has pore size of 1-3 µm and surface area of 1 $m^2$. Membrane module included five parallel membrane sheets with the distance of 5 cm. The dimension of each sheet was 38.0 cm in height and 25.5 cm in width. The membrane module located 50 cm from the tank bottom and 10-15 cm below water level. The effluent pipes of each membrane sheet were connected together and connected to suction pump (8 minutes suction and 2 minutes relaxation). The membrane module was operated at 1.6-6.2 LMH of flux (Table 2). Trans-membrane pressure (TMP) was monitored by a digital pressure gauge equipped right before the suction pump. When TMP reached to 80 kPa, the system would stop to replace another membrane module while cleaning the fouling one.

The correlation between TMP and total resistance is given by Darcy equation:

$$J = \Delta P/(\mu . R_t)$$
$$R_t = R_m + R_c + R_f$$

Where:
J : mean flux ($L/m^2.h$)
ΔP : trans-membrane pressure (Pa)
μ : permeate viscosity (Pa.s)
$R_t$ : total resistance (L/m)
$R_m$ : membrane resistance
$R_c$ : cake resistance
$R_f$ : fouling resistance
With clean water, $J = \Delta P/(\mu . R_m)$

Table 1. Treatment performance of various anaerobic MBR [3,4]

| Parameter | Type of wastewater | | | |
|---|---|---|---|---|
| | Oil processing industry | Alcohol distillation | Synthetic | Brewery |
| Tank volume (L) | 50 | 4 | 10 | 120 |
| Membrane area ($m^2$) | - | 0.36 | 0.2 | - |
| HRT (h) | 67 | 360 | 48; 80; 120 | 87-96 |
| SRT (day) | 161 | - | 26 | 59-83 |
| MLSS (g/L) | 50 | - | 15 | 31.5-38.3 |
| $COD_{inf}$ (mg/L) | 39,910 | 22,600 | 5000 | 46,200-84,010 |
| OLR ($kgCOD/m^3.day$) | 14.2 | 1.5 | 1.15-2.5 | 12-20 |
| COD removal (%) | 93.2 | 97 | > 98 | > 96 |
| Flux ($L/m^2.day$) | - | 5 | - | - |
| TMP (bar) | 1.5 | 2 | 0.5 | 1-2 |

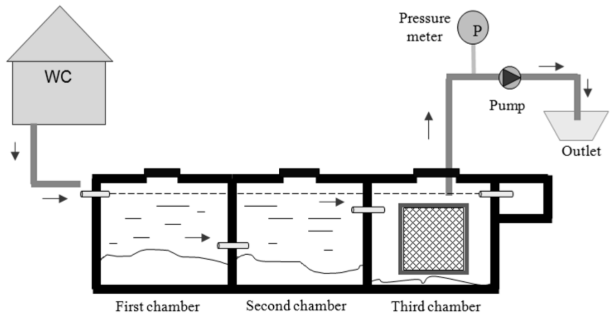


Figure 1. Membrane based septic tank (MBST) configuration

Table 2. Operating conditions of membrane based septic tank

| Period | Time (day) | Flux ($L/m^2.h$) | Period | Time (day) | Flux ($L/m^2.h$) |
|---|---|---|---|---|---|
| 1 | 1 – 28 | 1.6 | 5 | 67 – 70 | 6.2 |
| 2 | 29 –54 | 2.0 | 6 | 71 – 108 | 1.6 |
| 3 | 55 –62 | 3.4 | 7 | 109 – 136 | 2.0 |
| 4 | 63 –66 | 6.2 | 8 | 137 – 203 | 2.5 |

*2.2. Wastewater characteristics*

Wastewater originated from third chamber of MBST system has characteristics presented in Table 3.

Table 3. Wastewater characteristics in third chamber of septic tank

| Parameter | Unit | Values |
|---|---|---|
| pH | - | 7.6 – 8.1 |
| TSS | mg/L | 45 – 225 |
| COD | mg/L | 80 – 170 |
| TKN | mg/L | 40 – 74 |
| $NH_4^+$ -N | mg/L | 33 – 39 |
| $PO_4^{3-}$ -P | mg/L | 3.4–6.0 |
| Turbidity | NTU | 85 – 320 |
| Coliform | MNP/100mL | $2.2 \times 10^6 – 9.0 \times 10^6$ |

*2.3. Membrane cleaning*

Membrane was cleaned by both mechanical force and chemical reagents when TMP values reach to 80 kPa. For mechanical cleaning, membrane module was taken out of septic tank and putted into a punched plastic cage for sun drying. Until the cake layer gets dried, it is peeled and removed by a plastic brush. For chemical cleaning, this method is only applied if membrane resistance keeps in high rate after mechanical cleaning. The membrane module is placed in 0.03% NaOCl solution within 8 hours and rewashed in tap water.

*2.4. Analytical parameters*

Dissolved Oxygen (DO) and pH were determined by Hach electric probe, Sension 2 and 1 respectively. Turbidity was analyzed by HANNA-Hi-8733. Total COD, soluble COD, SS, TKN, $NH_4^+$-N, $PO_4^{3-}$-P and coliform were measured according to standard methods [5].

## III. RESULTS AND DISCUSSION

*3.1. Treatment performance*

*3.1.1. Removal of COD*

In general, organic removals in MBST were upward during experimental times even there were several duplicated operations at the same flux values. The influent had total COD concentration in average of 130 mg/L, which the highest was 153 mg/L. Resulting in approximately 60 % of efficiency; COD concentration in the effluent was always less than 50 mg/L. Soluble COD removal was lower, averaging 40% over seven experimental stages. Besides, the operational periods showed that there was a slight drop of COD removal efficiency when flux flow increased from 3.4 to 6.2 LMH. Additionally, those results were similar to study of van Voorthuizen et al. [6] which also investigated on Anaerobic MBR for black water treatment. Performing high $COD_t$ efficiency was given by high suspended solids rejection of membrane. Otherwise, low concentration of $COD_s$ caused by anaerobic biodegradation.

At every flux operational repetitions, the system also resulted in higher efficiencies comparing to the formers although COD concentrations of the later were greater. Explanation was given that during times of operation there was an increase of MLSS concentration, which would magnify organics conversion and degradation.

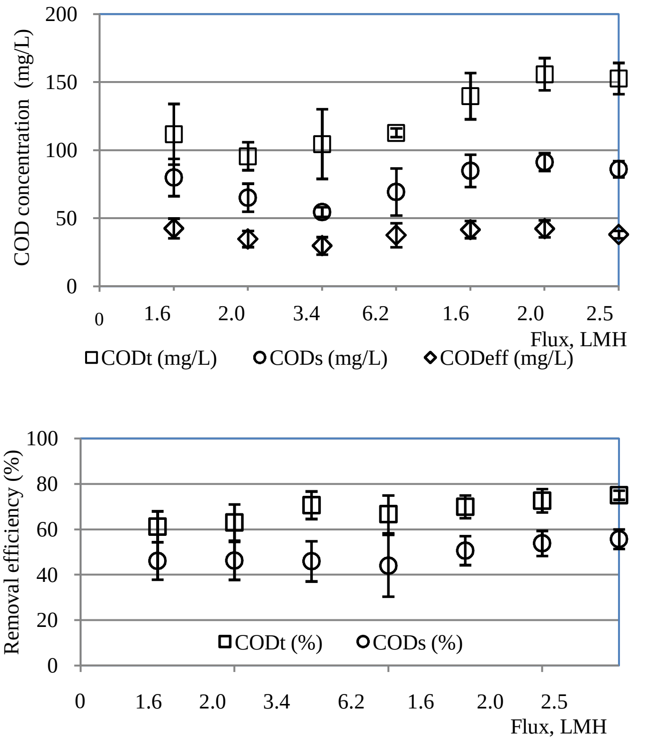


Figure 2. COD removal efficiency of membrane based septic tank at various fluxes

*3.1.2. Removal of SS and turbidity*

Figure 3 shows SS removal ability of MBST system. Permeate concentration of SS always presented minimal values of less than 2.5 mg/L, in accordance with exceeded 94% efficiency. This high solids rejection observed thanks to WFMF application with 1-3 μm pore size. Consequently, COD, nutrients and turbidity also removed in fraction [7]. In fact influent turbidity concentration was in range of 85-320 NTU, it was reduced to less than 10 NTU at every operational flux and matched type A of the national technical regulation on domestic wastewater (QCVN 14:2008/BTNMT).

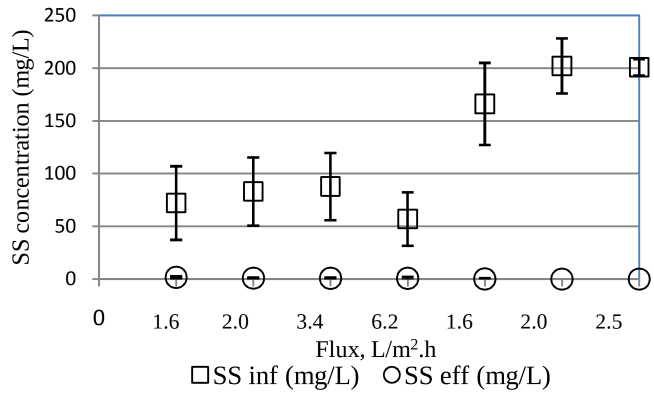


Figure 3. SS removal efficiency at various fluxes

*3.1.3. Removal of nitrogen and phosphorus*

It is obvious that in anaerobic condition microorganisms consumed small amount of nutrients whereas nitrification does not occur. Therefore the levels of nitrogen and phosphorus conservation in membrane permeate were high, accounted for around 90% (Table 4). More than 80% of nitrogen consisted of ammonium, which partly contributed in sludge production [8], the remaining left in SS rejection. Chu et al. [7] studied on anaerobic MBR also gave the same results. Similarly, the phosphorus conservation was very high. Effluent phosphorus concentration was modestly lower than the influent because an amount of phosphorus associated with suspended and colloidal material within MBST system.

Table 4. Conservation levels of nitrogen and phosphorus at various fluxes

| Parameter | Influent, mg/L | Removal efficiency, % | | | | |
|---|---|---|---|---|---|---|
| | | 1.6 LMH | 2.0 LMH | 2.5 LMH | 3.4 LMH | 6.2 LMH |
| TKN | 60 | 87 | 90 | 91 | 92 | 91 |
| $PO_4^{3-}$-P | 4.9 | 92 | 91 | 91 | - | - |

*3.1.4. Removal of Coliforms*

Total coliform concentration in permeate from experiment 2 to 8 accounted for $6x10^3$, $1x10^5$, $2.9x10^4$, 2.5 $x10^4$ and $2x10^4$ MPN/100 mL, respectively. In spite of a very well Coliform removal, exceeded 99%, this criteria could not match the national regulation due to the high amount consisted in the feed wastewater, ranging from $2.3x10^6$ to $9x10^6$ MPN/100 mL.

*3.2. Membrane performance*

Trans-membrane pressure (TMP) is a crucial criterion in evaluating fouling characteristic of MBST system by operational times. As given in Figure 4, TMP increased slightly at low flux (1.6; 2.0 and 2.5 LMH) and fluctuated wildly at high flux (3.4 and 6.2 LMH). Fouling rate occurred slowly at 1.6 LMH, TMP level went up steadily at 0.4 kPa per day and remained stable at 13 kPa. When TMP picked up with 80 kPa, cleaning membrane should be done; it took about 25 days of low flux and 10 days of high flux operation. It is clearly that at high flux operation, particles resist intensively on membrane surface, results in sooner fouling. Moreover, in anaerobic condition there was not any mechanical mixing which would reduce resistance on sides of membrane module [6, 9].

Re-operation at 1.6 LMH flux (day 70-108), TMP value inclined to 15 kPa after three days, much faster than the former (day 1-25); because the characteristic of black water in the third chamber had changed. In former stage, rain-water diluted SS and COD concentrations (SS = 72±35 mg/L; COD = 111 ± 22 mg/L) while in later stage, the concentrations were 167 ± 39 mg/L and 140 ± 17 mg/L, in that order. It indicated that concentration of pollutants also affect to membrane fouling in MBST. At duplication of 2.0 LMH also resulted similarly (fouling rate of 13 kPa/day). However, TMP levelled off and stabilized in the following day (1 kPa/day) because pumping broke down.

In general, the fouling of MBSP follows the linear correlation between with flux. The higher fouling rate was observed at higher flux in the membrane based septic tank.

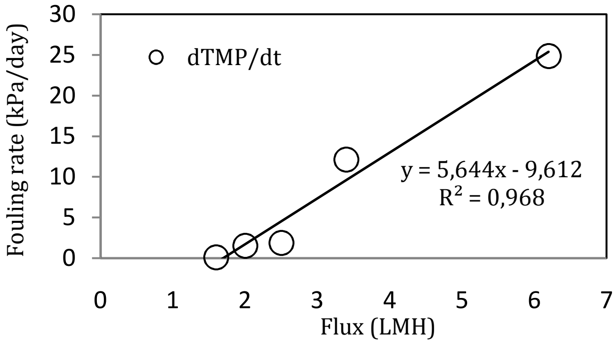


Figure 4. Fouling rate versus applied flux of the system during operation

## IV. CONCLUSIONS

As resulted above, it can be concluded that combining woven fibre microfiltration with septic tank operation is feasible. While effluent COD and SS concentrations matched the national regulation for domestic wastewater, nutrients conservation in treated wastewater were still high. This should be proposed to reuse as irrigation in housing and green public areas. However, total coliforms in the treated effluent still was very high even though removal efficiency achieved by 99%. Regarding to membrane fouling, WFMF membrane system operated well at fluxes lower than 3.4 L/m$^2$.h. Enhanced fouling would occur at intensive flux and/or high organic loading rate. Together with simple installation and operation, low cost and unchanged original structures, this membrane based septic tank can be applied to practice to upgrade current septic tank capability.

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## REFERENCES

[1]. C. Polprasert, V. Rajput, D. Donaldson and T. Viraraghavan, “Septic tanks and septic systems”. Environmental Sanitation Reviews No. 7/8. AIT, Bangkok, Thailand, 1982.
[2]. N.V. Anh, “Conventional septic tank and alternative septic tank”, Construction Publisher, Ha Noi (*in Vietnamese*), 2007.
[3]. A. Fakhrúl-Razi, “Ultrafiltration membrane separation for anaerobic wastewater treatment”, Water Science and Technology, 30 (12) 321-327, 1994.
[4]. K.H. Choo and C.H. Lee, “Membrane fouling mechanisms in the membrane – coupled anaerobic bioreactor”, PII: S0043-1354 00053-X, 1996.
[5]. APHA, “Standard Methods for the Examination of Water and Wastewater”; 20th edition. American Public Health Association, Washington, DC, 1998.
[6]. E. van Voorthuizen, A. Zwijnenburg, W. van der Meer, H. Temmink, “Biological black water treatment combined with membrane separation”, Water research 42, 4334 – 4340, 2008; doi: 10.1016/j.watres.2008.06.012
[7]. L.B. Chu, F.L. Yang, X.W. , Zhang, “Anaerobic treatment of domestic wastewater in a membrane-coupled expanded granular sludge bed (EGSB) reactor under moderate to low temperature”, Process Biochemistry 40, 1063-1070, 2004.
[8]. L. Grady et al., “Biological wastewater treatment”. ISBN: 0-8247-8919-9. Marcel Dekker, Inc, 1999.
[9]. B.X. Thanh, M. Sperandio, C. Guigui, R. Ben Aim, J.F. Wan, C. Visvanathan, “Coupling sequencing batch airlift reactor (SBAR) and membrane filtration: Influence of nitrate removal on sludge characteristics, effluent quality and filterability”, Desalination, 250(2), 850-854, 2010; doi: 10.1016/j.desal.2008.11.055