REMOVAL OF ORGANIC MATTERS FROM PIGGERY WASTEWATER IN ANAEROBIC MOVING BED BIOFILM REACTOR (MBBR)

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Received: 12 October 2019; Accepted for publication: 25 December 2019

Abstract. The objective of this study is to investigate the performance of Anaerobic Moving Bed Biofilm Reactor (MBBR) on the removal of organic matters (using COD, BOD₅ and TSS values) in piggery wastewater using two kinds of carrier: Polyurethane (PU) and Polyethylene (PE) - Different organic loading rates (OLRs) varying from 4.0 to 10 gCOD/l/day with controlled temperature 35 ± 2 °C, pH 7.0 - 7.5 were investigated. The seeded sludge was collected at the anaerobic tank of the wastewater treatment plant of the Sabeco Beer Manufacturing Plant (Nam Tu Liem district, Ha Noi) and grown in the MBBR for 15 days. For porous PU material, the COD, BOD₅ removal efficiencies reached around 67 – 69 % and TSS removal efficiencies achieved around 55 – 65 % at OLRs of 4.0 and 6.0 gCOD/l/day. Whereas for wheel-shaped PE material, the all COD, BOD₅ and TSS removal efficiencies were slightly higher with OLR of 6.0 gCOD/l/day: 71, 72.6 and 67 %, respectively. In addition, the PE seems to be slightly better than that of PU with the same OLRs of 4.0 and 6.0 gCOD/l/day. At 10 gCOD/l/day, all COD, BOD₅ and TSS removal efficiencies tended to increase, reached about 73, 75 and 72 %, respectively However, TSS removal efficiencies were found to be higher with PE carrier at higher OLR, reaching 72 % at 10 gCOD/l/day.

Keywords: anaerobic treatment, piggery wastewater, Moving Bed Biofilm Reactor (MBBR), Polyurethane (PU) and Polyethylene (PE) biofilm carrier.

Classification numbers: 3.4.2, 3.7.2.

1. INTRODUCTION
In recent decades, husbandry wastewater has been the object in a variety of scientific studies to evaluate the effectiveness and suitability of different treatment methods. Anaerobic reactor is a potential solution for piggery wastewater treatment as it can deal with high organic loading and generate CH₄, which can be collected and used as a source of renewable energy. In many countries, anaerobic treatment for high organic loading wastewater has been widely studied and applied [1-5]. In order to enhance the organic removal efficiency, the application of used attached growth to support biofilm formation, is in line with the trend of the world. The biomass formed inside and outside the supporting material enhances the contact between pollutants and digesting bacteria, thus, increase the efficiency of overall treatment [6].

Anaerobic process is popularly applied in high organic carbon wastewater treatment where the organic carbons in the digester are anaerobically decomposed into particulates and biodegradable material creating CH₄ and CO₂ as end products. This process is an efficient measure to decrease the organic carbon and Total suspended solids (TSS) loading rate before entering the next treatment stages. Application of biological carrier materials is a measure for improving the performance of the system. Lo et al. [7] used two-hybrid Upflow Anaerobic Sludge Blanket - UASB (with inserted fixed film for bacterial growth) reactors to treat screened swine wastewaters. At organic loading rates (OLRs) 0.9 - 1.78 gCOD/l/day, more than 95 % of Chemical oxygen demand (COD) was removed. When OLR increased to 3.5 gCOD/l/day, COD concentration in the effluent fluctuated wildly with a mean reduction of 57 and 61%, respectively in each reactor. The researcher also found that the addition of biofilm in this hybrid reactor increased the stability of the reactor [7]. A lab-scale researched by Chiemchaisri et al. using integrated up-flow floating media system with sponge cube floating bed for microbial attachment and suspended solid clarification under anaerobic condition to treat piggery wastewater reached 89 and 90 % of COD and SS removal efficiencies, respectively, at organic loading rate ranged from 4.2 - 6.1 gCOD/l/day [8]. A research by Ruiz et al. by the UASB and Anaerobic filter (AF) showed that for slaughterhouse wastewater with OLR of 5 and 6.5 g/l/day, the COD removal could reach up to 90 and 60 % in UASB reactor, respectively [9]. Van Anh et al. applied the short plastic tube as a carrier material in the moving bed biofilm anaerobic digester for improving the Total Volatile Solid (TVS) digestion efficiency up to 25 % at very short HRT with the inlet TOC concentration of 3 g/l for treatment of waste activated sludge [10]. In a research of Dang and Do (2015), a hybrid model of the Upflow Sludge Blanket Filtration (USBF) with suspended growth in UASB and attached growth in AF was used to deal with piggery wastewater within OLR range of 1.0 - 10 gCOD/l/day in accordance with reduced HRT from 36 to 9.6 hours. The system performed most effectively at OLR 6.0 gCOD/l/day, HRT 16 hours with 92 and 93 % COD and SS removed, respectively [11].

The objective of this study is to investigate the performance of Anaerobic Moving Bed Biofilm Reactor (MBBR) on the removal of organic matters in piggery wastewater using two kinds of carrier materials Polyurethane (PU) and Polyethylene (PE).

2. EXPERIMENTAL METHODOLOGY

2.1. Setup and operation of MBBR system

Scheme and photo of MBBR system using two carrier materials (PU and PE) are shown in Figure 1.

The column in MBBR reactor was manufactured from plexiglass tubes with the thickness of 6.5 mm, inner diameter of 127 mm and height of 1,100 mm given the volume of 12 litters.
Removal of organic matters from piggery wastewater in anaerobic moving bed biofilm reactor

The anaerobic reactor was filled with 4 litters of seeded sludge which was collected from the anaerobic tank of the Sabeco Beer Manufacturing Plant (Nam Tu Liem district, Ha Noi, Viet Nam), MLSS of 20 g/l was maintained in the MBBR for 15 days, and 1/3 volume were filled with biofilm carriers (4 litters) according to the previous study, the optimum filling ratios were 20 – 50 % [12]. Cubic-shaped PU carrier material was provided by the Institute of Chemistry, Vietnam Academy of Science and Technology with specific surface area of 80 - 240 m²/kg, porosity 90 – 95 %, size of 10×10×10 mm. Wheel-shaped PE carrier material with specific surface area of 13.3 - 16.7 m²/kg, size of 15×10 mm that was produced by Envitech Co. Ltd, Ha Noi, Viet Nam (see photo 1).

Figure 1. Schematic diagram and photo of the MBBR system

Photo 1. Carier materials a) PU and b) PE.

The wastewater was pumped into the experiment setup from the input wastewater tank at flow rate of 1 L/h (HRT of 12 hrs). This selected HRT was in accordance with the report of Pinjarkar et al., in which, the detention time of MBBR are usually of 5 to 12 hrs [1]. It passed through temperature controller maintained at 35 ± 2 °C, pH at 7.0 - 7.5, then entered the reactor from the bottom, passed through the sludge blanket and biofilm carriers. The biofilm carriers were moved within the reactor by the support of upflow influent (including feeding rate and sludge recycling rate) and were trapped by plastic rack in upper effluent to prevent them from the overflow of the reactor. To set up anaerobic condition, the reaction column and sedimentation are completely sealed, the output was designed in the goose neck for water. Biogas is collected in the top to measure flow rate and its compositions. The sludge is
recirculated for the microbial circulation and speed up the over flow rate at about 0.6 - 1.0 m/h according to Lettinga [13].

2.2. Sampling and analytical procedures

The raw wastewater was collected after cleaning the pigpen in the morning at the Tran Van Tinh livestock farm in Kim Xa commune, Vinh Tuong district, Vinh Phuc province. The wastewater was then stirred well, filtered via 1 mm sieve and diluted with tap water to reach the selected concentrations (around 2,000 - 5,000 mgCOD/l corresponding to organic loading rates of 4.0 - 10 gCOD/l/day) and feed the MBBR system. The organic and solid contents of the wastewater were assessed based on COD, Biological oxygen demand (5 days - BOD₅) and TSS.

All the samples were collected every 2 days using 500 ml plastic bottles according to TCVN 5992-1995; TCVN 5993-1995; TCVN 5994-1995, and then stored in a refrigerator at 4°C and prepared according to TCVN 6663-14:2000, ISO 5667-14:1998. COD test was carried out within 48 hours after sampling time. COD and BOD₅ were determined following TCVN 6491:1999 and TCVN 6001-1:2008; TSS was determined following TCVN 6625:2000.

3. RESULTS AND DISCUSSION

3.1. The characteristics of raw piggery wastewater

Table 1 provides a summary of characteristics of raw piggery wastewater taken from the farm in Kim Xa commune, Vinh Tuong district, Vinh Phuc province, Viet Nam.

| Parameter     | Values          | QCVN 62: 2016/BTNMT (Category B) |
|---------------|-----------------|----------------------------------|
| pH            | 7.1 - 7.5       | 5.5 - 9                          |
| COD (mg/l)    | 4,200 - 6,800   | 300                              |
| BOD₅ (mg/l)   | 2,200 - 3,600   | 100                              |
| TSS (mg/l)    | 1,500 - 2,800   | 150                              |
| TN (mg/l)     | 261 - 733       | 150                              |
| N-NH₄⁺ (mg/l) | 222 - 658       | -                                |
| TP (mg/l)     | 47 - 104        | -                                |

Note: (-) not regulated

In Table 1, COD, BOD₅ and TSS values were found to be significantly high which exceeded the National Technical Regulation on the effluent of livestock (QCVN 62: 2016/BTNMT). COD, BOD₅ and TSS contents of the raw wastewater ranged from 4,200 - 6,800, 2,200 - 3,600 and 1,500 - 2,800 mg/l, respectively which were 14 - 23; 22 - 36 and 10 - 19 times, respectively, higher than the required effluent quality.
3.2. COD, BOD$_5$ and TSS removal efficiencies in different OLRs with PU carrier

* COD and BOD$_5$ removal

The variation of COD, BOD$_5$ values and COD removal efficiencies of MBBR system with PU carrier during OLRs of 4.0 and 6.0 g COD/l/day are shown in Figure 2 and Figure 3.

![Figure 2](image1.png)

*Figure 2. Variations of COD values and COD removal efficiency of MBBR using PU.*

![Figure 3](image2.png)

*Figure 3. Variations of BOD$_5$ values and BOD$_5$ removal efficiency of MBBR using PU.*

Operating with OLRs of 4.0 and 6.0 gCOD/l/day, the average COD and BOD$_5$ removal efficiencies were found in the range of 68 – 70 % for both with no significant difference between the two OLR values. These removal efficiencies seem to be similar to the findings in the study of Rouhallah et al. [14]. In their study petroleum wastewater was treated in the MBBR filled
with 85 % PU carrier, however the influent COD values were lower, average range from 1,200 to 1,900 mg/l and HRT of 4.0 hrs than that in this study with the influent COD of 2,316 ± 179 and 3,341 ± 208 mg/l at OLRs of 4.0 and 6.0 gCOD/l/day, respectively. In study of Borka et al. BOD₅ removal efficiency found significant high, nearly 88 % with OLR of 0.73-3.48 kgBOD₅/m³.day at laboratory scale [2].

* TSS removal

The average influent TSS of 1,059 and 1,935 mg/l were found with OLRs of 4.0 and 6.0 g COD/l/day. After 58 days operating, the TSS removal efficiencies of MBBR system with PU carrier are shown in Figure 4.

As can be seen in Figure 4, in both periods of influent OLRs of 4.0 and 6.0 gCOD/l/day the average TSS removals occurred in an increasing tendency from 55 to 65.5 %. However, PU carrier has shown a disadvantage in the manner of clogging at the top of the reactor column in the period of high load of TSS corresponded with the influent OLR of 6 gCOD/l/day. The reasons for this phenomena may be due to a part of PU foam being unwetted and floated on the top and the other reason was because the solid particles in influent together with anaerobic sludge elevated the PU carrier and were blocked at the outlet at the top of the reactor column causing the mixture of water and sludge could not go to the settling tank.

3.3. COD, BOD₅ and TSS removal efficiencies in different OLRs with PE carrier

The experiments have been conducted in MBBR using PE carrier with 3 OLRs: 4.0; 6.0 and 10 g COD/l/day. The operating time lasts 78 days at temperature 35 ± 2 °C, pH 7.0 - 7.5.

*COD and BOD₅ removal

The variations of COD, BOD₅ values and of COD, BOD₅ removal efficiencies of the MBBR using PE carrier with OLRs of 4.0; 6.0 and 10 g COD/l/day are shown in Figure 5 and Figure 6.
During OLRs of 4.0; 6.0 and 10 gCOD/l/day, influent COD and BOD$_5$ values of 2,099 - 5,224 and 1,061 - 2,950 mg/l, the Standard deviations (SD) found from 178 to 288 and from 71 to 132 mg/l, respectively; the effluent COD and BOD$_5$ fluctuated in the range of 520 - 1,500 and 326 - 738 mg/l, respectively. The COD and BOD$_5$ removal efficiency varied in the range of 65 - 73 and 70 - 75 %. The average COD removal percentages were found to be rather similar in spite of the fluctuation in the influent organic loads, ranged from 68 to 73 %. These COD removal efficiencies were found similar and/or slightly lower in comparison to the 12 liters bioreactor MBBR to treat artificial wastewater (input COD 3,500 mg/l) where COD removal efficiency reached by 70 - 90% [15].
Figure 7 showed the values of influent and effluent TSS and variations of TSS removal efficiencies of MBBR system with PE carrier during OLR 4.0, 6.0 and 10 g COD/l/day.

![Figure 7. Variations of TSS values and TSS removal efficiency of MBBR with PE.](image)

The influent TSS values increased from 1,163 ± 168 to 1,921 ± 301 and 3,404 ± 282 mg/l corresponding to 3 investigated OLRs. For TSS removal efficiencies of MBBR system, there was a difference between 3 OLRs. The efficiencies tend to increase with the increasing of OLRs. The maximum TSS removal efficiency was found to be approximately 72 % at the OLR of 10 gCOD/l/day. These findings showed slightly higher TSS removal efficiencies of this study in comparison to the study of Sangramsingh [16] where TSS removal by pilot scale MBBR reached 65 % with HRT 48 hrs.

Table 2 summarized the values of COD, BOD<sub>5</sub> and TSS in influent and effluent as well as COD, BOD<sub>5</sub> and TSS removal efficiencies. As can be seen, no significant difference was found between PU and PE in COD and BOD<sub>5</sub> removal at 4.0 and 6.0 gCOD/l/day. However, at higher OLR (10 gCOD/l/day), the removal efficiencies of MBBR using PE found higher for all COD, BOD<sub>5</sub> and TSS. In addition, the MBBR using PE carriers could be operated up to the influent OLR of 10 gCOD/l/day without any problem of clogging.

In the study of Ruiz et al. [9], the COD removal percentages ranged from 60 to 63 % at 3 influent OLRs with PE carrier, HRT of 12 hours which is approximately equal to the COD removal of 60 % using UASB and anaerobic filter for slaughterhouse wastewater treatment with OLR of 6.5 gCOD/l/day. These COD removal efficiencies were much lower than the results of study of Dang and Do [11] which obtained the COD removal of 92 % on the hybrid system of USBF and AF (applied the Anox Kaldnes K1 carriers) at OLR of 6.0 gCOD/l/day with HRT of 16 hours. It was because the hybrid system was operated with the longer HRT, the carriers in USBF and AF were gathered together to create a secondary filter layer and occupied on a half upper top of the reactor column which could be supported for thorough TSS removal. In another study, the moving-bed sequencing batch reactor (moving-bed SBR) system with held medium

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*TSS removal*

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was used to treat piggery wastewater. The results found that with OLRs varying from 0.59 to 2.36 gCOD/l/day, the COD treatment efficiency of moving-bed SBR was higher than 60 % at the lowest OLR and kept increasing up to 80 % at the OLRs of 1.18 - 2.36 gCOD/l/day [5]. However, these OLRs were much lower than that of this study.

Table 2. Summary of the COD, BOD₅ values and TSS of MBBR using PU and PE carriers.

| Biofilm carrier | PU | PE |
|-----------------|----|----|
| ORLs (g/l/day)  | ~4.0 | ~6.0 | ~4.0 | ~6.0 | ~10 |
| COD influent    | 2,316 ± 179 | 3,341 ± 208 | 2,099 ± 288 | 3,165 ± 178 | 5,224 ± 217 |
| COD effluent    | 699 ± 101 | 1,091 ± 227 | 674 ± 129 | 924 ± 54 | 1395 ± 78 |
| COD removal (%) | 69.6 ± 3.3 | 67.3 ± 4.1 | 68 ± 2.7 | 71 ± 2.0 | 73.3 ± 1.7 |
| BOD₅ influent   | 1135 ± 102 | 1580 ± 76 | 1061 ± 109 | 1553 ± 71 | 2950 ± 132 |
| BOD₅ effluent   | 348 ± 61 | 502 ± 39 | 326 ± 71 | 407 ± 80 | 738 ± 56 |
| BOD₅ removal (%)| 69.3 ± 4.9 | 68.1 ± 3.2 | 69.6 ± 8.4 | 72.6 ± 4.0 | 74.9 ± 2.0 |
| TSS influent    | 1,059 ± 199 | 1,935 ± 264 | 1,163 ± 168 | 1921 ± 301 | 3404 ± 282 |
| TSS effluent    | 467 ± 63 | 653 ± 117 | 424 ± 40 | 636 ± 157 | 951 ± 124 |
| TSS removal (%) | 54.9 ± 8.1 | 65.5 ± 8.3 | 63.2 ± 3.7 | 67.0 ± 6.0 | 71.9 ± 4.2 |

4. CONCLUSIONS

The characteristics of the stock piggery wastewater at the livestock farm where research group collected samples, COD, BOD₅ and TSS of the raw wastewater ranged from 4,200 - 6,800, 2,200 - 3,600 and 1,500 - 2,800 mg/l, respectively. These values are much higher than the Viet Nam required effluent quality for livestock, 14 - 23, 22 - 36 and 10 - 19 times for COD, BOD₅ and TSS, respectively.

At the lab-scale experimental conditions, no significant difference in COD and BOD₅ removal efficiencies were found between PU and PE at 4.0 gCOD/l/day. However, at 6 gCOD/l/day PE carrier performed a slightly better than that of PU for COD, BOD₅ and TSS removal efficiencies that increasing from the range of 65.5 - 68.1 % to 71.0 - 74.9 %, respectively. At 10 gCOD/l/day with PE biofilm carriers, all COD, BOD₅ and TSS removal efficiencies tended to increase and reached average of 73, 75 and 72 %, respectively.

Acknowledgement. The authors would like to thank the financial and technical support from National-scale Project NĐT 31.JPA/17 in collaboration with the University of Kitakyushu, Japan.
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