

POTENTIAL OF POLYETHYLENE FOAM MEDIA FOR BIOGAS EFFLUENT WASTEWATER TREATMENT

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Abstract

This study aimed to find a suitable media for treating biogas effluent wastewater from pig farms. The research recycled polyethylene foam (PE foam) as a material and used it as a microbial adhesion media and immersed in the wastewater of an Aerotank model. The experiment was performed with 3 treatments and three repetitions, including: Aerotank with media from PE foam (treatment 1); Aerotank with MBBR biochip (treatment 2); and Aerotank without media (treatment 3(control)). The results showed that the PE foam media exhibited higher treatment efficiency than the commercially available media (MBBR biochip) and the control, with average removal efficiencies of 79.44%, 62.46%, 79.63%, and 84.95% for COD, TSS, BOD, and N-NH₃, respectively. The media from PE foam can be used as a replacement for commercially available media and an option for improving the quality of biogas effluent wastewater.

Keywords: Aerotank; biogas effluent wastewater; microbial adhesion media; polyethylene foam.

1. Introduction

Pig farming in Vietnam is identified as a key industry (Department of Livestock Production, 2022). Pig farming in Vietnam involved approximately 4 million households with a total herd of about 25 million pigs, an increase of 6.7% compared to 2021. Alongside the growth of the pig farming industry, Environmental pollution caused by pig farming waste is also a significant concern. In pig farming waste, major pollutants such as organic matter (BOD, COD) and nutrients (TN, TP), if not treated and discharged directly into water environment, will cause water pollution, eutrophication, leading to the rapid growth of algae and aquatic plants UNESCO (2018), causing ecosystem degradation and posing risks to human health (González-Valencia et al., 2025).

To treat pig farming waste, most farms have used biogas technology. This is considered a practical solution for the sustainable development of the livestock industry (Do Quang Trung et al., 2018). However, this technology has been generating a considerable amount of wastewater with concentrations of pollutants exceeding required standards. The acceptance of wastewater from biogas systems will further pollute the environment (Proskynitopoulou et al., 2024). Yet, most pig farms do not have a treatment system for this type of wastewater.

The addition of media to improve wastewater treatment efficiency has become a common solution (Pham van Duong, 2018). Media are materials added to treatment processes to increase the contact surface area between microorganisms and wastewater and facilitate the decomposition of organic matter (Nguyen Minh Ky, 2017). However, media are expensive. The investment cost per cubic meter of treatment tank using media can reach up to \$200, posing a significant challenge for businesses choosing this treatment technology. Furthermore, polyethylene foam is causing serious pollution due to the large amount of it generated after packaging, affecting environmental quality, causing pollution, and detracting from the environmental landscape.

Therefore, this study aims to investigate the biogas effluent big farming wastewater treatment capacity of PE foam media, and find an effective substrate for treating biogas effluent wastewater of pig farms, while also solving the pollution problem caused by solid waste from PE foam.

2. Research Methods

Wastewater sample

Biogas effluent wastewater samples were collected from a pig farm in Phu Giao ward, Ho Chi Minh City, Vietnam. The collection and preservation of wastewater samples followed TCVN 6663-3: 2016 standards. Wastewater quality parameters were analyzed according to the standard methods (APHA, SMEWW, and ISO).

Materials

PE foam (figure 1) was collected from electronics stores. They are discarded in the form of unused packaging. The MBBR biochip (figure 1) was bought at the Regreen company, Thu Duc ward, Ho Chi Minh city. All materials and chemicals used in this study were highly pure and of analytical quality.

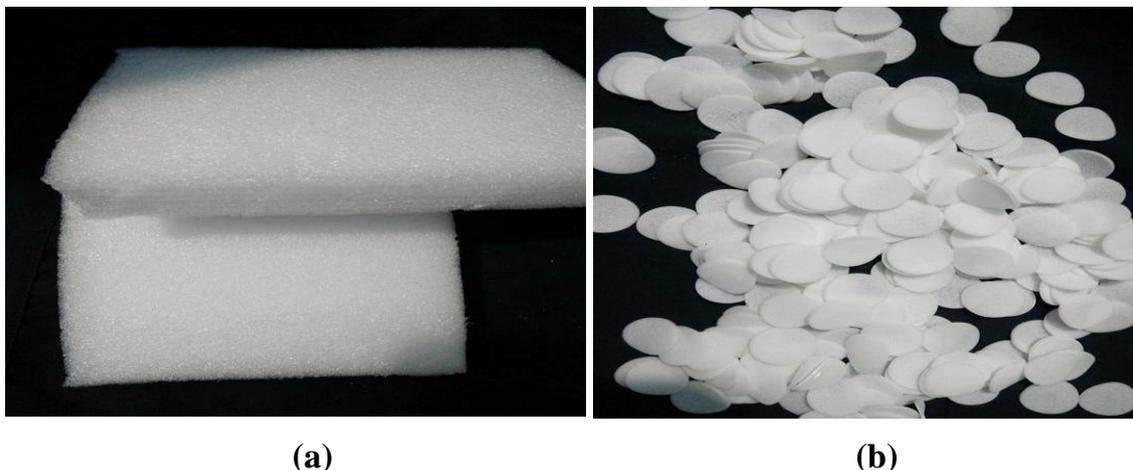


Figure 1. PE foam (a) and MBBR Biochip (b)

Source: Author, 2025

Creating media from PE foam

PE foam is collected, washed, and cut into flat circular shapes with a diameter of 25mm and a thickness of 1.1mm, and quantities of 300g. (These sizes and shapes are similar to the MBBR biochip).



Figure 2. The media from PE foam

Source: Author, 2025

Design of the treatment model

The treatment model is designed as an Aerotank consisting of three 21L water tanks. Water pipes are then used to connect the three tanks, creating a model with a height of 0.30m per compartment, a diameter of 0.22m, and an overflow height of 0.15m. The total volume of the model is 0.33m³.

The experimental model is performed similarly to Figure 3 with 3 treatments and three repetitions. 3 treatments were carried out, including: Aerotank with media from PE foam (treatment 1); Aerotank with MBBR biochip (treatment 2); and Aerotank without media (treatment 3(control)). The media volume should be 5% of the tank volume. This is equivalent to 300g of media.

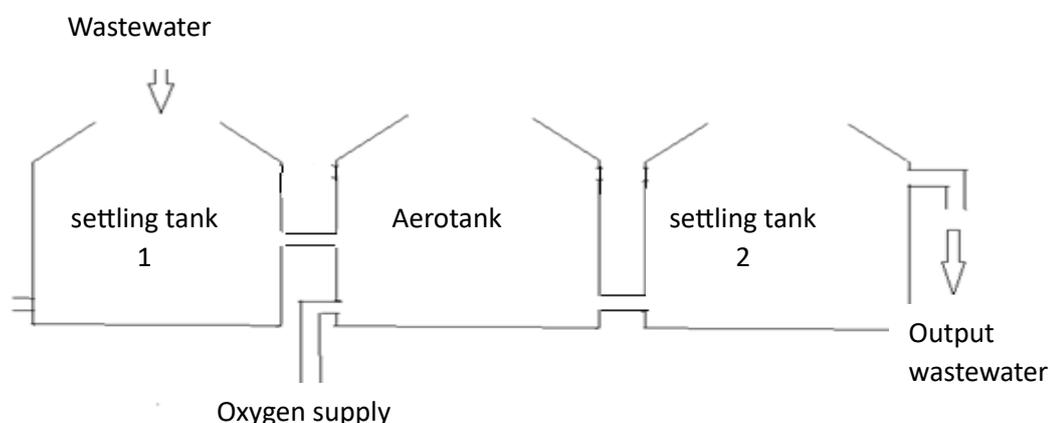


Figure 3. The experimental model

Source: Author, 2025

Operating the processing model

After collection, the biogas effluent wastewater from pig farming will be analyzed to determine initial parameters. Firstly, wastewater and sludge are transferred to settling tank 1. Then it is discharged to the Aerotank (designed for continuous aeration). Water from the Aerotank will flow to settling tank 2, where the sludge will continue to settle, yielding the treated wastewater with solids retention time once a day, water retention time

10h, and DO ≥ 2 mg/L. The inlet wastewater flow rate is calculated $(V_{\text{tank}} - V_{\text{media in tank}})/10$.

Analysis of water quality parameters

COD, SS, BOD₅, N-NH₃, and color were analyzed at 0, 10, and 20 days of the experiment. The efficiency of wastewater treatment is evaluated through the formula:

$$E(\%) = \frac{C_1 - C_2}{C_1} \times 100 \quad (\text{Ahmad Soleh Setiyawan et al.,2022})$$

Where:

E - The removed efficiency of pollutant (%)

C1 - Pollutant concentration at the system input (mg/l)

C2 - Pollutant concentration after treatment at the system output (mg/l)

Data analysis

All data collected during the study process will be calculated for the average value and standard deviation for each value. The data is displayed as graphs using MATLAB R2020b software.

4. Results and Discussion

Assessment of inlet biogas effluent wastewater quality

The analysis results of biogas effluent wastewater quality parameters were presented in Table 1. The analysis data showed that the pH and temperature of the wastewater at the study site reached the allowable limits specified in QCVN 40:2011/BTNMT. However, SS, COD, BOD₅, and N-NH₃ have a fairly high content. The basic parameters of the wastewater all exceed the permissible standards many times. Compared with QCVN 40:2011/BTNM, SS, COD, BOD₅, and N-NH₃ exceed the permissible standards by 2.06, 40.8, 21.2, and 4.29 times, respectively. Wastewater from pig farming, even after passing through biogas digesters, still causes significant pollution of parameters such as BOD, COD, Nitrogen (N), Phosphorus (P), and bacteria (Coliform). Biogas effluent wastewater still contains many difficult-to-decompose organic substances (BOD, COD), total nitrogen (TN), and ammonia (NH₃), far exceeding permissible standards. Biogas effluent wastewater still contains many difficult-to-decompose organic substances (BOD, COD), total nitrogen (TN), and ammonia (NH₃), far exceeding permissible standards. According to the survey results of Ho Bich Lien (2017), 100 % of surveyed breeding farms (15/15) exhibited total phosphorus, total nitrogen, chemical oxygen demand (COD), and coliforms could not meet this regulation (column B). 73.33 % of surveyed breeding farms (11/15) exhibited biology oxygen demand (BOD₅) could not meet this regulation (column B). 93.33 % of surveyed breeding farms exhibited suspended solids (SS). SS could not meet this regulation (column B). Wastewater with high COD and BOD content depletes oxygen in the receiving water due to bacteria decomposing organic matter, causing fish deaths and ecosystem imbalance (Ogunfowokan et al., 2005).

Table 1. Characteristics of inlet biogas effluent wastewater (mean \pm standard deviation)

Parameters	pH	T° (°C)	SS (mg/L)	BOD ₅ (mg/L)	COD (mg/L)	N-NH ₃ (mg/L)
Biogas effluent wastewater	7.1 ± 0.2	29.6 ± 0.2	206 ± 1.6	2042.3 ± 1.3	3172.5 ± 0.4	42,9 ± 0.1
QCVN 40:2011/BTNMT	5.5-9	40	100	50	150	10

Source: Author, 2025

The efficiency of PE foam media for biogas effluent wastewater treatment

Concentrations of parameters in biogas effluent wastewater exceeded the permissible limits according to QCVN 40:2011/BTNMT standards, indicating the presence of organic matter and nutrients that need to be treated. The study utilized PE foam media to treat biogas effluent wastewater, and the results are shown in Table 2.

Table 2. Changes of parameters of biogas effluent wastewater (mean \pm standard deviation)

Retention time (days)	0	10			20			QCVN 40:2011/ BTNMT
	NT1/NT2/NT3	NT1	NT2	NT3	NT1	NT2	NT3	
SS (mg/L)	206 ± 1.6	85.7 ± 1.3	111 ± 2.2	130 ± 1.6	77.3 ± 0.5	88.3 ± 0.9	112.3 ± 0.9	100
BOD ₅ (mg/L)	2042.3 ± 1.3	1064.3 ± 1.2	1119.9 ± 1.5	1646.1 ± 0.4	416,9 ± 0.1	440.6 ± 0.3	1136.4 ± 0.9	50
COD (mg/L)	3172.5 ± 0.5	1569.9 ± 0.5	1507.9 ± 0.5	1936.6 ± 0.5	652.4 ± 0.6	709.4 ± 0.5	1436.7 ± 0.4	150
N-NH ₃ (mg/L)	42,9 ± 0.1	10,5 $\pm 0,5$	11,2 ± 0.3	12,8 $\pm 0,4$	6,5 $\pm 0,6$	8,5 $\pm 0,2$	12,9 $\pm 0,2$	10

Source: Author, 2025

The results from Table 4.2 show that the concentrations of pollutants in biogas effluent wastewater of the pig farm decreased in all treatments after 20 days of experiment. The concentrations of SS, BOD₅, COD, and N-NH₃ decreased most significantly in the treatment using PE foam media. This was followed by the treatment using the MBBR biochip, and the most significant decrease was in the treatment without media. This indicates that the wastewater treatment efficiency depends on the use of media in the Aerotank model.

Wastewater treated through the PE foam media in the aerotank had significantly lower concentrations of pollutants compared to the influent (Table 2). SS, BOD₅, COD, and N-NH₃ decreased significantly after 20 days of treatment. Similarly to PE foam media, with MBBR biochip media, SS and N-NH₃ met the limits in QCVN 40-2011/BTNMT. However, BOD and COD still exceeded the standard by 2 times. Meanwhile, not adding

media also reduced the concentration of pollutants, but the pollutant concentrations were still insufficient QCVN 40-2011/BTNMT. Compared with QCVN 40:2011/BTNM, SS, BOD₅, COD, and N-NH₃ exceed the permissible standards by 1.1, 22.7, 9.6, and 1.3 times, respectively.

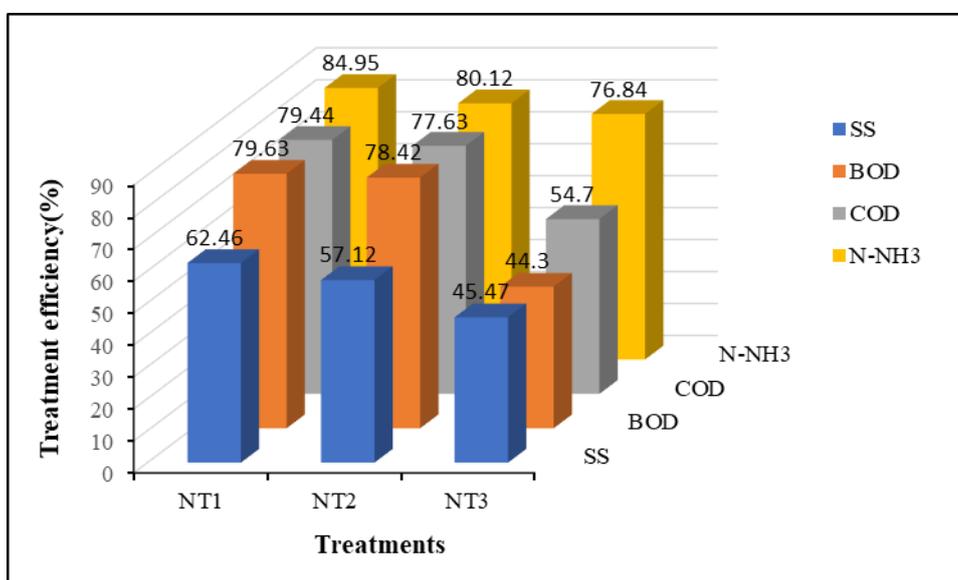


Figure 4. Removal of the parameters of treatments

Source: Author, 2025

The removal efficiencies of SS, BOD₅, COD, and N-NH₃ after 20 days of PE foam media were 62.46%, 79.63%, 79.44%, and 84.95%, respectively. A combination of PE foam media and aerotank showed the most effective treatment for N-NH₃, BOD, and COD. Adsorption onto media and biodegradation were the processes that helped remove N-NH₃, BOD, and COD in the aerotank. Microbial adhesion media are crucial for the formation of biofilms (Ahmad Soleh Setiyawan et al., 2022). The metabolic activity of microorganisms attached to the media influenced the performance of the reactor, as evidenced by the removal efficiency of SS, BOD, COD, and N-NH₃ (Table 2). The removal efficiency of COD of PE foam media obtained in this study was higher than that of Ahmad Soleh Setiyawan et al. (2022). The COD removal efficiencies was 72.75% and 72%, 67%, 65%, 60.52%, and 64.96% for PET-1 and PET-2, HDPE, acrylic, PVC, and PP, respectively. With PE foam media. The N-NH₃ removal efficiency ranged 85.95%, which was higher compared to N-NH₃ removal which ranged from 40.56 to 63.86% of PET-1 and PET-2, HDPE, acrylic, PVC, and PP. This indicates that PE foam material promotes a higher biofilm growth rate and the formation of a more stable biofilm. Another previous study reported that HDPE removed 93% of COD, 51% of NH₄⁺-N, and 49% of TN in the treatment of total wastewater and required a start-up time of 22 to 32 days for biofilm formation (Mao et al., 2017). PP is capable of removing 80% of COD, as well as 63.70% of N-NH₃ (Zhu, 2017).

However, the SS removal efficiency of PE foam materials is still quite low when added to aeration tanks. The low SS (suspended solids) removal efficiency of the substrate is mainly due to its mechanism of action focusing on biodegradation (BOD/COD) rather than mechanical filtration. Low efficiency is caused by microbial biofilm shedding, pore

blockage, high turbulence preventing settling, and excessive microbial growth increasing SS output.

Visually, the wastewater passing through the aerotank tanks with PE foam media and MBBR biochip is clearer in color and has less odor than the initial influent wastewater (Figure 5).

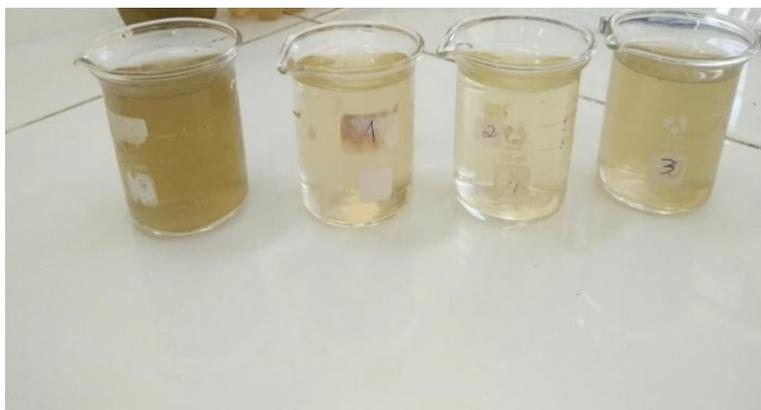


Figure 5. Output biogas effluent wastewater input of treatments

Source: Author, 2025

4. Conclusion

PE foam media showed higher treatment efficiency compared to MBBR biochip media and models without media. The treatment efficiency of the PE foam reached 79.44% for COD, 62.46% for SS, 79.63% for BOD₅, and 84.95% for N-NH₃. Compared to the QCVN 40:2011/BTNMT standard, the PE foam media reduced the concentration of pollutants, and the SS and N-NH₃ concentrations in the effluent met the standard (column B) according to QCVN 40:2011/BTNMT. However, the COD and BOD₅ indicators did not meet the standards as specified in QCVN40:2011/BTNMT.

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